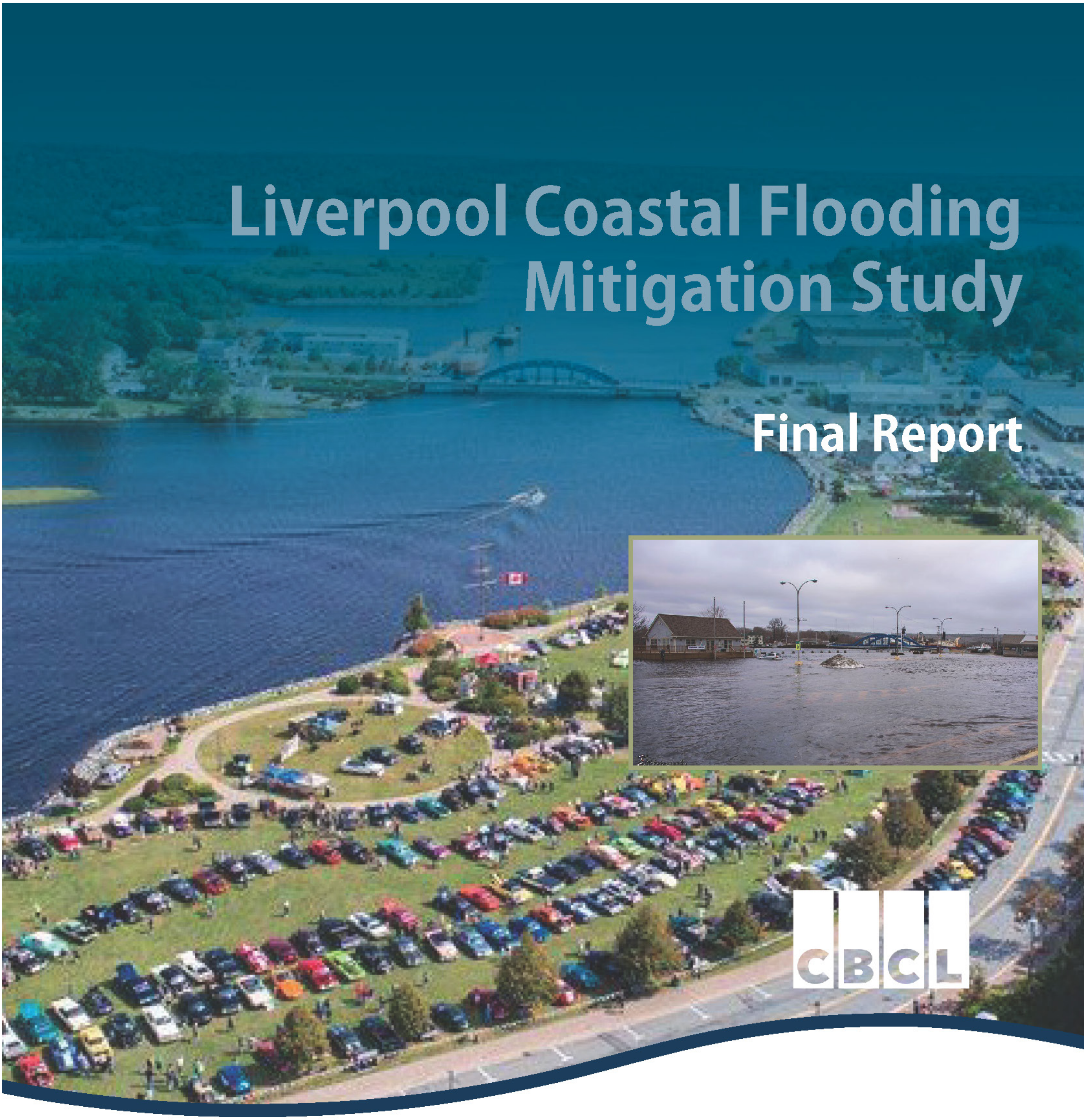
# Liverpool Coastal Flooding Mitigation Study

## Final Report



CBCL

Prepared for

Region of Queens Municipality

181109.00 • Final Report • October 2019

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October 29, 2019

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249 White Point Road
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Dear Mr. Rowter:

*RE: Liverpool Coastal Flooding Mitigation Study Final Report*

Please find attached our final report for the Liverpool Coastal Flooding Mitigation Study.

As we have discussed since beginning this work, the focus of this study was to confirm anticipated high water level for today and the future, consider future development levels as well as developing a concept for addressing the flooding issue that has been experience at the parking lot between Henry Hensey Drive and Water Street.

It was discovered during the earlier stages of this study that it is not likely cost effective to attempt to protect the waterfront parking lot, and climate change will likely render any efforts to protect this parking lot ineffective. It was also discovered during the study that stormwater plays a significant role in the flood conditions for the waterfront areas of downtown. Due to these findings, it was decided to re-focus project resources to expand the study to investigate a larger area of the Liverpool waterfront and to review the existing stormwater management plan against current climate change predictions to prepare Liverpool for the future with respect to climate change and coastal flooding.

We trust that you will find the information within this report useful and informative. Please contact the undersigned with any questions, comments or concerns.

Sincerely,

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A Community of Liverpool Coastal Still Water Flood Maps

B Downtown Liverpool Concept Plans

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# Chapter 1 Introduction

The downtown area of Liverpool houses important economic and cultural assets that include retailers, restaurants, museums and public spaces as well as other services such as the Liverpool Fire Department unit, and critical municipal infrastructure and services such as the wastewater treatment plant. The downtown parking lot provides direct access to most of these locations encouraging the development of economic activities in the area. Over the last 15 years, frequent storm surge events in combination with the low elevation of the downtown area have caused various flooding events and flood-related damages that have resulted in substantial repair and maintenance costs.

CBCL was engaged by The Region of Queens Municipality to conduct an engineering assessment of the flooding risks in the parking lot area including concept design of potential mitigation measures as well as detailed design and cost estimates of the preferred solution. The first phase of this study was completed, resulting in a draft report issued to the Municipality highlighting the risks to the downtown area and presenting potential concept solutions along with high level cost estimates. Upon review of this draft report, it was agreed to pursue a change of scope due to the high costs of all potential concept solutions and the need for understanding coastal flood risks throughout the community. The study diverged from detailed design of the downtown area and instead focusing on expanding the risk assessment to the entire Community of Liverpool.

As part of the risk assessment exercise, flood line mapping was developed which illustrates land uses and the extents of flooding impact for multiple storm surge and sea level rise scenarios. These maps are used as the basis to identify regions of at-risk infrastructure and to identify potential areas of refuge if relocation of assets is required. From this assessment an Infrastructure Asset Risk analysis is performed to identify infrastructure regions at risk and to develop a priority list for the Municipality's consideration. This analysis was completed based on the risk and priority methodology of the Public Infrastructure Engineering Vulnerability Committee (PIEVC) Protocol developed by Engineers Canada. Mitigation options and high-level cost estimates of each potential solution are provided.

Further to this, the study was expanded to include an evaluation and update to the previous Stormwater Management Plan for Liverpool which was issued in 1993 by CBCL. This analysis included a review of the original plan, watershed delineation using LiDAR data, generation of peak runoff flows using computer modeling (accounting for climate change), and finally comparing runoff values from the original plan to the computer model generated flows.

# Chapter 2 Coastal Floodline Mapping

## 2.1 Overview

The flood risk component of this study examines the coastal flooding risk to determine infrastructure at risk and mitigation options. This section describes the factors which impact the existing and projected extreme water levels that Liverpool will likely experience and describes the method for developing the coastal floodline maps presented in Appendix A.

## 2.2 Coastal Site Characterization

### 2.2.1 Water Levels

Local water levels are due to the combined effects of tides, storm surge, and local sea level rise (SLR).

#### 2.2.1.1 Tides

The local tides at Liverpool are semi-diurnal with a maximum range of 2.2m (source: DFO 2019, Canadian Tide and Currents Tables). Upon consultation with DFO an additional 0.1m was added to the tidal elevations to account for sea level rise that has occurred since the year 2000, when the tidal datum was last updated.

#### 2.2.1.2 Storm Surge

Storm surge is due to meteorological effects on sea level, such as wind set-up[1] and low atmospheric pressure, and can be defined as the difference between the observed water level during a storm and the predicted astronomical tide. Based on storm surge modeling by Bernier[2], the storm surge for Liverpool was assumed to be similar to that of Halifax.

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[1] Wind set-up refers to the increase in mean water level along the coast due to shoreward wind stresses on the water surface.
[2] Bernier, N. B., and K. R. Thompson. 2006. "Predicting the frequency of storm surges and extreme sea levels in the northwest Atlantic." J. Geophys. Res., C10009.

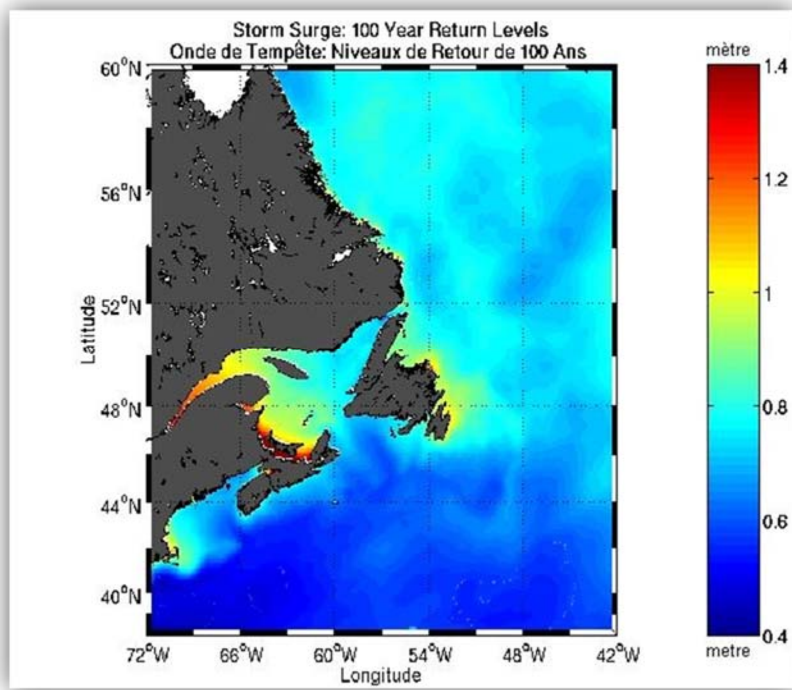


**Figure 2.2.1: Modeled 100-yr Return Storm Surge Levels in Atlantic Canada (Tide not Included), Source: Environment Canada**

Table 2.2.1 shows the assumed total extreme still water levels[3] for Liverpool based on the occurrence of extreme storm surges at higher high water large tide (HHWLT). These levels do not account for potential overtopping from the north-west direction, potential water level contribution from the Mersey River, or tidal amplification/ reduction along the River.

Based on the SLR projections, existing extreme water levels with a low return period will be considered common in a few decades, increasing the potential damage frequency. From Table 2.2.1 it can be seen that as time passes, low frequency events become more common which increases the risk of flooding, and the site may experience larger events that were not considered during development. Therefore, given the economic significance and permanent nature of infrastructure, it must be necessary to consider the effect of SLR on flood risk when assessing infrastructure at risk and considering mitigation measures.

[3] "Still Water Level" refers to water levels (tidal or extreme storm surge) without wave run-up.

**Table 2.2.1: 2019 Tides and Extreme Still Water Levels Estimated for Liverpool (Chart Datum to Canadian Geodetic Vertical Datum Conversion of 1.13 as Indicated for Liverpool by DFO)**

| Extreme Values by Return Period | | |
|---|---|---|
| [Years] | Meters above Chart Datum [CD] | Meters above CGVD28 |
| 100-yrs | 3.5 | 2.4 |
| 50-yrs | 3.4 | 2.3 |
| 10-yrs | 3.2 | 2.1 |
| 5-yrs | 3.1 | 2.0 |
| 1-yrs | 3.0 | 1.9 |
| **2019 Tidal Elevations** | | |
| Higher High Water Large Tide | 2.5 | 1.4 |
| Higher High Water Mean Tide | 2.1 | 1.0 |
| Mean Water Level | 1.1 | 0.0 |
| Lower Low Water Mean Tide | 0.5 | -0.6 |
| Lower Low Water Large Tide | 0.1 | -1.0 |

Notes: "Still Water Level" refers to water levels (tidal or extreme storm surge) without wave run-up.

### 2.2.1.3 Sea Level Rise (SLR)

The Department of Fisheries and Oceans (DFO) developed the online Canadian Extreme Water Level Adaptation tool, based on the study by Zhai et al. (2014) accounting for local factors which can impact sea level. CAN-EWLAT is a science-based planning tool for climate change adaptation of coastal infrastructure related to future water-level extremes. The tool was developed to provide SLR allowances for DFO harbours across Canada. Allowances are estimates of changes in elevation of a site that would maintain the same frequency of inundation that the site has experienced historically. These estimates are determined based on the Representative Concentration Pathway (RCP) scenarios of the projections of regional sea level rise from the IPCC Fifth Assessment Report (AR5, IPCC 2013). CAN-EWLAT was used to forecast the relative SLR at Liverpool. Given the requirement for long-term protection, this assessment presents values based on the high emission scenario (RCP 8.5). This translates into 0.51m sea level rise in the next 50 years (2019 to 2069) and 1.02m sea level rise within the next 80 years (2019-2100). No SLR projections were available from CAN-EWLAT past 2100. Table 2.2.2 shows the upper-bound SLR estimates for different time frames. Given the SLR projections, extreme water levels with a low return period today will be very common in a few decades, therefore increasing the potential damage frequency.

**Table 2.2.2: CAN-EWLAT Sea Level Rise Estimates for Liverpool, NS**

| Climate Scenario | CAN-EWLAT, Liverpool, NS - SLR [m] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 | 2080 | 2090 | 2100 |
| Model RCP8.5 | 0.05 | 0.11 | 0.19 | 0.29 | 0.40 | 0.51 | 0.66 | 0.82 | 1.02 |

The nearest tidal gauge to Liverpool is located at Halifax, from this tide gauge it is possible to compare the historical observed sea level rise with future projections, Figure 2.2. Recent research[4] emphasizes that multi-meter sea level rise may happen faster than expected if greenhouse gas emissions are not curtailed. Studies subsequent to the IPCC 2013 and DFO 2014 study suggests that previous Global Mean Sea Level (GMSL) predictions may be too modest. These studies updated the scientifically supported upper-end GMSL projections, including recent studies of the potential for rapid ice melt in Greenland and Antarctica. DFO's Han et al. study[5] revisited mean sea level rise scenarios to include a High Scenario for Halifax of 1.97 m projected SLR to year 2100 relative to 2010. Subsequently, a 2017 NOAA publication[6] present a year 2100 GMSL forecast range discretized into six GMSL rise scenarios: a Low (0.3m), Intermediate-Low (0.5m), Intermediate (1.0m), Intermediate-High (1.5m), High (2.0m) and Extreme (2.5m). A key finding was that along regions of the Northeast Atlantic (Virginia coast and northward), regional SLR is projected to be greater than the updated global average for almost all future scenarios (e.g. by 0.3 to 0.5 m under the Intermediate scenario by year 2100). Finally, studies indicate that the human carbon footprint to date has already committed Earth to a long-term GMSL rise of ~1.7m[7]. Given these findings, the 2014 DFO estimates based on IPCC AR5 RCP8.5 may now be considered *Intermediate* projections, with *High* and *Extreme* SLR scenarios to range 1.0 to 1.5 m higher than previously anticipated. 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.

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[4] Hansen, J., M. Sato, P. Hearty, R. Ruedy, M. Kelley, V. Masson-Delmotte, G. Russell, G. Tselioudis, J. Cao, E. Rignot, I. Velicogna, E. Kandiano, K. von Schuckmann, P. Kharecha, A. Legrande, M. Bauer, and K. Lo, Ice melt, sea level rise and superstorms: evidence that 2°C global warming is highly dangerous, Atmos. Chem. Phys. Disc., 23 July 2015.

[5] Han G., Ma Z., Zhai L., Greenan B., Thompson R. 2016. Twenty-first century mean sea level rise scenarios for Canada. Canadian Technical Report of Hydrography and Ocean Sciences 313.

[6] Sweet W.V, Kopp R.E., Weaver C.P., Obeysekera J., Horton R.M., Thieler E.R., Zervas C., 2017. NOAA Technical Report NOS CO -OPS 083: Global and Regional Sea Level Rise Scenarios for the United States. Silver Spring, Maryland.

[7] Clark P.U, Shakun J.D, Marcott S.A, Mix A.C, Eby M., Kulp S., Levermann A., Milne G.A , Pfister P.L., Santer B.D, Schrag D.P, Solomon S, Stocker T.F., Strauss B.H, Weaver A.J, Winkelmann R., Archer D, Bard E, Goldner A, Lambeck K, Pierrehumbert R.T & Plattner GK., 2016 Consequences of twenty-first-century policy for multi-millennial climate and sea-level change. Nature Climate Change 6, 360–369

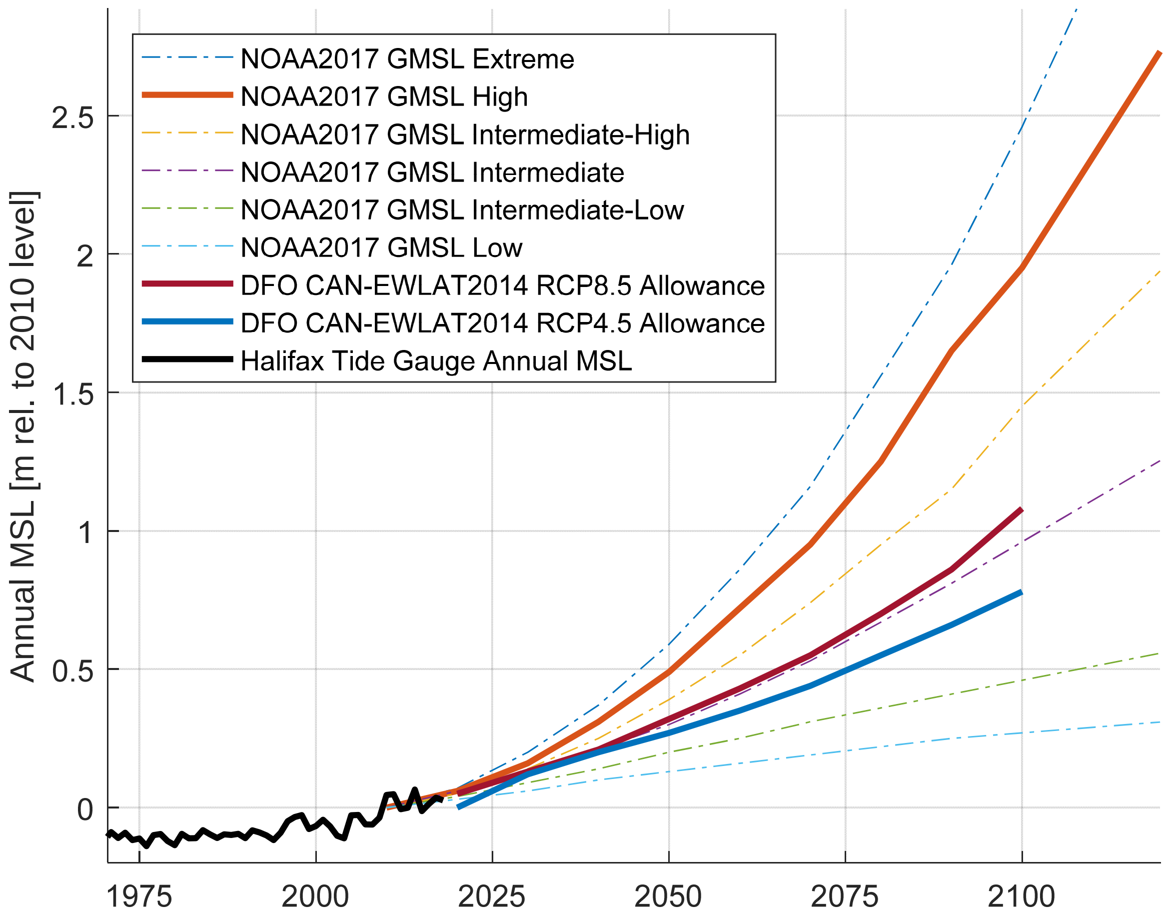



**Figure 2.2.2: Observed Sea Level Rise at Halifax and Future Projections**

### 2.2.1.4 Projected Water Levels at Liverpool

The projected extreme water levels are shown in Table 2.2.3. These are based on the 2019 tidal and storm surge predictions and the CAN-EWLAT SLR. These projections do not take into consideration the potential increase in storms that may occur as a result of climate change which may result in large storm surge events happening more frequently. These projections were the basis for the development of the coastal floodmaps. Blue cells in the table above are meant to highlight the phenomenon that as time passes, low frequency events become more common, increasing the risks of flooding. From the table, we can see that a floodline elevation of a 100 year storm in 2020 will be the same elevation for the High Water Large Tide in the year 2100, 2.4 m CGVD28.

**Table 2.2.3: Projected Total Extreme Water Levels at Liverpool (Storm Surge + HHWLT)**

| Extreme Values by Return Period [years] | | | | | |
|---|---|---|---|---|---|
| Return Period [years] | 2020 [m CGVD28] | 2040 [m CGVD28] | 2060 [m CGVD28] | 2080 [m CGVD28] | 2100 [m CGVD28] |
| 100-yr | 2.4 | 2.6 | 2.8 | 3.1 | 3.4 |
| 50-yr | 2.3 | 2.5 | 2.7 | 3.0 | 3.3 |
| 10-yr | 2.1 | 2.3 | 2.5 | 2.8 | 3.1 |
| 5-yr | 2.0 | 2.2 | 2.4 | 2.7 | 3.0 |
| 2-yr | 1.9 | 2.1 | 2.3 | 2.6 | 2.9 |
| Tidal Elevations with SLR | | | | | |
| HHWLT | 1.4 | 1.6 | 1.8 | 2.1 | 2.4 |
| HHWMT | 1.0 | 1.2 | 1.4 | 1.7 | 2.0 |
| MWL | 0.0 | 0.2 | 0.4 | 0.7 | 1.0 |
| LLWMT | -0.6 | -0.4 | -0.2 | 0.1 | 0.4 |
| LLWLT | -1 | -0.8 | -0.6 | -0.3 | 0.0 |

## 2.3 Flooding Risk Analysis

### 2.3.1 Coastal Floodmaps

The coastal flood lines were determined by assessing the regions within the study site with elevations lower than the extreme still water levels for Liverpool (as shown in Table 2.2.3). This shows the low areas within the region which are susceptible to flooding during extreme events. The accuracy of the flood risk analysis is based on the resolution and quality of the elevation map. Accuracy is greatest in open areas with little tree cover.

Coastal floodmaps were generated for extreme events under existing conditions for the 2-, 5-, 10-, 50- , and 100-year storm surge events, as well as the 100-year storm surge events considering sea level rise from 2040 up to the year 2100. The flood risk areas within the maps are based on the calculated still water level and do not take into account tidal amplification or reduction along the river estuary, or waves.

### 2.3.2 Observations

Figure 2.3 shows a close up of one of the coastal floodline maps, Map 1F, which are presented in Appendix A. This map shows that roads such as Henry Hensey Drive and Water Street are at risk of flooding for the existing 1 in 2 year flood with larger events posing flood risk along Legion St and Market St. The area at risk also includes the surrounding Waterfront Plana and Hell Bay Brewery. Figure 2.4 is a closeup of Map 2F that shows that as sea level rises, the extent of area and infrastructure at risk increases. This highlights the need to consider SLR when assessing infrastructure at risk and considering mitigation measures. The next chapter discusses these floodmaps in greater detail; identifying infrastructure at risk and determining potential solutions and order of magnitude costs for implementation.

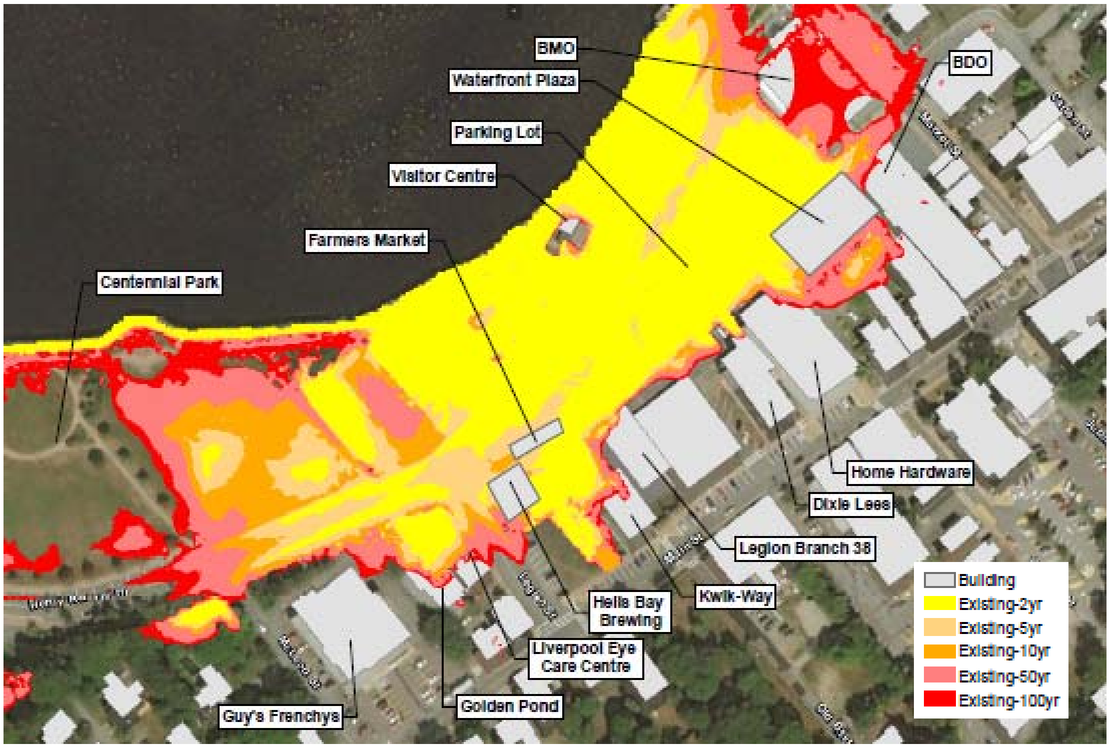



**Figure 2.3.1: Sample Floodline Map for Downtown Liverpool Under Existing Conditions**

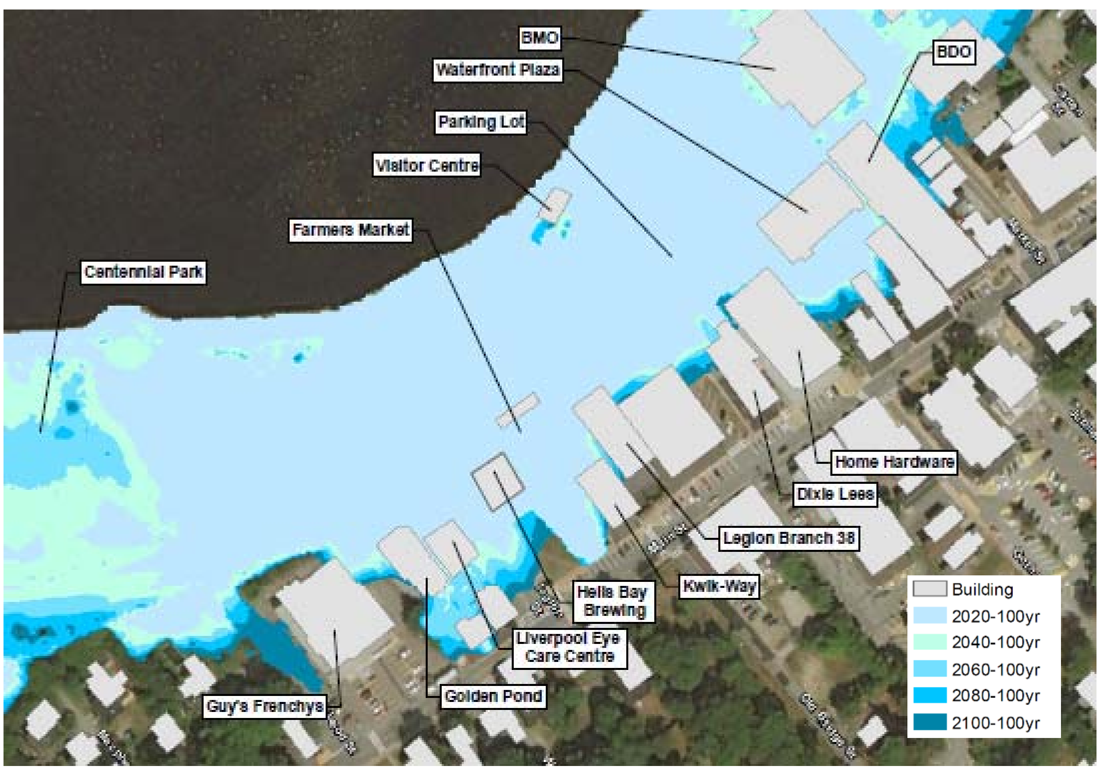
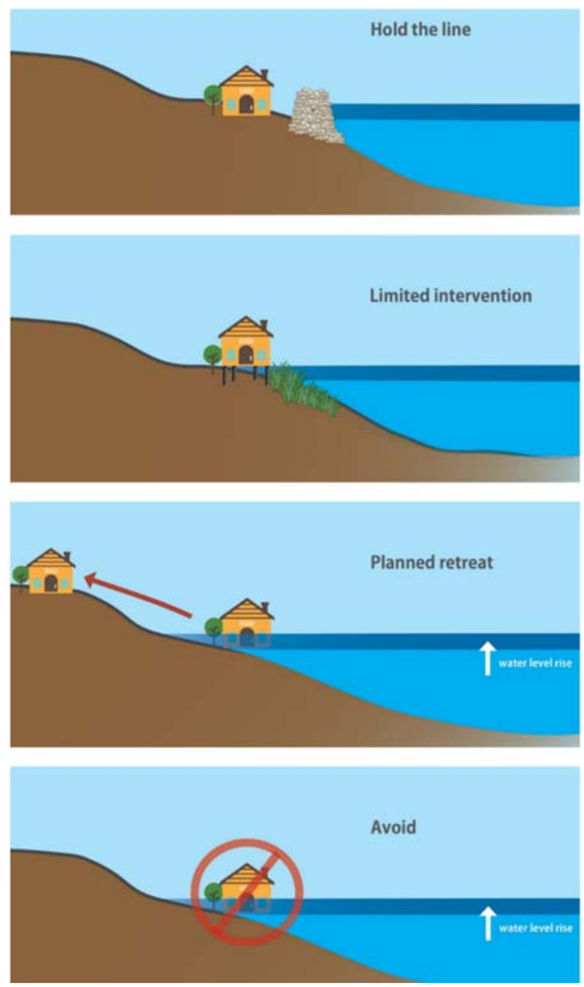



**Figure 2.3.2: Sample Floodline Map for Downtown Liverpool Considering Sea Level Rise**

## 2.4 General Design Considerations

Traditionally, the use of coastal defenses to mitigate flood risks has relied on the construction of structural defenses designed to withstand waves and storm surges up to a specific magnitude. The standard design criterion is generally the 100-year event (i.e. the event that has a 1% chance of occurrence each year). This approach has provided many communities with access to areas naturally prone to flooding and incentivized the development of valuable real state and economical activities in the proximities to the ocean. However, in the face of climatic changes and potential acceleration of sea level rise, effective flood and disaster mitigation measures require solutions that are feasible, adaptable and cost effective. Reducing the risk of flooding under changing conditions requires the selection of a particular solution that allows to address present needs of protection and to plan for future land uses, reduce the risks of future damage and avoid additional costs of re-designing for the new conditions. The Province of Nova Scotia and the Federal Government have recognized these challenges through a funding agreement for infrastructure project under the green-infrastructure stream for adaptation, resilience, and disaster mitigation. CBCL developed concept designs for four flood mitigation options based on the application of the following flood management approaches:




**Holding the Line:** This approach maintains land uses and development in the vulnerable areas and relies in the design and maintenance of hard infrastructure to resist extreme events to a set level.

**Limited Intervention:** This approach involves changing land uses in exposed areas using infrastructure that can tolerate flooding. Examples of this approach include raising or flood proofing vulnerable infrastructure and using floating structures.

**Retreat:** This long-term approach consists of relocating people and infrastructure away from hazardous coastal areas. Managed retreat involves selecting what to relocate and mitigating the environmental impacts of leaving infrastructure exposed to natural processes. Abandonment is another type of retreat that does not involve planning for relocation or for the impacts that abandonment may cause on the environment. Abandonment is not a beneficial adaptation strategy but may be necessary in cases of emergency.

**Avoid:** This approach prevents development in hazardous coastal and riparian areas and locates critical infrastructure such as hospitals and emergency services in areas where risks of flooding are negligible.

The following chapter looks at various infrastructure regions around Liverpool, assesses the risk to each region, and examines potential solutions with the above design considerations in mind.

# Chapter 3 Infrastructure at Risk & Implementation Plan

This chapter identifies infrastructure at risk by isolating and evaluating regions where infrastructure assets are grouped together. Infrastructure regions are evaluated through use of the coastal floodline maps which are presented in Appendix A. As part of the evaluation process, regions are assessed through the use of a risk assessment matrix. Regions are then organized in a priority list based on the outcome of the risk assessment. Each region is then discussed in greater detail, highlighting potential risks and possible solutions. The one exception being for the Downtown Liverpool region which is discussed in the next chapter. Lastly, a summary table outline implementation measures for each region and order of magnitude costs is presented.

## 3.1 Identification of Infrastructure at Risk

There are two different kinds of flood maps that were developed for this study to help identify infrastructure assets at risk:

→ Coastal flood scenarios at existing sea levels with varying storm surge return periods (2, 5, 10, 50, and 100 year).
→ Coastal flood scenarios for a 100 year storm surge event for multiple future time horizons (20, 40, 60, and 80 years) accounting for sea level rise.

Both sets of maps identified above help identify areas that are prone to coastal flooding. Comparing the existing sea level condition maps to the future sea level rise maps helps in with future planning and making infrastructure spending decisions. The former can identify properties that are currently at risk and that should be prioritized whereas the latter identifies properties that are safe from flooding for now, but should be addressed in the coming years. A Land Use Map illustrating various land uses of all properties in Liverpool was also created using data provided by the Municipality. Considering both sets of mapping along with the land use map, infrastructure regions were created as a means to better assess the isolated flooding risks, develop potential solutions, and create a priority system for mitigation measures. The regions and detailed descriptions, along with their associated Map IDs corresponding to maps found in Appendix A, are listed in the table below:

**Table 3.1.1: Description of Infrastructure Regions**

| Region Name | Map IDs | Description of Region and Notable Assets |
|---|---|---|
| Region A: Trestle Trail | Map 1A<br>Map 2A | Area to the south of the Highway 103 eastbound off-ramp. Encompasses mainly forested land and a section of the Trestle Trail. |
| Region B: Sobeys Commercial Plaza | Map 1B<br>Map 2B | Commercial plaza to the east of the Milton Road (Trunk 8) and Lighthouse Route (Trunk 3) intersection. Includes the Sobeys and Tim Horton's buildings and parking lots. |
| Region C: Waterfront near Bristol Avenue | Map 1C<br>Map 2C | Includes waterfront properties along Bristol Avenue, including residential south of Mersey Avenue and commercial on Rent Road. |
| Region D: Waterfront near Cowie Street and Main Street | Map 1D<br>Map 2D | Includes residential waterfront properties on Cowie Street and along Main Street between King Street and Amherst Street. |
| Region E: Fire Hall and Surrounding Area | Map 1E<br>Map 2E | Large area that mostly encompasses the Liverpool Fire Hall, Municipal Services Building, residential properties near the Union Street canal and along Main Street, and vacant lots along Henry Hensey Drive. |
| Region F: Downtown Liverpool | Map 1F<br>Map 2F | Downtown area that includes properties within the boundaries of Main Street, Market Street (Trunk 3), McLeod Street, stretching to the waterfront. Includes multiple commercial properties, a common asphalt parking lot, and park land along the waterfront. |
| Region G: East Industrial Waterfront | Map 1G<br>Map 2G | Encompasses industrial waterfront properties to the east of Market Street (Trunk 3). Assets include warehouse buildings, docks, and a boat ramp. |
| Region H: East Residential Waterfront | Map 1H<br>Map 2H | Encompasses residential waterfront properties along Main Street to the east of School Street. |

Isolating these regions, where infrastructure asset types are generally grouped together, creates the opportunity to uniquely assess each area and develop tailored solutions. The next step is to create a priority list that is based on importance of the infrastructure in each region, the Risk Exposure, and the Risk Timeline. This priority list then feeds into an implementation plan that can be used to phase different solutions based on most prioritized first. This prioritization methodology is discussed in greater detail in the next section.

## 3.2 Prioritization of Infrastructure Regions

After identifying the various regions, the next step was to develop a prioritization system to examine which regions are most at risk. This involved creating a matrix where all regions are listed and assigned risk ratings based on different factors. These factors include type of infrastructure within the region, risk exposure to the area, and risk timelines. This methodology was based on fundamentals from the Public

Infrastructure Engineering Vulnerability Committee (PIEVC) Protocol[8] developed by Engineers Canada. From the PIEVC website "The PIEVC created a protocol to assess the vulnerabilities of infrastructure to extreme weather events and future changes in climate. This enables better planning and design of safe and climate-resilient infrastructure." Though the exact PIEVC Protocol methodology was not applied for this study, it formed the basis for how risk was evaluated in terms of identifying contributing risk factors, assigning scores, and developing an infrastructure region priority list.

The first parameter to evaluate is the level of importance of the infrastructure within the region in question. Each region has different types of infrastructure located within its boundaries. Some regions include residential properties whereas others have commercial or industrial businesses or even emergency services. Importance of the assets is measured by the function that the asset serves; firstly and foremost if the asset provides some function during an emergency such as a fire station or a hospital it will be given the highest score.

The second parameter evaluated in this study is Risk Exposure. Risk Exposure can be defined as the likelihood and level of confidence of how prone a region is to flooding. Some regions are further inland and it is difficult to estimate how exposed it is to the risk of flooding without additional analysis. This could be compared to a low-lying region along the coast, where coastal flooding is easier to predict. The threat of flooding also varies from region to region based on different timelines.

The third and last parameter is the Risk Timeline. Risk Timelines are associated with the sea level rise scenarios which include present day, 20 year, 40 year, 60 year, and 80 year increments. A property within a region may be above a projected floodline for the 20 year time interval but that may change for the 80 year time interval as sea level is expected to rise. All these factors; infrastructure importance, risk exposure, and timeline, are presented within the risk matrix found in the table below. Each factor, for each region, is assigned a score of 1 to 5. The scores are then added up which then acts as a basis to determine priority for each region.

[8] More on the Engineers Canada PIEVC and The Protocol can be found on the PIEVC website: https://pievc.ca/

**Table 3.2.1: Infrastructure Regions Risk Matrix**

| Region | Infrastructure Importance | Risk Exposure | Risk Timeline | Priority Score | Priority Rank |
|---|---|---|---|---|---|
| Region A: Trestle Trail | 1 | 1 | 1 | **3** | **6** |
| Region B: Sobeys Commercial Plaza | 4 | 3 | 2 | **9** | **T4** |
| Region C: Waterfront near Bristol Avenue | 4 | 3 | 4 | **11** | **3** |
| Region D: Waterfront near Cowie Street and Main Street | 2 | 2 | 4 | **8** | **5** |
| Region E: Fire Hall and Surrounding Area | 5 | 4 | 4 | **13** | **2** |
| Region F: Downtown Liverpool | 5 | 5 | 5 | **15** | **1** |
| Region G: East Industrial Waterfront | 3 | 3 | 3 | **9** | **T4** |
| Region H: East Residential Waterfront | 3 | 2 | 4 | **9** | **T4** |

Based on the calculated priority scores, rankings were assigned for each respective region. These rankings are arranged in descending order in the table below as a summary.

**Table 3.2.2: Priority List for Infrastructure Regions**

| Region | Priority Rank |
|---|---|
| Region F: Downtown Liverpool | **1** |
| Region E: Fire Hall and Surrounding Area | **2** |
| Region C: Waterfront near Bristol Avenue | **3** |
| Region B: Sobeys Commercial Plaza | **T4** |
| Region G: East Industrial Waterfront | **T4** |
| Region H: East Residential Waterfront | **T4** |
| Region D: Waterfront near Cowie Street and Main Street | **5** |
| Region A: Trestle Trail | **6** |

## 3.3 Regional Risks and Possible Solutions

The sections below describe the infrastructure regions in further detail and identify high level mitigation measures as solutions that could be applied. These solutions are later discussed in the implementation plan in the next section.

### 3.3.1 Region F: Downtown Liverpool

This region not only ranked highest on the priority list, but also scored the maximum amount of points for each parameter. The existing infrastructure assets in the area consist primarily of commercial properties and is anchored by a central, common asphalt parking lot.

Due to its scope and size, mitigation measures for this region are further detailed in its own separate chapter. Chapter 4 provides additional information on the area and details on an area-specific study and implementation plan for this area.

### 3.3.2 Region E: Fire Hall and Surrounding Area

This region ranked second in priority, just behind the Downtown Liverpool region. The Fire Hall region is located adjacent to the Downtown area and the risks both regions face are similar. One could argue that these first two regions can make a grander area that should be considered together when determining a planning and implementing solutions.


*Liverpool Fire Hall*

This region is particularly important because of the presence of the Liverpool Fire Department for emergency services. In times of emergency, such as widespread flooding, it is crucial to keep services such as firefighting operational throughout. From the mapping it can be seen that though there is no immediate risk to the Fire Station and Municipal Services Building for the 100 year return period at existing sea levels, but there is a risk to the surrounding area. Particularly to the streets leading to the building; Main Street and Henry Hensey. Residential properties in the surrounding area, as well as the vacant lots around the building, also show some vulnerability. This is likely a result from the open channel, known as Mill Brook, that passes between Civic 472 and 478 on Main Street and then adjacent to Union Street before emptying into the Mersey River to the north. During high tide, the drainage capacity of that channel becomes compromised as the tides move upstream through the channel. This likely causes flooding to the backyards of the residential properties along Main Street.

From the long-term mapping, we see that the Fire Station becomes prone to flooding under the 100 year return for 2060 sea level rise scenario. While this may be 40 years in the future, it is still vital to consider the importance of the structure relative to other assets. It is a combination of this potential disruption to emergency service, along with the near-term implications to the surrounding area that results in the region's high prioritization.

**Solutions**

There are two mitigation measures worth discussing for this region. One deals with addressing the fire hall itself and the other with the open canal.

<u>Fire Hall</u>

With a 40-year outlook, the existing Fire Station will likely have outlasted its useful life. Options should be looked at whether to replace/upgrade the building at its existing site or construct a new Fire Hall elsewhere in the community. If the first option is examined, the site will either need to be raised to counter against sea level rise or a broader coastal flooding protection system will need to be implemented that would serve this region and the downtown region as well. More on this coastal protection system can be found in the next chapter.

If the building is upgraded or demolished and rebuilt, there will have to be a plan in place for how these services will remain operational during construction. Existing grades will have to be raised if the fire hall is built in the same location, as well as the surrounding roads to ensure proper access.

Another option examines the possibility of a new fire station elsewhere in the community. With this option, a siting study could be completed to ensure that the Fire Station is located on higher ground that is not prone to flooding.

Mill Brook

Mill Brook, the canal adjacent to Union Street, is a little more difficult to assess. Due to its open nature, the canal has the potential to overflow during storm events. This risk increases exponentially if the storm occurs at a high tide event. The risk is further increased as sea level rises, which will compromise the channel's ability to drain effectively. There are also flood risks during periods of high tides and spring melt off of snow.

Targeted solutions for this area during this phase of high level study is challenging since possible solutions may have unintended consequences. Further analysis of this watercourse and the surrounding watershed would be required to provide a more confident solution. Possible solution could include the combination of increasing capacity of the brook, reducing/restricting the influence of the tides, and decreasing the runoff being directed to the brook. Further to this, BMPs can be introduced elsewhere in the watershed feeding Mill Brook to reduce the level of runoff and thus, flow through the channel. Encouraging more infiltration and slowing down the flow of water, through the use of stormwater BMPs, would help in reducing and managing the flows through Mill Brook and therefore reduce the required capacity.

*Mill Brook at Outlet to Mersey River*

*Open Channel at Main Street Looking North*

### 3.3.3 Region C: Waterfront near Bristol Avenue

This region includes the waterfront properties along Bristol Avenue, just north of the Liverpool Bridge. It includes residential properties, one commercial property, and a large industrial property on the north side of the river directly after the bridge. The residential properties include mostly 2-storey detached housing units whose backyards extend out towards the River. The industrial property is owned by Mersey Seafoods, who was mentioned earlier as owning property on the other side of the river as well. It is understood that Mersey Seafoods used this property, north of the river, for most of its operations. This industrial site hosts a number of operations buildings, a few secondary structures such as sheds and equipment storage buildings, as well as two parallel wharves. The company has also completed construction on a new, state-of-the-art facility for scallop processing directly off Bristol Avenue. The company has cited climate change and rising sea levels as one of the reasons for picking a site further inland and at a higher grade for its new processing plant.

*Mersey Seafoods Processing Plant*

*Mersey Seafoods Property - North*

*Mersey Avenue Looking East*

*Lane's Privateer Inn & Restaurant*

Coastal floodline maps indicate that the commercial property, a hotel with a restaurant and parking lot, and the residential properties are prone to coastal flooding along the water's edge even at the 2 year storm return period at current sea levels. At this scenario, existing residential buildings at the end of Mersey Avenue also appear to be at risk of coastal flooding. The industrial property is also at risk for that scenario, with the wharves exhibiting vulnerability at the 50 year return period for existing sea levels. The area at risk becomes larger when looking at future sea level rise projections. For the future time horizons, floodlines creep further inland and cover additional buildings, both on south side and north side.

**Solutions**

In the near term, the residential properties at the end of Mersey Avenue exhibit the highest risk and are likely currently experiencing periodic flooding. Other residential properties become vulnerable in the long term. The same solutions for residential properties discussed for Region H: East Residential

Waterfront would apply here as well. To avoid repetition, please see the section above regarding these residential properties. The solutions can be summarized as follows: installing and maintaining an armour revetment in the near-term to prevent coastal erosion, raising existing grades and buildings, berming around the coastline, and/or a phased retreat. Any further development on these coastal lots should also be restricted.

Another area of concern is the parking lot for the hotel and restaurant property on the south side of Bristol Avenue just after the bridge. This parking lot could be regraded and raised to match the elevations of Bristol Avenue as it appears that the road is safe for the most part other than for the most extreme cases. Currently, it appears as if the parking lot slopes directly toward the water. If the grades were raised, attention will have to be given to proper drainage as a stormwater system will be required.

Lastly, we arrive to the Mersey Seafoods industrial property on the north side of Bristol Avenue just after the bridge. It is encouraging to see that the new facility being constructed is on higher ground and does not exhibit vulnerability to flooding. That being said, there are still other buildings on the site that should be assessed. These buildings will either need to be raised or relocated to avoid the risks of flooding. Another important note is that though flooding to the wharves may not be a major concern, rising sea levels may pose an operational issue for the boats that use the wharves to berth. The wharves may have to be raised if rising sea levels will interrupt the boats' ability to dock and use the harbor facilities. Mersey Seafoods should be consulted to determine if they have a plan to deal with this potential issue.

### 3.3.4 Region B: Sobeys Commercial Plaza

The Sobeys Commercial Plaza area is ranked fourth on the prioritization list, along with two other regions that will be discussed later in this chapter. This region primarily consists of the Sobeys and Tim Horton's buildings and their respective asphalt parking lots.

*Sobeys Building Looking North*

From the floodmaps, it can be seen that there is no major near-term risk to these assets. The risk becomes evident in the future sea level rise scenarios where parking lots become vulnerable in the 100 year return period 60 and 80 year future sea level rise scenarios and the buildings in the 100 year future sea level rise scenario. The floodmaps show that the area directly behind these properties are prone to flooding even at the 2-year return period for present-day sea level conditions. This is not a surprise as the area is classified as a wetland according to Department of Lands and Forestry databases. The only concern is that if development were to occur here, additional impact to the surrounding area from a stormwater management point of view should be properly examined.


Structure on Hank Snow Drive Looking Northwest

For the Sobeys and Tim Hortons properties, it is identified that the risk to infrastructure won't be apparent until 60 to 80 years in the future. This should be considered when implementing any kind of mitigation measure. Due to the nature of the still-water elevation projections on the maps, it is difficult to tell just how susceptible to coastal flooding these assets are, recognizing how far inland the properties are located. That being said, the properties main risk likely comes from its ability to drain effectively in times of a storm event during high tide. Assuming that the parking lots drain towards the wetlands to the east, stormwater management will become compromised if the wetlands become further inundated from high tides due to rising sea levels. It appears as if all drainage flows through a structure at Hank Point Drive.

**Solutions**

It should firstly be stated that not much is known on the area and that further stormwater analysis would be required to gauge how vulnerable infrastructure is in this area. One conceptual option, if further analysis warrants the need, would be to install a flow restricting structure at Hank Snow Drive to control and/or restrict tides from entering upstream and hence inundating the wetlands behind the properties.

Raising grades and therefore raising the buildings in the area is likely not warranted for this region. However, green infrastructure and stormwater Best Management Practices (BMPs) could be applied in the area to encourage more infiltration on site. Stormwater BMPs are further discussed in Chapter 5 of this report.

### 3.3.5 Region G: East Industrial Waterfront

This region, also tied for fourth on the priority list, is primarily concentrated on one parcel of land that is owned by Mersey Seafoods Limited (PID 70029186). Mersey Seafoods is one of Liverpool's prime employers, having ongoing operations in Liverpool since 1964 and currently providing hundreds of people with employment.[9] The property includes some large warehouse buildings, a maintenance shed, berth/dock, and a boat ramp. It is CBCL's understanding that this property is used to conduct minor maintenance of fishing vessels from time to time.

The coastal floodline maps reveal that the northeastern side of the property exhibits the most vulnerability in the near term, with flooding occurring for a storm with a 50-year return period at existing sea levels. This causes the berth and maintenance shed to experience flooding, but it is unknown at this point how critical this infrastructure is to ongoing operations. If we look ahead, to the future projections for sea level rise, it becomes evident that the warehouses and virtually the entire property becomes prone to flooding. Again, at this point, it is unknown how these assets integrate into

[9] http://hankfm.ca/news/1739575731/mersey-seafoods-reveal-plans-new-scallop-processing-plant

the company's operations and what the future plans are for this property. It should be noted that due to its location at the mouth of the harbor, it does offer prime real estate for fishing and/or fish processing activities. That being said, it appears that most of the company's operations are concentrated north of the river, directly opposite of this property. This area, labelled as Region C: Waterfront near Bristol Avenue in this study, is discussed above.

**Solutions**

*Mersey Seafoods Property South*

Most of the existing infrastructure in this area is dated and most likely near or beyond its useful life. It should be determined what Mersey Seafoods currently uses this property for and what the future plans for the site are. If valuable commercial use can be proven, then action should be taken in the mid-term to protect the site from future sea level rise. This could include a variety of different solutions. One solution could include raising the grades in the area. Re-grading the site could occur at the same time when redevelopment of the area is planned to capitalize on simultaneous construction. Raising the grades would also have to include raising the berth/dock on the northeast side of the property.

If future industrial/commercial use cannot be proven, Liverpool may consider returning this area to its natural shoreline with armour revetment to protect against coastal erosion. From the coastal floodmaps, it is not apparent that the properties along Main Street are prone to coastal flooding. Repurposing an existing industrialized area may, however, prove to be difficult given the involvement of external private stakeholders.

### 3.3.6 Region H: East Residential Waterfront

Moving further east, and also tied for fourth on the priority list, are the residential properties along Main Street on the waterfront side, east of School Street. Many of the houses on these properties are 2-storey residential buildings that have a backyard extending to the Mersey River. The backyards slope down to the water where there is an armoured slope at the interface between land and sea.

By examining the floodmaps, we discover that most of the backyard areas are already prone to coastal flooding at the 2 year storm return period for existing sea level conditions. The residential buildings themselves don't appear to be at risk until future time horizons.

**Solutions**

Though the backyard areas appear to be protected by the armoured coastline, ongoing maintenance will be required to ensure that the foreshore is protected. Proper maintenance will ensure that no further coastal frontage will be lost to erosion. Additionally, any further development on these lots should be restricted.

As for the long-term implications of the buildings themselves, there are few options available. Grades and the buildings could be raised, but it is not known how feasible this may be considering some homes may have basements. Another option is to create a berm along the seaside to prevent tides and sea levels from getting in. Though a berm option will block the tides from coming in, it does create a stormwater management issue by preventing overland flow from reaching the waterfront. The last option is to prepare for a phased retreat, moving away from the water and the coastal areas most at risk. A more detailed study will be required, however, to determine if this option is warranted.

### 3.3.7 Region D: Waterfront near Cowie Street and Main Street

This region includes the waterfront properties along Cowie Street and the stretch of Main Street between King Street and about a 100 metres east of Amherst Street. The properties at risk of coastal flooding are mostly all 2 storey residential buildings with frontage extending out towards the water. At the existing sea level conditions, all properties along Cowie Street and the two just east of Amherst Street exhibit some vulnerability to coastal flooding. At future time horizons, with rising sea levels, virtually all properties show risk to coastal flooding.  Additionally, a stretch of Main Street between Amherst Street and Brunswick Street will also be prone to flooding.

**Solutions**

In the near term, properties along Cowie Street and few along the water across from the Amherst Street intersection exhibit the highest risk and likely, currently experience periodic flooding. Other residential properties become vulnerable in the long term. Solutions presented here are similar to the mitigation measures presented for the residential waterfront properties in Region H: East Residential Waterfront. To avoid repetition, please see the section above regarding these residential properties. The solutions can be summarized as follows: raising existing grades and buildings, constructing a berm around the coastline, and/or a phased retreat. Additionally, any further development on these lots should be restricted.

Another solution worth discussing here is an extension of a dyke or seawall from high ground just west of Amherst Street, wrapping around the Downtown Liverpool coastline, and tying to proposed raised grades at Market Street. This solution offers coastal protection to multiple regions, including the Main Street, the Fire Hall, and the Downtown Liverpool area. The solution comes with its own complexities, such as cost and integration with surrounding infrastructure, including stormwater. The seawall is discussed in the next Chapter, where a focus on Downtown Liverpool is provided.

*Intersection of King and Cowie Streets*

*Properties on Main Street*

### 3.3.8 Region A: Trestle Trail

Finishing off at the bottom of the prioritization list is the Trestle Trail region, located just southeast from the Highway 104 - Exit 19 Interchange. This region is made up largely of a forested area with an active transportation trail, the Trestle Trail, weaving through. The Trestle Trail is a converted rail line to active transportation trail that meanders along the Mersey River and then across the Trestle Bridge. Because of the former rail line's built-up cross section, the trail is higher than the surrounding area, making it less prone to flooding. The trail doesn't show any vulnerability to coastal flooding for existing sea level conditions. Flood risks only appear for the 100 year storm return period for the year 2060.

**Solutions**

Given the type of infrastructure and the risk involved, the trail is listed at the bottom of the priority list. A simple solution, however, to mitigate risk is to raise the section of trail that appears to be prone to flooding. This involves raising about 350 metres of gravel trail. Alternatively, a do-nothing approach could also be taken without too much consequence.

## 3.4 Summary and Conceptual Costs

The table below summarizes the potential mitigation solutions for each region and lists the associated high-level conceptual costs.

| Region (Sorted by Priority) | | Mitigation Measures | Order of Magnitude Cost Estimate | Additional Notes |
|---|---|---|---|---|
| Region F: Downtown Liverpool | NT | See Chapter 5 | See Chapter 5 | - |
| | LT | See Chapter 5 | See Chapter 5 | - |
| Region E: Fire Hall and Surrounding Area | NT | Coastal protection solutions could be tied into options presented in Chapter 5. | $2 to $5 million | Could include extending sea wall or berm or raising grades on ocean side. Additional study required at Mill Brook. |
| | LT | Fire hall could be reconstructed or relocated. | $5 to $10 million | Demolition = $1 million<br>Raising grades = $500,000<br>New structure = $4-6 million |
| Region B: Sobeys Commercial Plaza | NT | No near-term action required. | - | - |
| | LT | Evaluate capacity of wetlands to handle drainage of adjacent parking lots. Raising of grades may not be warranted, but stormwater BMPs could be applied here to reduce flooding risk. Possibility of tide passage restriction on Hank Snow Drive. | Less than $1 million | Closer look shows that this area isn't as prone to flooding. BMPs could be implemented at low cost whereas tide restriction at Hank Snow Drive may be a more costly venture. |
| Region G: East Industrial Waterfront | NT | No near-term action required. | - | - |
| | LT | Regrade and redevelop area. Site will need to be raised and buildings will need to be demolished and new buildings constructed or the site could be repurposed. | $5 to $10 million | Demolition = $2 million<br>New Structures = $5-10 million |
| Region H: East Residential Waterfront | NT | No near-term action required. | - | - |
| | LT | Demolition, raising grades, and reconstruction of new homes. Planned retreat is the more feasible option. | $1 to $5 million | 4 residential properties affected<br>Demolition = $500,000<br>Reconstruction = $1.5 million |
| Region C: Waterfront near Bristol Avenue | NT | Planned retreat for properties at the end of Mersey Avenue. | Less than $1 million | 2 residential properties affected |
| | LT | Industrial site and hotel parking lot should be regraded and buildings will have to be demolished and reconstructed. A planned retreat for residential properties is best suited. | $10 million + | 5 residential properties affected<br>Demolition = $2 million<br>Reconstruction = $4 million<br>Partial Hotel Reconstruction = $2 million |

| Region (Sorted by Priority) | Mitigation Measures | | Order of Magnitude Cost Estimate | Additional Notes |
|---|---|---|---|---|
| | | | | Industrial Reconstruction = $5 - $10 million |
| Region D: Waterfront near Cowie Street | NT | Planned retreat for properties on Cowie Street and Main Street. | $1 to $2 million | 6 residential properties affected |
| | LT | Planned retreat for affected properties. Raising Main Street or coastal protection solution with dykes or seawall. | $2 to $5 million | A berm could be built along the shoreline to protect inland properties |
| Region A: Trestle Trail | NT | No near-term action required. | - | - |
| | LT | Raising section of trail not warranted, but could be completed if maintenance work is also scheduled. | Less than $1 million | Multi-use trail is not a critical asset. Could be allowed to flood once in a while. Could be raised during future maintenance efforts. |

***NT: Near-Term***

***LT: Long-Term***

# Chapter 4 Downtown Liverpool Review & Coastal Protection Options

This chapter firstly describes the risks associate with the Downtown Liverpool region and identifies possible mitigation measures that could be applied to the area. Later in the chapter, an implementation plan is developed that considers all infrastructure regions, potential solutions, and associated order-of-magnitude costs.

## 4.1 Region F: Downtown Liverpool

This region ranked number one on the priority list and scored the most points on every parameter. Given its importance to the Community of Liverpool, the historical flooding issues that have been experienced, and the future risk that it is exposed to, a dedicated chapter on the coastal flooding vulnerabilities and possible solutions was warranted.

### 4.1.1 Flooding Risks

It is first important to understand the region’s vulnerability to coastal flooding. Figure 4.1.1 shows floodlines delineated for the following extreme events, identifying areas at risk:

→ 1 in 2 year event under present climate conditions. Water elevation 1.9m.
→ 1 in 100 year event under present climate conditions. Water elevation 2.4m.
→ 1 in 100 year event under projected climate conditions for the year 2070. Water elevation 2.9m.
→ Hurricane Juan under present conditions assuming landfall at Liverpool and HHWLT. Water Elevation 3.9m.

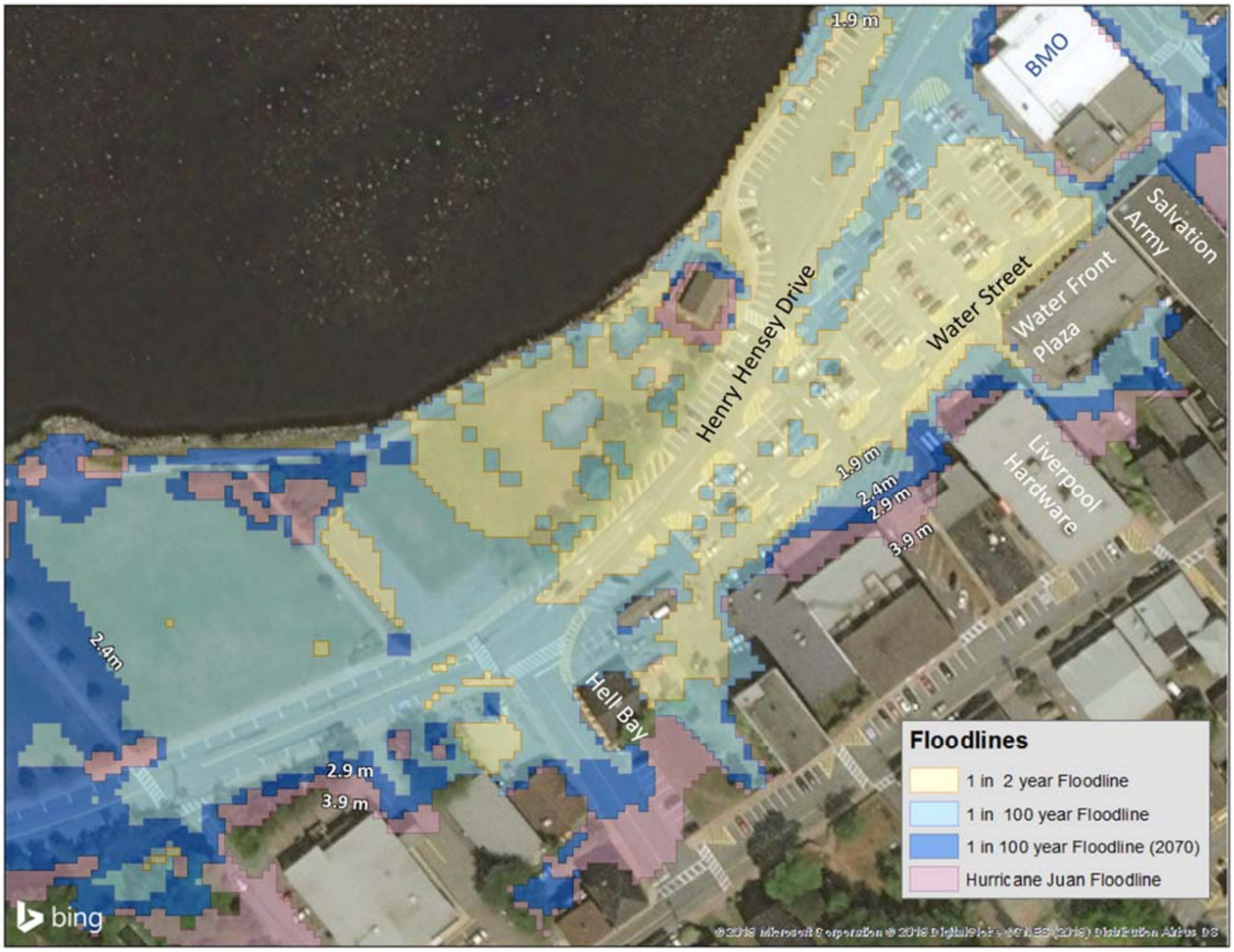



**Figure 4.1.1: Still Water Level Flood Lines**

The floodmap above (Figure 4.1), shows that mitigation measures at an elevation of 2.4 m would reduce flooding risks in the areas shaded in yellow and light blue which include 300 m of Henry Hensey Drive and 350 m of Water Street. This area also includes the surroundings of the Waterfront Plaza and the building of the Hell Bay Brewery.

The 1 in 100 year floodline estimated for the year 2070 shows that as sea level rises, the extent of areas at risk increases to include the BMO building. Therefore, in 50 years, coastal flood defenses with an elevation lower than 2.9 m will likely require an upgrade.

The Hurricane Juan Floodline shows the areas at risks if a storm surge similar to that observed during Hurricane Juan in Halifax, NS made landfall in Liverpool. Even though events of such magnitude are less frequent than a 1 in 100 year storm, the map shows that infrastructure at an elevation lower than 3.9 m could be exposed to flooding during these types of events.

In conclusion, an elevation of 2.40 m is the minimum recommended target elevation for defense measures to mitigate flooding risks events under current climatic conditions.

### 4.1.2 Historical Development

Figure 4.1.2 compares the shoreline location of the Liverpool waterfront in 1945 and 2019. The top of the figure presents an air photo from 1945. Water Street was located at the back edge of a series of wharves that provided access to the water front, and behind a series of ponds. The bottom of the figure shows the current shoreline location. It is estimated that the original shoreline for the Mersey River in this location is close to the current location of Water Street, or just to the South of Water Street. The alignment of Main Street remains unchanged and most of the alignment of Water Street remains the same. The north edge of the ponds coincides with what today is Henry Hensey Drive. Between 1945 and 2019 the shoreline was advanced an average of 75 m towards the sea over an area infilled with materials than range from scrap wood from old wharves to boulders and fine grains. Discussions with Municipality staff has confirmed this condition. An investigation of geotechnical investigations in the infilled area will be critical for any civil works proposed for flood mitigation areas in the area.

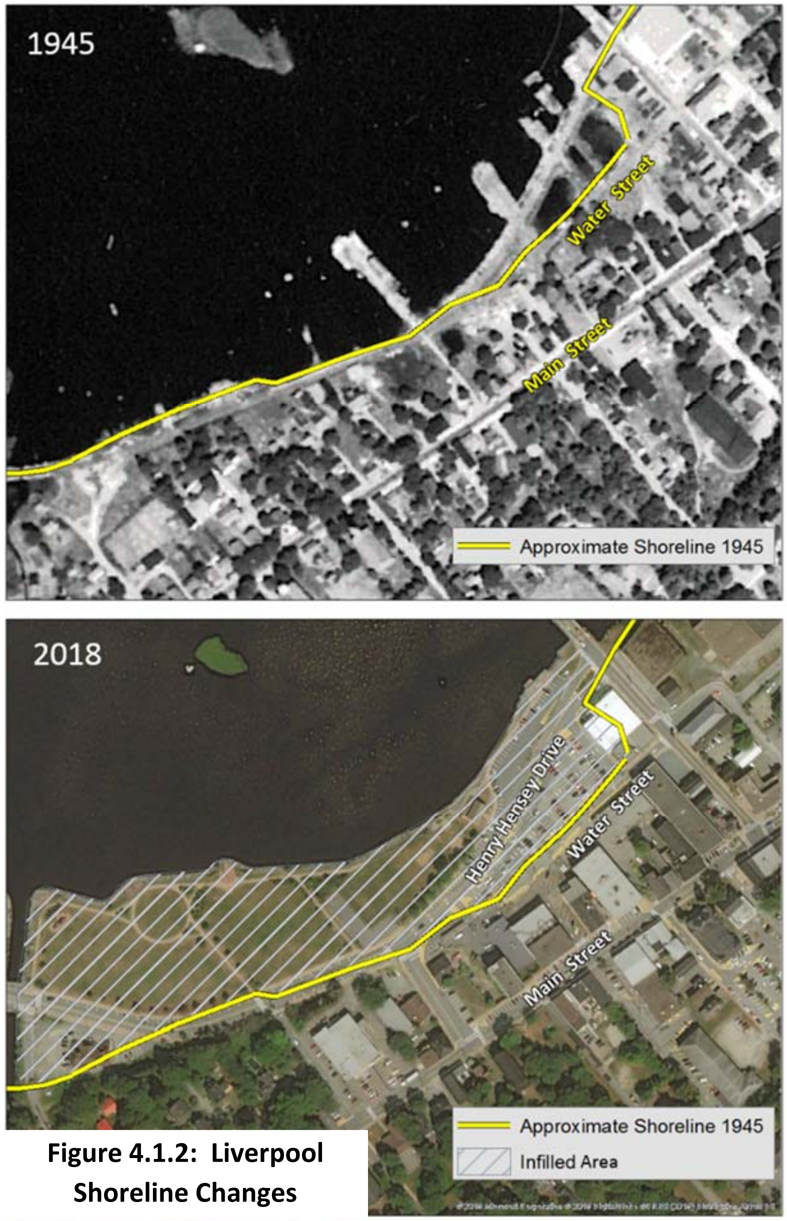



**Figure 4.1.2: Liverpool Shoreline Changes**

### 4.1.3 Existing Infrastructure Assets

The region consists largely of commercial businesses surrounding a community asphalt parking lot. The parking lot, including parking spaces along the waterfront, has capacity for about 125 vehicles. Towards the west, the parking lot transitions to grassed, relatively flat, recreational parkland stretching to an open channel watercourse at the intersection of Union Street. The waterfront boasts an armoured revetment on the seaside that meets a concrete walkway at the top of the slope. The walkway extends from the bridge all the way to Union Street, totaling about 450 metres. Businesses in the area vary from restaurants, banking, and general goods stores. All of these businesses benefit from the communal parking lot that is owned by the Region of Queens County.

A list of businesses and their finished floor elevation (FFE) is shown in the table below.

**Table 4.1.1: FFE or Ground Elevations for various Infrastructure Assets**

| Business | FFE / Ground El. (m) |
|---|---|
| Memories Café | 1.745 |
| Queens Learning | 1.754 |
| Kelly Hatt | 1.876 |
| Farmers Market | 1.922 |
| Centenial Park | 1.928 |
| Hell Bay Brewing | 2.129 |
| Salvation Army | 2.16 |
| Royal Canadian Legion | 2.176 |
| BDO | 2.184 |
| Ships Mast | 2.321 |
| Liverpool Professional | 2.331 |
| Liverpool Eye | 2.371 |
| **2020 – 1:100 Return Extreme Water Level** | **2.4** |
| 160 Henry Hensey | 2.467 |
| Bowling Alley | 2.482 |
| BMO | 2.602 |
| Golden Pond | 2.626 |
| Guard House | 2.655 |
| 44 Market Street | 2.718 |
| Community Services | 2.779 |
| Works Garage | 2.939 |
| VIC | 2.99 |
| Home Hardware | 3.099 |
| Tiger Warrington | 3.394 |
| **2100 – 1:100 Return Extreme Water Level** | **3.4** |
| Bargain Shop | 3.523 |

Note that a colour scheme is used to illustrate how prone each asset is to flooding. If an asset's FFE/Ground Elevation is lower than 2.40 m, the extreme water level for a 1:100 year storm for the year 2020, it is highlighted in red. Any assets between this and 3.40 m, the extreme water level for a 1:100 year storm for the year 2100 accounting for sea level rise, it is highlighted in orange. A further note that the FFEs and Ground Elevations were extracted from survey data provided by Region of Queens Municipality.

From this data, we can see that 12 buildings/properties are under the 2.40 m recommended target elevation for coastal protection. This equates to about half of the assets in the area, including the communal parking lot as well. Condition and age of the various buildings also vary from building to building. For the most part, buildings are either one or two storey traditional construction, with no building younger than 10-15 years old.

Considering these issues, the following concept solutions have been developed. The concept designs seek to mitigate the flooding risks around the parking lot between Water Street and Henry Hensey Drive. Considerations underlying the presented concept designs include flooding risks, intended design purpose, design life, land uses, and potential for adaptation and resilience to climate change impacts.

Each concept design is illustrated with its own plan and general cross sections included in Appendix B. The following sections also outline the advantages and disadvantages of each option together with the associated opinion of probable cost. Each concept solution comes with its own positives and negatives which are highlighted towards the end of this chapter.

## 4.2 Concept 1 – Sea Wall

For this concept, a seawall would be built along the top of slope of the shoreline between Market Street and the western end of Centennial Park with a design top elevation of 2.5-3.0m to mitigate flooding risks up to the 1 in 100 year storm. Figure 2 in Appendix B illustrates this concept design. The seawall could be further extended down the coastline towards the west tying into high ground on Main Street near Amherst Street.

As discussed in the previous chapter, historical data in this area provides evidence that area of Centennial Park and the Liverpool parking lot adjacent to Henry Hensey Drive was infilled over a period of time to make way for development. Soils in this area are assumed to be weak, unsuitable, and porous; therefore, a seawall that would extend into the original river bottom would help preventing seawater from infiltrating the fill material and existing storm management infrastructure under the parking lot area. Based on bathymetric data from the previous Liverpool Flood Study and navigational charts, CBCL estimates that the original ocean bed, prior to infilling would have been at an elevation of -5 m. Therefore a design bottom elevation of -7 m was selected as a conservative assumption to minimize the infiltration of sea water into the parking lot and provide an adequate foundation for the seawall. These elevation would require confirmation through a geotechnical drilling program prior to design.

Metal sheet pile was selected as the design material for this structure. A small earthen berm will also be required along the top of slope of the shoreline to the east of Main Street, as well as to the east of Market Street. This achieves the goal of meeting a 2.5m gradeline around the parking lot and adjacent infrastructure to protect from storm surge. This assumes that the geotechnical conditions in this area do not warrant a cut-off wall.

### 4.2.1 Evaluation of Options for Stormwater Management

The Liverpool parking lot that is the focus of this study is located at the outlet of a series of watersheds covering an area of 72 hectares draining towards the Mersey River estuary. The construction of a seawall at the edge of the waterfront would obstruct the surface drainage towards the sea, increasing the risk of flooding during most rainfall events. Therefore, this option would require a series of stormwater management measures to mitigate these risks. A hydrologic and hydraulic assessment was carried out to quantify runoff flows draining towards the parking lot and estimate the magnitude and cost of stormwater management options behind the seawall. To support this assessment, calculations were performed using the hydrologic and hydraulic modelling program PCSWMM.

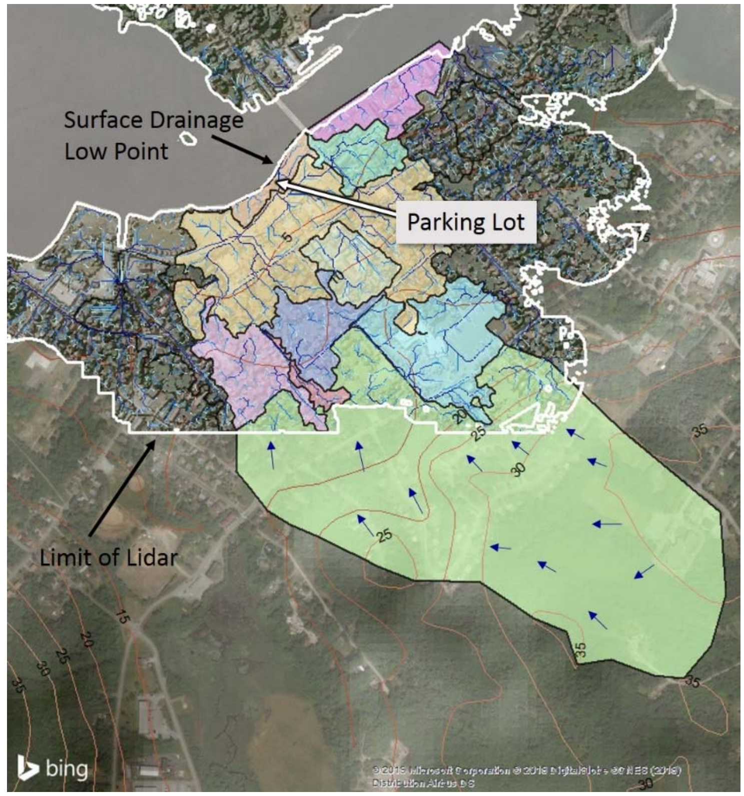



**Figure 4.2.1: Watersheds Draining towards the Liverpool Parking Lot**

PCSWMM integrates Version 5 of the Storm Water Management Model (SWMM) with a GIS engine and is capable of performing 1D and2D hydrodynamic simulations. SWMM is a hydrologic and hydraulic model developed by the United Stated Environmental Protection Agency to study semi-urban drainage systems. It conducts unsteady flow calculations to simulate water backup, pooling and culvert hydraulics by dynamically solving the continuity and momentum equations with a finite difference scheme.

### 4.2.1.1 Hydrologic and Hydraulic Model Analysis

A hydrologic model was assembled using PCSWMM to estimate the flows from each of the watersheds shown in the adjacent figure. The model inputs include watershed delineation and hydrologic characteristic (Table 4.2.1). With the exception of W2, the watersheds were delineated using the LiDAR digital elevation model provided by the Region of Queens Municipality. Watershed W2 was delineated based on the 5 m contours available from Nova Scotia Department of Natural Resources (NSDNR).

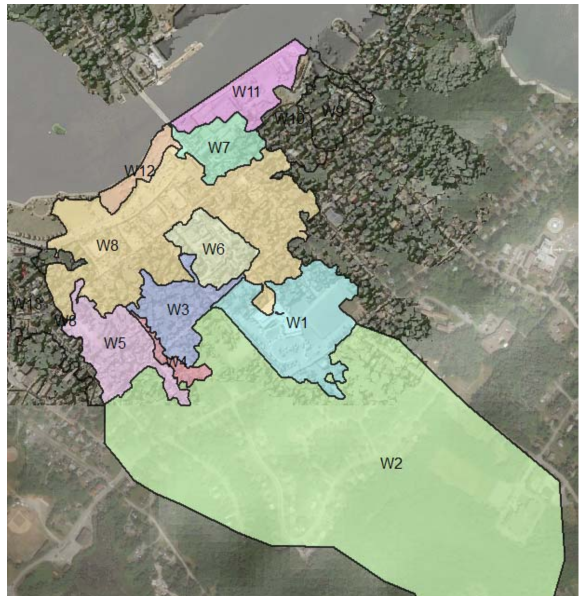



**Figure 4.2.2: Watershed Names**

Aerial photography and the NSDNR land use database were used to estimate the surface roughness coefficients, impervious percentages, soil types, forested land percentages of the watersheds and sub-watersheds. Other hydrologic characteristics (surface area, maximum overland flow length and average surface slope) were estimated using a three-dimensional ground surface generated by ArcView, based on LiDAR mapping.

**Table 4.2.1: Watershed Hydrologic Characteristics**

| Name | Area (ha) | Width (m) | Flow Length (m) | Slope (%) | Imperv. (%) | N Imperv | N Perv | Suction Head (mm) | Conductivity (mm/hr) | Initial Deficit (frac.) |
|---|---|---|---|---|---|---|---|---|---|---|
| W1 | 5.4148 | 112.89 | 479.636 | 2.09 | 80 | 0.013 | 0.4 | 88.9 | 3.3 | 0.02 |
| W2 | 38.7614 | 428.91 | 903.719 | 2.00 | 50 | 0.013 | 0.5 | 88.9 | 3.3 | 0.02 |
| W3 | 2.5722 | 104.38 | 246.427 | 2.63 | 80 | 0.013 | 0.4 | 88.9 | 3.3 | 0.02 |
| W4 | 0.5235 | 43.4 | 120.622 | 2.04 | 80 | 0.013 | 0.4 | 88.9 | 3.3 | 0.02 |
| W5 | 3.2011 | 245.87 | 130.195 | 2.76 | 80 | 0.013 | 0.4 | 88.9 | 3.3 | 0.02 |
| W6 | 2.0837 | 164.81 | 126.426 | 3.64 | 80 | 0.013 | 0.4 | 88.9 | 3.3 | 0.02 |
| W7 | 1.9032 | 140.43 | 135.523 | 2.54 | 80 | 0.013 | 0.4 | 88.9 | 3.3 | 0.02 |
| W8 | 12.4469 | 246.8 | 504.33 | 2.45 | 80 | 0.013 | 0.4 | 88.9 | 3.3 | 0.02 |
| W9 | 1.6727 | 116 | 144.198 | 3.01 | 80 | 0.013 | 0.4 | 88.9 | 3.3 | 0.02 |
| W11 | 2.4569 | 336.38 | 73.039 | 2.10 | 80 | 0.013 | 0.4 | 88.9 | 3.3 | 0.02 |
| W12 | 0.9123 | 206 | 44.286 | 2.05 | 80 | 0.011 | 0.15 | 88.9 | 3.3 | 0.02 |

### 4.2.1.2 Extreme Watershed Flow Estimation

The hydrologic model calculated extreme runoff flows from each watershed for the 1 in 100 year rainfall event under present climatic conditions, as any storm management measure behind the seawall should be designed to handle an extreme rainfall event.

A rainfall hyetograph following the Chicago Distribution with 5-minute discretization intervals and 24-hour durations was developed based on the Intensity-Duration-Frequency (IDF) curves (upper bound 95% confidence interval) from Environment Canada for the Western Head climate station, the closest climate station to Liverpool.

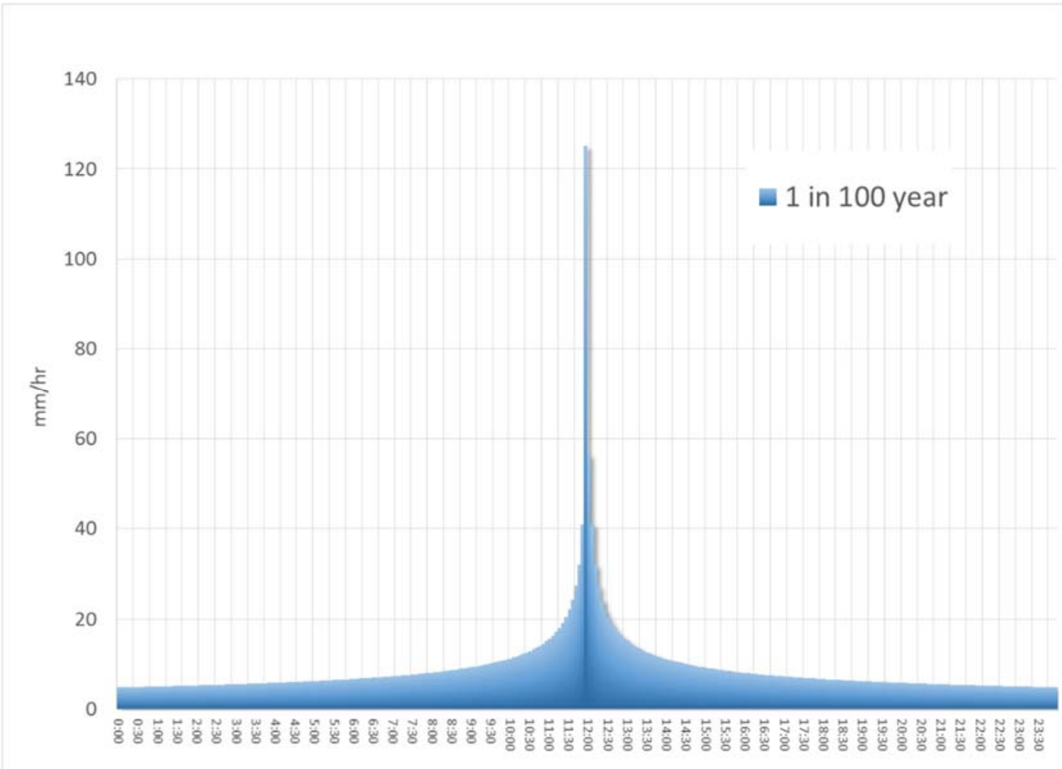



**Figure 4.2.3: 1:100 Rainfall Event Under Present Climactic Conditions**

Table 4.2.2 presents the calculated flows at each watershed, as well as the total flows draining towards the parking lot.

**Table 4.2.2: Estimated Peak Flows and Runoff Coefficients for the 1 in 100 Year Event**

| Name | Peak Runoff ($m^3/s$) | Runoff Coefficient |
|---|---|---|
| W1 | 0.55 | 0.818 |
| W2 | 2.12 | 0.733 |
| W3 | 2.72 | 0.984 |
| W4 | 0.11 | 0.917 |
| W5 | 0.52 | 0.833 |
| W6 | 0.36 | 0.834 |
| W7 | 0.41 | 0.917 |
| W8 | 3.78 | 0.948 |
| W9 | 0.36 | 0.917 |
| W11 | 1.03 | 0.966 |
| W12 | 0.27 | 0.92 |
| Total Runoff Flow | 3.96 $m^3/s$ | |

Model calculations indicate that during a 1 in 100 year event, 3.78 $m^3/s$ (62,800 USG/m) flow towards the parking lot, and into the ocean.

#### 4.2.1.3 Impact of Climate Change on Rainfall

The worst-case climate change scenario, RCP8.5, as defined in the IPCC 5th Assessment Report (IPCC 2013)[10] indicate that the most extreme future storms could increase rainfall intensity by 136%, whereas the minimum future increase could be as low as 14%[11]. Previous assessments in Halifax and Charlottetown found the percent increase in intensity to be between 8.59% and 52%, and between 18.85% and 46.3% respectively. These estimates are generally close to a 30% average increase by the year 2100. Therefore, it was estimated that storm management measures installed to handle runoff flows behind the seawall are likely to require a capacity upgrade ranging between 15 and 30 % within the lifecycle of the seawall and related infrastructure.

### 4.2.2 Stormwater Management Options

To avoid an increase of the risk of flooding in the parking lot area after the construction of a seawall, stormwater management measures behind the wall require a design that mimics the current drainage system (continuous un-obstructed surface drainage into the sea with minimal ponding), such that it allows complete drainage of consecutive storm events. This assessment evaluates the feasibility of the following stormwater management measures to provide drainage behind the seawall with the required performance:

→ Stormwater pumps and storage.

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[10] IPCC. 2013. IPCC 5th Assessment Report, Climate change 2007: The physical Science Basis. [Solomon S., D. Qin, M. Manning, Z., Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge, UK, and New York, USA.: Cambridge University Press.

[11] Westra , S. , H. J. Fowler , J. P. Evans, J. V. Alexander, P. Berg, F. Johnson, E. J. Kendon, G. Lenderink, and N. M. Roberts. 2014. "Future Chances to the Intensity and Frequency of Short-duration Extreme Rainfall." Review of Geophysics 522-555.

→ Best Management Practices.
→ Tide gates at grade level.
→ Drainage diversion.

The following sections describe each measure and provide some preliminary dimensions as well as a description of their limitations. Please note that this analysis does not take into consideration the impact of climate change.

#### 4.2.2.1 Stormwater Pumping and Storage

Calculations with the model indicate that if pumping all stormwater without storage requires a pumping capacity equal to the 1 in 100 year peak discharge, 5.51 m3/s or 87,350 us gpm. In order to reduce this to a more manageable pump system, partial stormwater storage is required. Storage options could include a pond, underground tanks or a range of smaller storage units spread out throughout the watershed. Existing stormwater infrastructure in the area would be re-directed to this storage facility.

With the combination of stormwater pumps and storage, model calculations indicate that a pumping capacity of 1.8 $m^3/s$ (28,500 gpm) would be required to mitigate risks of stormwater flooding at the commercial buildings located at the edge of Water Street. In addition, a storage volume of 20,000 $m^3$ would be required, which is equivalent to the entire surface of the parking lot with a depth of 2 m. It is noted that this option will still allow partial flooding of the waterfront to a depth of 17 cm, up to an elevation of 1.69 m.

The volume required is significant, relative to the available space, and would take up most of the Water Street, Henry Hensey Street, all of the commercial parking lot, and part of Centennial Park. The approximate area of this pond is presented in the concept drawing. The stormwater would require an excavation depth of 2.5-3.0 metres, well into unknown soil conditions in the downtown area. This poses significant uncertainties and risks as historical data points to this area being infilled over the last century with unknown and, quite likely, unsuitable materials.

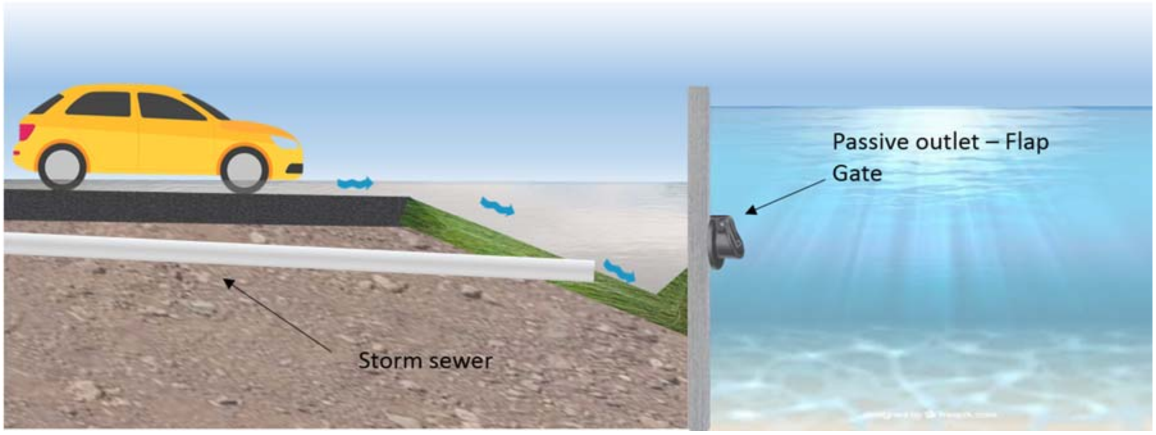
The system would also require the design of an outlet with capacity to restore the storage volume within a few hours after the storm in anticipation of a subsequent event. Tidal water levels would limit the performance of the system if the outlet operation is limited to passive means such as tide gates. If a pumping system with storage is installed, back-flow prevention would be required on the outfalls to facilitate drainage of smaller events with minimal pumping.

The pumping system will require redundancy as well as back-up power.

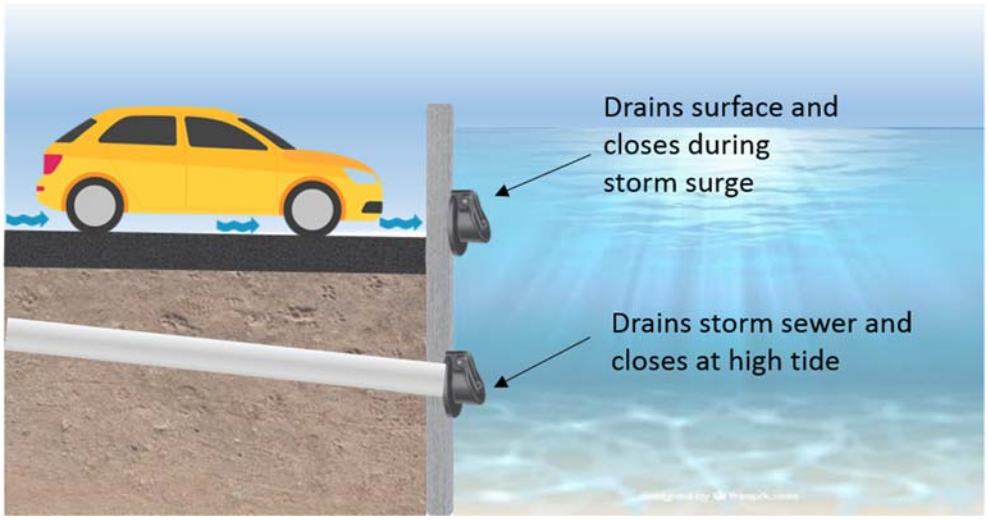
### 4.2.3 Flap Gates at Grade Level

The existing drainage system includes a storm sewer system with a check valve isolated on one catchbasin located in the parking lot but the effectiveness of this check valve is limited. One possible solution for the stormwater system here is to install a passive outlet system in the form of a flap gate at the end of the outfall pipe. This gate allows the discharge of stormwater when water levels to the inland side are higher than those on the ocean side. When tidal water levels start to increase above the stormwater level, the gate closes to prevent sea water from entering the sewer system. One disadvantage, however, is that the discharge capacity of the system would be limited during high tide and storm surges.

**Schematic Cross Section of Partial Storage Option with Passive Discharge**




**Flap Gate Operation**




### 4.2.4 Best Management Practices (BMPs)

BMPs include systems that use a combination of storage, stormwater retention and infiltration to control storm water flows. These include grass swales, infiltration trenches, permeable pavements, rain gardens, stormwater planters. These options would require a large scale and long term upgrade and retrofit throughout Liverpool. Managing stormwater flooding risks while this retrofit is completed would require additional temporary measures such as storage and pumping. This option could be considered in the long term as part of a Municipal stormwater management

**Example of Permeable Pavement**

strategy. Stormwater BMPs are discussed in greater detail in Chapter 5 – Stormwater Management.

### 4.2.5 Drainage System Diversion

Diversion of the existing drainage system along the main tributary flow paths would require upgrades to the existing system in adjacent areas to avoid increasing risks of flooding and erosion in those areas. In addition, the downstream sections of these areas are likely to require coastal flooding protection as well in the near future. Similar to the parking lot, these areas would require stormwater management measures. Therefore, the addition of diverted stormwater to these areas would result in additional costs to mitigate future flooding risks and were not studied in depth at this stage.

## 4.3 Concept 2 – Raised Parking Lot

The existing parking lot is at an elevation range of 1.7m to 1.5m. For this option, it is proposed that the parking lot will be built to an elevation of approximately 2.5m and sloped back to existing ground as shown in Figure 3 of Appendix B. The site will remain schematically identical to existing conditions only except that the entire surface would be raised.

This option would include removals of existing surfaces (asphalt, sidewalk, etc.), import of new fill, demolition and relocation of existing affected buildings, raising of all catchbasins and manholes, and reconstruction of the road and asphalt parking lot.

A small earthen berm will also be required along the top of slope of the shoreline to the east of Main Street as discussed in Concept #1. Another small berm, of top elevation equal to 2.5m, would be required across Centennial Park, connecting the raised Parking Lot to existing ground along the shoreline that is equal to or greater than elevation 2.5m. The purpose of this is to best protect inland areas from the design tide level of 2.44 m.

The presence of underlying layers of material likely unsuitable for infilling represents the largest uncertainty and risks of this options. If further geotechnical investigations confirm the presence of poor quality material, structural reinforcement would be required to provide suitable foundations for the additional weight associated with raising the parking lot. In the long term this becomes fundamental to allow adaptation to the rising sea levels.

### 4.3.1 Demolition and Relocation of Existing Buildings

There are a number of buildings around the site that have Finished Floor Elevations (FFE) lower than our design height of 2.44 metres. These building will remain prone to flooding under current climate conditions and thus have been recommended to be demolished and residents relocated for this option. Some buildings, due their design and orientation, may be partial or full demolition. Four buildings in total have been identified:

→ BDC Building.
→ Waterfront Plaza.
→ Royal Canadian Legion.
→ Hell Bay Brewing.

Details of the estimated costs of demolishing and relocating these buildings can be found in the Option #2 Cost Estimate, part of Appendix C.

## 4.4 Concept 3 – Raising Water Street

Concept #3 includes raising and reconstruction of Water Street between Market Street and Legion Street. Water Street would be raised to 2.50 m and would also be slightly realigned to tie into Henry Hensey Drive on the western end. Water Street would effectively turn into Henry Hensey Street as it move east to west and Legion would tie in creating a new intersection. Figure #4 in Appendix B illustrates the concept configuration of the new road.

This option would include removals of existing surfaces (asphalt, sidewalk, etc.), import of new fill, demolition and relocation of existing affected buildings, raising of all catchbasins and manholes, a new retaining wall between the new road alignment and the existing parking lot, and reconstruction of Water Street.

A small earthen berm will also be required along the top of slope of the shoreline to the east of Main Street as discussed in Concept #1 and #2. Another small berm, similar to Concept #2, would be required across Centennial Park, connecting the raised Water Street to existing ground along the shoreline that is equal to or greater than elevation 2.5m. The purpose of this is to best protect inland areas from the design tide level of 2.50 m.

Demolition and relocation of existing building will also be required for this Concept #3, identical to Concept #2 discussed above.

This option implies repurposing the land uses of the parking lot to one does not increase the weight on top of the infilled area and tolerates flooding. In the medium term, relocation of the existing parking lot would be required. In the long term this option may provide the first steps towards the construction of a flood defense adaptable to sea level rise.

## 4.5 Concept 4 – Managed Relocation and Limited Intervention

In order to fully evaluate all options, a limited intervention or manage relocation approach must be included. This option would not require infrastructure work with the exception of demolishing the buildings identified as being below the target elevation of 2.5m and relocating the businesses.

In time, as parking requirements are potentially reduced in this area with the potential removal of businesses and associated existing infrastructure degrades, this parking area can be modified to facilitate access and parking for Visitor Information Centre and to create open/park space that is more resilient to flooding. In the long term this option provides a cost-efficient approach to climate change adaptation. However, effective implementation of this option requires the input of stakeholders.

## 4.6 Cost

Cost estimates were prepared for each concept design. Unit rates are based on CBCL's database of construction work around the province, along with experience for the type of work in similar areas.

All costs are in Canadian dollars (2019). The detailed cost estimates for each concept design are provided in Appendix C. A summary is provided in Table 4.6.1, as presented on the following page:

**Table 4.6.1: Cost Summary for Downtown Liverpool Concept Options**

| Concept | Estimated Construction Cost | Cost of Relocating Buildings | Total Cost |
|---|---|---|---|
| 1 | $9,100,000 | $0 | $9,100,000 |
| 2 | $2,100,000 | $2,500,000 | $4,600,000 |
| 3 | $1,100,000 | $2,500,000 | $3,600,000 |
| 4 | $325,000 | $2,500,000 | $2,825,000 |

### 4.6.1 Costing for Building Demolition and Relocation

The approach taken for estimate costs for building demolition and relocation was order of magnitude replacement costs consistent with the existing building construction types, but reconstructed to the current National Building Code of Canada standards. Areas were measured where possible and priced at unit rates considered competitive for buildings of this type. Estimating reflects opinion of probable construction costs in the Liverpool area, and assumes competitive bidding for every portion of the work. However, it is not a prediction of low bid.

The buildings identified for demolition and relocation are a mixture of basic wood frame, light steel frame, or commercial grade and masonry. Further details on each building are listed below:

- → RC Legion - Basic SOG, wood frame, asphalt shingled gable roofs, insulated exterior wood walls & siding.
- → Hell Bay Brewing - Basic SOG, wood frame, asphalt shingled gable roofs, wood siding, c/w premium to move process eq.
- → Thrift Store & Waterfront Plaza – Flat roof light steel frame, steel stud exterior walls & siding.

## 4.7 Comparison of Concept Designs

A comparison of concept designs allows to identify the more advantageous option taking into consideration land uses, present and future flood mitigation considerations and cost. Table 4.7.1 compares key components that are quantifiable, and Table 4.7.2 below provides a comparison on an advantage/disadvantage basis.

**Table 4.7.1: Cost Details for Downtown Liverpool Concept Options**

| Option | Impacted Area ($m^2$) | Required Excavation ($m^3$) | Required Fill ($m^3$) | Construction Cost* | Cost of Relocating Buildings | Total Cost |
|---|---|---|---|---|---|---|
| 1 | 13,000 | 30,000 | 0 | $9,100,000 | $0 | $9,100,000 |
| 2 | 12,000 | 2,000 | 8,400 | $2,100,000 | $2,500,000 | $4,600,000 |
| 3 | 3,000 | 500 | 1,900 | $1,100,000 | $2,500,000 | $3,600,000 |
| 4 | 1,000 | | 500 | $320,000 | $2,500,000 | $2,820,000 |

*Includes demolition of identified existing buildings

For a qualitative analysis, the apparent advantages and disadvantages of the four options are presented in Table 4.7.2 as follows:

**Table 4.7.2: Advantages & Disadvantages of Each Concept Design**

| Concept | Advantages | Disadvantages |
|---|---|---|
| 1<br>Seawall | → No major effect to existing buildings. | → Reduces visibility to the waterfront.<br>→ Most costly, almost double the cost of the next alternative concept design.<br>→ Elimination of existing parking lot and part of Centennial Park to provide space for stormwater storage.<br>→ Mechanical and electrical subcomponents of the pumping system will require operation and ongoing maintenance.<br>→ Several unknowns in excavation, could encounter unsuitable material.<br>→ Does not blend with surrounding aesthetics of the Liverpool waterfront.<br>→ More complex than other concept designs.<br>→ Largest construction footprint of all the concept designs. |
| 2<br>Raise Parking | → Maintains existing layout and schematic of parking lot and surrounding streets.<br>→ Maintains existing drainage system with only a few catchbasins/manholes needing to be raised.<br>→ Little to no excavation required.<br>→ Less complex than Concept #1.<br>→ Full site brought up to above elevation 2.44 m.<br>→ Creates some space for appropriate re-development (open air market, additional parking). | → Some buildings and residents affected by demolition and relocation.<br>→ More fill required than Concept #3.<br>→ Unknowns of settlement issues when more fill introduced on parking lot area (high risk).<br>→ Larger construction footprint than Concept #3. |
| 3<br>Raise Water Street | → Maintains most of the existing parking lot.<br>→ Maintains existing drainage system with only a few catchbasins/manholes needing to be raised.<br>→ Little to no excavation required. | → 2nd lowest cost option.<br>→ Restores Water Street to 2-way traffic and allows the elimination of the Henry Hensey intersection near the bridge.<br>→ Buildings and residents affected that will require demolition and relocation. |

| Concept | Advantages | Disadvantages |
|---|---|---|
| | → Opportunity to revitalize downtown core with no street alignment.<br>→ Least costly of all the concept designs.<br>→ Least complex.<br>→ Allows for climate change adaptation.<br>→ Creates some space for appropriate re-development (open air market, additional parking). | → Parking lot still under 2.44 m elevation and prone to flooding during 1-100 year storm and HHWLT event. |
| 4<br>Retreat | → Least cost.<br>→ Maintains existing parking lot (in the short term).<br>→ Provides a cost effective alternative for adaptation to the medium term impacts of climate change. | → Buildings and residents affected that will require demolition and relocation. |

# Chapter 5 Stormwater Management

## 5.1 Introduction

The study area is subject to recurring flooding risks. To identify remediation measures, several options were investigated. Several of the proposed concept designs for flood mitigation measures due to coastal flooding have the potential to limit the discharge of runoff water from major storm events into the ocean. Therefore, an evaluation of stormwater runoff in the area, followed by recommendations for stormwater management measures, is presented. The intent is to holistically present viable and feasible options for coastal protection from flooding as well as management of discharges of stormwater into the ocean, which are closely related for this community.

The following chapters present the stormwater management analysis for the Community of Liverpool. The chapter is composed of three main sections; a hydrologic analysis for comparison of the flows generated from the last Stormwater Management Plan for Liverpool conducted in 1993 by CBCL, a hydrologic analysis to assess runoff through development of a computer model of the study area, and finally a description of low impact development and stormwater best management practices. The study presents stormwater runoff with respect to both current and future conditions. Future conditions refer to the impact of climate change on predicted rainfall events during the year 2100 at the site.

## 5.2 Background

CBCL issued a Stormwater Management Plan for Liverpool in 1993 (1993 Report). The objectives of this report were to create a comprehensive planning tool which would identify drainage areas tributary to the Community of Liverpool, estimate peak runoff flows with respect to future development of the delineated areas, and present development policies so that future development does not cause the generated peak flows to be exceeded. This report has been used extensively since its creation to design and construct the current stormwater management infrastructure in the community.

The scope of the report was defined by the tributary drainage areas within the existing Liverpool's boundaries with respect to future development. The report presented the results in a series of maps which show illustrations of the delineated watersheds, and provide relevant watershed characteristics including; area, slope, stream length, stream slope, land use, and flow. The resultant flows provided are in terms of the determined future development for the site at the time of the study. Overall, nine major watersheds were identified within the defined study area. These watersheds were then divided into sub-watersheds to define the areas draining towards a specific point within the major watershed. The sub-watersheds were then further divided into a total of 552 sub-areas to show the local areas that would generate flow paths within the sub-watershed. The information provided within these maps and the methodologies presented within the 1993 Report were used as a reference to update the flows presented in Section 5.4 Rational Method Hydrologic Assessment to account for current and future conditions in terms of rainfall events.

The methodology of the report consisted of using the Rational Method to determine the peak flows for each subarea and determined major networks within the system. The Rational Method is a simplistic method to determine peak discharge from a drainage basin. The equation is based on four fundamental hydrological characteristics including; runoff coefficient, intensity, time of concentration and area. Each of these parameters were required for each sub-area in order to follow a similar methodology of the 1993 Report for comparison purposes. Since the flows presented on the maps are with respect to future development, associated runoff coefficients and time of concentrations are expected to have been evaluated based on future development as well. Within the 1993 Report rainfall data was acquired from the Environment Canada Shearwater Airport climate station. The Intensity Duration Frequency (IDF) curve was used to determine peak rainfall intensities for representative durations for return periods of 5 and 100 years. This IDF was based on data ranging from 1955-1986 and is presented in Appendix D. Based on a detailed analysis of culvert capacities to peak flows, problem areas were identified within each watershed and development and planning policies including control development recommendations were presented within the report.

The methodologies and data presented within the 1993 Report were used as the basis for the Rational Method Hydrologic Assessment presented in Section 5.4 and will be further discussed within that section.

## 5.3 Project Site Characterization

Liverpool is located near the mouth of the Mersey River along the South Shore of Nova Scotia. The river is tidally influenced and acts as the main drainage source of runoff within the community. The runoff of stormwater within Liverpool and from surrounding upstream areas are directed though several drainage courses. According to the 1993 Stormwater Management Plan, the systems within Liverpool consist of mostly combined sewer systems and a few separate stormwater sewer systems in terms of the underground stormwater collection system. Overland flow is regulated as channelized flow through a series of culverts and bridges along historical drainage paths and streams.

The Community of Liverpool includes a developed downtown core which involves a high degree of buildings and paved areas including streets, sidewalks and parking lots. Roofs and paved areas alter the predevelopment runoff by increasing flows due to lowered capacity for infiltration as well as an increased rate of runoff. A large park area is situated along the coast near a tributary of the Mersey River which flows throughout the community and is connected to Meadow Pond. The community also consists of a high degree of residential areas which include permeable areas such as yards, parks, fields, and forested areas as well as impermeable areas as previously noted. Further upstream from the downtown and residential areas the land may be characterized as undeveloped forest with roads cutting through at specific sections.

Due to the limited availability of high resolution LIDAR for the area, the study area is defined by the watershed boundaries delineated within the 1993 Report.

Liverpool has experienced increased flooding within recent years and recommended coastal flood mitigation options presented in this report require an evaluation of stormwater management.

## 5.4 Rational Method Hydrologic Assessment

A hydrologic assessment for the Community of Liverpool was conducted using the methodologies and data presented within the 1993 Stormwater Management Plan as described in Section 5.0 Background. The flows presented on the maps from the 1993 Report for each sub-area were updated utilizing the sub-area characteristics provided with current rainfall intensity data from the Shearwater Airport IDF. Flows for each subarea were also calculated with respect to future conditions accounting for the impact of climate change to rainfall events.

There are two types of stormwater systems; major and minor. Minor stormwater systems accommodate runoff from relatively frequent storm events and typically consist of gutters, catch basin inlets, storm sewers and minor channels. The major stormwater system is the route in which runoff flows when the capacity of the minor system is exceeded form the occurrence of a significant rainfall event. The major system is typically comprised of roadway surfaces, median drains, storage areas, channels etc. Stormwater systems are typically sized for a 1 in 5 year rainfall event, and the impact of the 1 in 100 year event on the system is evaluated for identification of critical capacity locations. Therefore, the peak flows for both the 5 year and the 100 year rainfall events were determined for both current and future conditions. This was done in order to compare the flows generated within the 1993 Report to that of flows generated using current rainfall data and future rainfall events.

The Rational Method was used as the basis for determining peak runoff from each delineated subarea. The peak runoff flows provided on the maps are presented with respect to the determined future development of the Community of Liverpool at the time of the study. Development increases the amount of runoff within a given area due to the influence of impermeable surfaces restricting the capacity for infiltration. Therefore, the runoff coefficients and time of concentrations for each subarea are also representative of future conditions with respect to the time of the study. Based on this premise, the runoff coefficients derived for each subarea, as explained later in this chapter, are used within the Rational Method to determine peak runoff with respect to current and future conditions at the site.

A number of the parameters required to obtain updated flows using similar methodology within the 1993 Report were not available in our project archives. These parameters include; runoff coefficients, time of concentration, method of evaluating time of concentration, and the IDF coefficients. As explained in following sections, these parameters were either back calculated in order align with the methodologies of the previous report or were evaluated using current best practices.

### 5.4.1 IDF Curve Coefficients

IDF curves utilize recorded rainfall data to characterize the statistical recurrence of extreme rainfall events of particular durations for specific locations. The Shearwater Airport Environment Canada climate station was used for the evaluation of the intensity of rainfall events at Liverpool due to it being the closest most representative station to the site with sufficient data. The Environment Canada IDF curves for specific return periods are functions of two coefficients. Within the Rational Method, the IDF coefficients are used to calculate the intensity of a rainfall event with respect to the watersheds time of concentration. The IDF curve used in the 1993 Report did not include the IDF coefficients which are normally presented separately with associated statistical information. Furthermore, the Environment Canada archives did not span back to the reference period and also could not provide the statistical parameters of the curve. Because of this, the coefficients were extrapolated by using the data provided in the IDF curves for both the 5 year and 100 year return periods.

For flows with respect to future conditions, the effects of potential climate change on the rainfall intensity were considered. Environment Canada (EC) has used the results from several Global Climate Change models to estimate changes in the 24-hour rainfall amount for various return periods at several major climate stations in the region. Some of these climate stations include: Greenwood, Shearwater, and Sydney. The results are outlined in the 2009 EC report "Climate Change Scenarios for Atlantic Canada Utilizing a Statistical Downscaling Model". According to the report, rainfall in the Halifax area may increase by 30% within the next 100 years. The fact that the location of Liverpool is along the coast as well as along the Eastern Shore allows the use of these results to estimate the potential effect of climate change in the study area. In order to incorporate these climate change results into the Rational Method the IDF curve equation was evaluated. It was determined that increasing the A coefficient of the current IDF by 30% would integrate these conclusions and the resulting IDF coefficients were used to determine future flows with respect to climate change.

Although it is projected that rainfall will increase in the future under climate change due to the increased potential of the water cycle, a slight decrease in the IDF curves from the Shearwater Airport between the reference periods 1955-1986 and 1955-2016 (current IDF for the Shearwater Airport Environment Canada climate station) is depicted. A 1.8% and 5.3% decrease from the historical intensity of a 24-hour storm for the 5 and 100 year return periods respectively was determined at the site.

Since IDF curves are based off of a 30-year reference period it is possible for decadal oscillations in rainfall intensities to be captured in the IDF statistics. Decadal oscillations refer to the natural oscillations of rainfall throughout the decades as a result of shifting climatic patterns such as El Nino and El Nina. The shifting of these cycles may cause a geographical location to experience slightly less or more rainfall over a 30-year reference period then within previous recorded 30-year periods. However, it is well understood that the overall trend in rainfall as a result of climate change is an increase in the frequency and intensity of rainfall events.

To further explore the rainfall data at the site, IDF curves available from Environment Canada between the historical and current reference periods from the Shearwater Airport were analyzed as shown in Table 5.4.1 and 5.4.2, associated IDF curves are presented in Appendix D.

**Table 5.4.1: Shearwater Airport IDF Statistics over a Range of Reference Periods**

| Shearwater Airport Climate Station Reference Period | Return Period (years) | A Coefficient | B Coefficient | Intensity of 24 hour storm) (mm/hr) |
|---|---|---|---|---|
| 1955-1986 | 5 | 26.1 | -0.562 | 4.4 |
| | 100 | 43.4 | -0.564 | 7.2 |
| 1955-2006 | 5 | 25.0 | -0.556 | 4.3 |
| | 100 | 39.8 | -0.554 | 6.8 |
| 1955-2016 | 5 | 24.9 | -0.553 | 4.3 |
| | 100 | 39.8 | -0.554 | 6.8 |
| Future Conditions | 5 | 32.4 | -0.553 | 5.6 |
| | 100 | 51.7 | -0.554 | 8.9 |

**Table 5.4.2: Shearwater Airport IDF Comparison over a Range of Reference Periods**

| Reference Period Comparison | Return Period (years) | Percent Change |
|---|---|---|
| (1955-1986) to (1955-2006) | 5 | -2.3% |
| | 100 | -5.3% |
| (1955-2006) to (1995-2016) | 5 | 0.5% |
| | 100 | 0.0% |
| (1955-1986) to (1955-2016) | 5 | -1.8% |
| | 100 | -5.3% |
| (1955-2016) to Future Conditions | 5 | 30.2% |
| | 100 | 30.1% |
| (1955-1986) to Future Conditions | 5 | 27.8% |
| | 100 | 23.2% |

### 5.4.2 Time of Concentration

The method of calculating the time of concentration for each sub-area was not provided within the 1993 Report and could not be determined from the project records. Therefore, a best practice of determining the time of concentration for a watershed was applied based on area, maximum overland flow length, and velocity (calculated using slope and ground surface type). The results of this analysis is presented in Appendix E.

### 5.4.3 Runoff Coefficient

The runoff coefficients with respect to the presented future development flows were not provided within the 1993 report or within the project records. Therefore, the flows provided on the maps for both respective return periods were used in conjunction with the parameters derived above and provided on the maps to determine the runoff coefficient that would provide the associated flow for each subarea. The results of this analysis is presented in Appendix E. The runoff coefficients for each sub-area were determined using this method and were then used in conjunction with current rainfall intensity data to determine the runoff for both current and future conditions.

### 5.4.4 Results

The sub-area characteristics and resultant runoff coefficients and time of concentration, as well as the runoff generated with respect to current and future conditions, and the future flows provided within the 1993 Report, are all presented in Appendix E for each of the subareas delineated from the 1993 Report.

For comparison purposes, the subarea runoff were summed into their respective sub-watersheds for analysis of percent differences between the respective time periods for individual sub-watersheds as well as the average and median values of percent changes for the main watersheds and the entire study area. These results are presented in Table 5.4.3**.**

Table 5.4.3: **Runoff Comparison between References Periods using the Rational Method**

| Watershed | Sub-Area Identifier | Runoff (m³/s) 1993 Return Period (year) 5 | 1993 100 | 2019 Return Period (year) 5 | 2019 100 | Future Conditions Return Period (year) 5 | Future Conditions 100 | Percent Change 1993 to 2019 Return Period (year) 5 | Percent Change 1993 to 2019 100 | Percent Change 1993 to Future Conditions Return Period (year) 5 | Percent Change 1993 to Future Conditions 100 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Amherst Street** | Average | | | | | | | -7.0% | -10.6% | 21.5% | 16.4% |
| | Median | | | | | | | -6.8% | -10.5% | 21.2% | 16.3% |
| | Amherst Street A | 0.3 | 0.6 | 0.3 | 0.5 | 0.4 | 0.7 | -7.2% | -10.7% | 21.2% | 15.8% |
| | Amherst Street B | 0.5 | 0.8 | 0.4 | 0.7 | 0.6 | 0.9 | -6.3% | -10.2% | 21.7% | 16.6% |
| | Amherst Street C | 0.3 | 0.5 | 0.3 | 0.4 | 0.3 | 0.5 | -6.8% | -10.2% | 21.2% | 16.4% |
| | Amherst Street D | 4.0 | 6.5 | 3.7 | 5.8 | 4.9 | 7.7 | -7.8% | -11.2% | 22.5% | 17.6% |
| | Amherst Street E | 0.3 | 0.5 | 0.3 | 0.4 | 0.4 | 0.6 | -6.8% | -10.5% | 21.2% | 16.0% |
| | Amherst Street F | 0.1 | 0.2 | 0.1 | 0.1 | 0.1 | 0.2 | -6.8% | -10.5% | 21.2% | 16.1% |
| **Birch Avenue** | Average | | | | | | | -6.0% | -9.7% | 22.1% | 17.2% |
| | Median | | | | | | | -6.0% | -9.7% | 22.2% | 17.3% |
| | Birch Avenue A | 2.6 | 4.3 | 2.5 | 3.9 | 3.2 | 5.0 | -6.0% | -9.7% | 22.2% | 17.3% |
| | Birch Avenue B | 1.2 | 1.9 | 1.1 | 1.7 | 1.4 | 2.2 | -6.5% | -10.2% | 21.5% | 16.5% |
| | Birch Avenue C | 3.9 | 6.3 | 3.6 | 5.7 | 4.7 | 7.5 | -5.4% | -9.2% | 22.7% | 17.8% |
| **Bog Pond** | Average | | | | | | | -13.2% | -18.3% | 21.5% | 15.6% |
| | Median | | | | | | | -6.8% | -10.3% | 21.3% | 16.4% |
| | Bog Pond A | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -61.3% | -69.0% | 21.2% | 7.5% |
| | Bog Pond B | 0.2 | 0.4 | 0.2 | 0.3 | 0.3 | 0.4 | -6.9% | -10.5% | 21.0% | 16.1% |
| | Bog Pond C | 0.5 | 0.9 | 0.5 | 0.8 | 0.6 | 1.0 | -6.9% | -10.2% | 21.0% | 16.5% |
| | Bog Pond D | 0.7 | 1.1 | 0.7 | 1.0 | 0.8 | 1.3 | -6.6% | -10.2% | 21.4% | 16.5% |
| | Bog Pond E | 0.4 | 0.7 | 0.4 | 0.6 | 0.5 | 0.8 | -6.7% | -10.3% | 21.3% | 16.4% |
| | Bog Pond F | 0.5 | 0.9 | 0.5 | 0.8 | 0.7 | 1.0 | -6.7% | -10.3% | 21.3% | 16.3% |
| | Bog Pond G | 0.2 | 0.3 | 0.1 | 0.2 | 0.2 | 0.3 | -6.8% | -10.6% | 21.2% | 15.9% |
| | Bog Pond H | 2.1 | 3.5 | 1.9 | 2.7 | 2.6 | 4.1 | -10.3% | -23.8% | 22.8% | 18.0% |
| | Bog Pond I | 1.1 | 1.8 | 1.0 | 1.6 | 1.3 | 2.1 | -6.3% | -10.0% | 21.8% | 16.8% |
| | Average | | | | | | | -9.4% | -13.1% | 22.0% | 17.0% |

| Watershed | Sub-Area Identifier | Runoff (m³/s) | | | | | | Percent Change 1993 to 2019 | | Percent Change 1993 to Future Conditions | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1993 | | 2019 | | Future Conditions | | | | | |
| | | Return Period (year) | | Return Period (year) | | Return Period (year) | | Return Period (year) | | Return Period (year) | |
| | | 5 | 100 | 5 | 100 | 5 | 100 | 5 | 100 | 5 | 100 |
| Bristol Avenue West | Median | | | | | | | -9.4% | -13.1% | 22.0% | 17.0% |
| | Bristol Avenue West A | 4.1 | 6.7 | 3.5 | 5.6 | 5.0 | 7.9 | -13.0% | -16.3% | 22.2% | 17.2% |
| | Bristol Avenue West B | 2.2 | 3.7 | 2.1 | 3.3 | 2.7 | 4.3 | -5.8% | -10.0% | 21.8% | 16.8% |
| Bristol Avenue East | Average | | | | | | | -9.5% | -11.0% | 22.6% | 17.6% |
| | Median | | | | | | | -6.8% | -10.6% | 23.3% | 18.4% |
| | Bristol Avenue East A | 0.4 | 0.6 | 0.4 | 0.6 | 0.5 | 0.7 | -6.8% | -10.6% | 21.2% | 15.9% |
| | Bristol Avenue East B | 0.4 | 0.6 | 0.3 | 0.5 | 0.4 | 0.7 | -5.2% | -8.9% | 23.3% | 18.4% |
| | Bristol Avenue East C | 12.8 | 21.2 | 10.7 | 18.3 | 15.8 | 25.1 | -16.4% | -13.5% | 23.3% | 18.5% |
| Cobbs Ridge | Average | | | | | | | -6.7% | -10.3% | 21.3% | 16.3% |
| | Median | | | | | | | -6.8% | -10.4% | 21.2% | 16.1% |
| | Cobbs Ridge A | 2.9 | 4.9 | 2.7 | 4.4 | 3.5 | 5.6 | -6.8% | -10.4% | 21.2% | 16.1% |
| | Cobbs Ridge B | 1.3 | 2.1 | 1.2 | 1.9 | 1.6 | 2.5 | -6.8% | -10.5% | 21.2% | 16.1% |
| | Cobbs Ridge C | 1.2 | 2.0 | 1.1 | 1.8 | 1.5 | 2.3 | -6.8% | -10.5% | 21.2% | 16.0% |
| | Cobbs Ridge D | 0.4 | 0.7 | 0.4 | 0.6 | 0.5 | 0.8 | -6.8% | -10.5% | 21.1% | 16.1% |
| | Cobbs Ridge E | 2.6 | 4.3 | 2.4 | 3.9 | 3.2 | 5.0 | -6.8% | -10.5% | 21.1% | 16.1% |
| | Cobbs Ridge F | 0.4 | 0.7 | 0.4 | 0.6 | 0.5 | 0.8 | -7.0% | -10.3% | 20.9% | 16.3% |
| | Cobbs Ridge G | 0.8 | 1.3 | 0.7 | 1.2 | 1.0 | 1.5 | -6.7% | -10.4% | 21.3% | 16.2% |
| | Cobbs Ridge H | 1.4 | 2.2 | 1.3 | 2.0 | 1.7 | 2.6 | -6.8% | -10.3% | 21.1% | 16.4% |
| | Cobbs Ridge I | 0.2 | 0.3 | 0.1 | 0.2 | 0.2 | 0.3 | -6.1% | -9.5% | 22.0% | 17.5% |
| Hospital Area | Average | | | | | | | -6.5% | -10.0% | 21.6% | 16.8% |
| | Median | | | | | | | -6.6% | -10.2% | 21.4% | 16.5% |

| Watershed | Sub-Area Identifier | Runoff (m³/s) | | | | | | Percent Change 1993 to 2019 | | Percent Change 1993 to Future Conditions | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1993 | | 2019 | | Future Conditions | | | | | |
| | | Return Period (year) | | Return Period (year) | | Return Period (year) | | Return Period (year) | | Return Period (year) | |
| | | 5 | 100 | 5 | 100 | 5 | 100 | 5 | 100 | 5 | 100 |
| | Hospital A | 0.8 | 1.2 | 0.7 | 1.1 | 0.9 | 1.4 | -6.6% | -10.2% | 21.5% | 16.5% |
| | Hospital B | 0.1 | 0.2 | 0.1 | 0.2 | 0.2 | 0.3 | -6.8% | -10.4% | 21.2% | 16.2% |
| | Hospital C | 0.1 | 0.2 | 0.1 | 0.2 | 0.1 | 0.2 | -6.8% | -9.6% | 21.2% | 17.2% |
| | Hospital D | 1.2 | 1.9 | 1.1 | 1.7 | 1.4 | 2.2 | -6.6% | -10.2% | 21.4% | 16.4% |
| | Hospital E | 0.6 | 1.1 | 0.6 | 1.0 | 0.8 | 1.2 | -5.7% | -9.3% | 22.6% | 17.7% |
| | Average | | | | | | | -10.4% | -14.7% | 22.4% | 17.5% |
| | Median | | | | | | | -6.7% | -10.5% | 22.2% | 17.3% |
| | Meadow Pond A | 1.1 | 1.8 | 1.0 | 1.6 | 1.3 | 2.0 | -6.7% | -10.3% | 21.3% | 16.3% |
| **Meadow Pond** | Meadow Pond B | 0.9 | 1.4 | 0.8 | 1.3 | 1.0 | 1.6 | -6.8% | -10.7% | 21.1% | 15.8% |
| | Meadow Pond C | 4.7 | 7.7 | 4.4 | 6.6 | 5.8 | 9.2 | -5.9% | -14.5% | 23.3% | 18.5% |
| | Meadow Pond D | 1.2 | 2.0 | 1.1 | 1.8 | 1.5 | 2.3 | -6.7% | -10.3% | 21.3% | 16.4% |
| | Meadow Pond E | 7.0 | 11.5 | 6.6 | 10.3 | 8.6 | 13.6 | -6.2% | -10.3% | 23.0% | 18.2% |
| | Meadow Pond F | 32.7 | 53.8 | 23.0 | 36.5 | 40.7 | 64.5 | -29.8% | -32.2% | 24.6% | 19.9% |
| | Average | | | | | | | -8.5% | -9.7% | 22.2% | 17.3% |
| **Wolfe Street** | Median | | | | | | | -8.5% | -9.7% | 22.2% | 17.3% |
| | Wolfe Street A | 0.9 | 1.5 | 0.9 | 1.4 | 1.1 | 1.8 | -6.6% | -10.2% | 21.4% | 16.5% |
| | Wolfe Street B | 3.6 | 5.9 | 3.2 | 5.4 | 4.4 | 7.0 | -10.4% | -9.2% | 22.9% | 18.0% |
| **Study Area** | Average | | | | | | | -8.8% | -12.6% | 21.7% | 16.6% |
| | Median | | | | | | | -6.8% | -10.3% | 21.3% | 16.4% |

Overall, the study area is expected to experience increased average runoff of approximately 22% and 17% for the 5 and 100 year returns periods respectively in terms of future conditions as determined through the Rational Method.

It is noted, as described above, that parameters used within the Rational Method to generate the current and future flows presented for comparison were extrapolated and calculated using best practices when the methodology from the 1993 Report was unclear. Furthermore, the runoff coefficient for each sub-area was derived from the predictions of future development at the time of the 1993 Report. These account for potential sources of error for the direct comparison of the generated flows to the previous flows provided on the 1993 maps.

## 5.5 SWMM Hydrologic Assessment

The purpose of the hydrologic assessment is to define the physical components of the earth's surface and contributing watersheds to the study area in order to model how water will infiltrate and runoff throughout the site.

### 5.5.1 Watershed Delineation and Characteristics

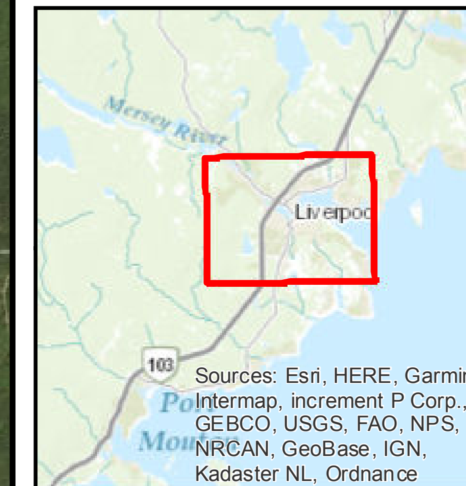
A hydrological assessment was carried out to determine the peak runoff of contributing watersheds to downstream systems with respect to current and future conditions. Peak runoff was determined at intermittent intervals along the projected flow path within delineated watersheds. This was done in order to determine the cumulative runoff that would propagate throughout the stormwater system from the upstream areas towards the coastal outlets. Therefore, the runoff that conveyance structures along the flow path will require the capacity to handle may be identified. This was done by parameterizing and modelling how rainfall is converted into infiltration and runoff at the site with respect to defined watersheds within the study area. Runoff calculations were conducted using version 7.1 of the USA Environmental Protection Agency Storm Water Management Model (SWMM). Due to the intensive nature of depicting individual flow paths to each stormwater structure and the available information provided, it was determined this would be the most comprehensive analysis for the determination of runoff to the stormwater system, without having access to all details of each flow path in the entire system.

High resolution LIDAR was provided for the downtown area but did not span across a large portion of the upstream watersheds which contribute stormwater runoff. Therefore, the provincial Digital Elevation Model (DEM) of 20 m resolution was stitched to the high-resolution LIDAR in order to acquire an elevation model which covered a large percentage of the study area. However, a digital elevation model of 20 m resolution is relatively coarse for delineations of watersheds for stormwater. Through analysis of the previous 1993 Stormwater Management Plan it was concluded that the watersheds, sub-watersheds, and sub-areas were delineated based on 5 m contour intervals. Due to the higher resolution of this data as compared to the available DEM, the delineations of watersheds outside the high-resolution LIDAR from the 1993 Report were used to define contributing watersheds.

The delineated watersheds from the 1993 Report were provided on a number of maps, these maps were georeferenced within GIS and layered over the DEM. High and low elevation points and general contributing areas were confirmed based on the coarse DEM. For comparison purposes, between the Rational Method Hydrologic Analysis provided in Section 5.4 to the model generated runoff, the 9 major contributing watersheds were delineated. Where determined appropriate, the watersheds were further subdivided into their respective sub-watersheds. Minor adjustments were applied to the boundaries of the watersheds within the high-resolution LIDAR areas, however, without an in-depth analysis of the stormwater system, the contributed flow to individual structures cannot be determined without further site investigation.

Once the watersheds and sub-watersheds were delineated they were further subdivided at intermittent intervals from the upstream to the downstream flow path. This was done in order to determine cumulative runoff throughout the stormwater system from the upstream to the downstream general outlet locations within each individual watershed. The Municipality has provided the characteristics for a number of conveyance structures within the stormwater management system. These were fed into the SWMM model in order to assess appropriate intervals at which to divide the watershed to an upstream portion.

The delineated watersheds with associated names for ease of comparison to the 1993 Report are shown in Figure 5.1. The red dotted lines denote the direction of runoff within the major watersheds and the stormwater system information provided by the client is included as well. In addition, Figure 5.2 provides the watersheds and subwatersheds delineated in the 1993 Report for reference.


Storm Water Structures
Flow Paths
Subcatchments

CBCL LIMITED
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**Town of Liverpool**
**Coastal Flooding Mitigation Study**

Watershed Boundaries from SWMM Model

| | |
|---|---|
| Drawn: RM | Fig: 5.1 |
| Checked: LF | CBCL Project #: 181109.00 |
| Date: 29/10/2019 | Scale @ 11"x17" 1:27,633 |

Notes:

0 0.375 0.75 1.5 Km

Coordinate System: NAD 1983 UTM Zone 20N

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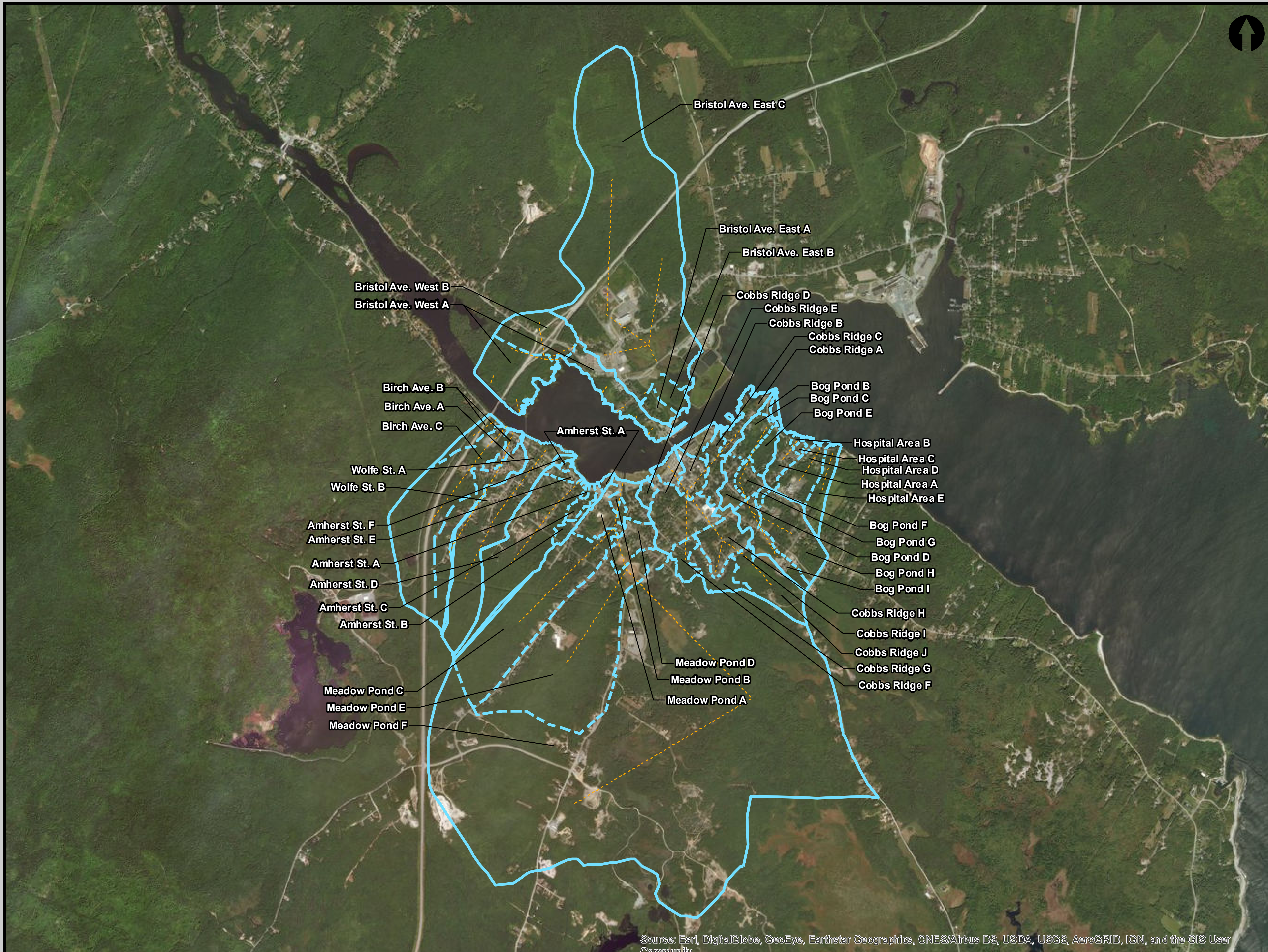


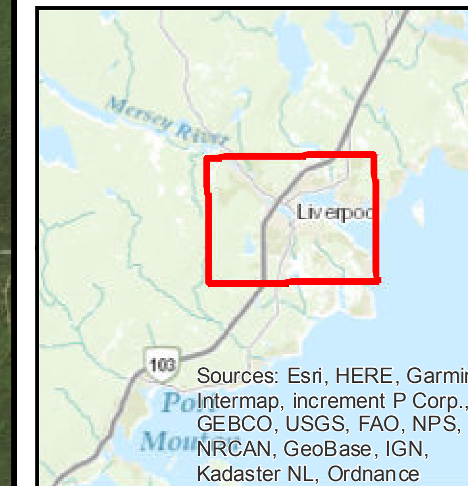


Flow Paths
Watershed Boundary

CBCL LIMITED
Consulting Engineers

**Town of Liverpool**
**Coastal Flooding Mitigation Study**

Watershed Boundaries from 1993 Report

| | |
|---|---|
| Drawn: RM | Fig: 5.2 |
| Checked: LF | CBCL Project #: 181109.00 |
| Date: 29/10/2019 | Scale @ 11"x17" 1:27,633 |

Notes:

0 0.375 0.75 1.5 Km

Coordinate System: NAD 1983 UTM Zone 20N

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### 5.5.2 Watershed Characteristics

In order to represent the infiltration and transport of water within the watersheds, the SWMM model requires several parameters which are specific to the local topography, land use, soil type, vegetation, and level of urbanization. These parameters include slope, maximum flow length, and hydraulic conductivity of the surficial soil, suction head, surface roughness, and percentage of area that is impervious.

Aerial photography was used to identify the land uses in each watershed, which were in turn used to determine surface roughness within the defined watersheds (combined using an area-weighted average) and percentage of area that is impervious.

To determine the quantity of water that infiltrates into the ground the Green-Ampt infiltration method was used. This method is used to estimate depth of infiltration as a function of soil suction head, porosity, hydraulic conductivity and time.

Table 5.5.1 presents the characteristics determined for each of the 49 defined sub-watersheds within the study area.

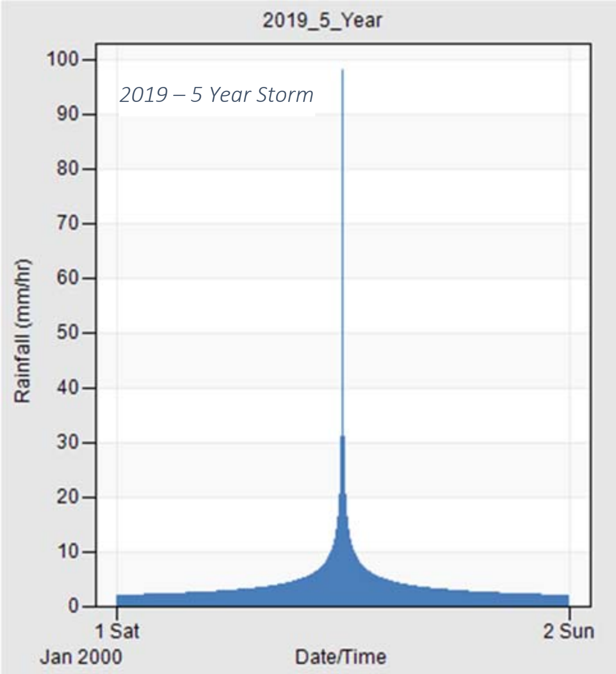
**Table 5.5.1: Watershed Characteristics**

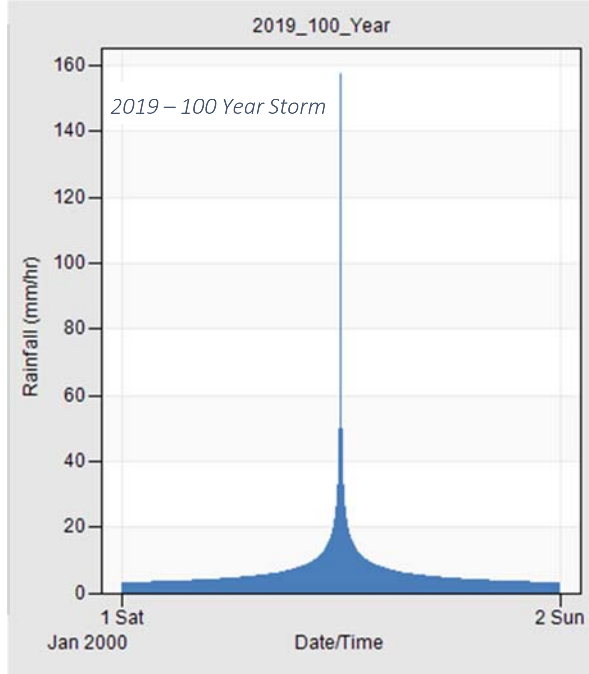
| Watershed | Identifier | Area (ha) | Average Slope (%) | Maximum Overland Flow Length (m) | Surface Roughness | | |
|---|---|---|---|---|---|---|---|
| | | | | | Impervious Area Manning's n | Pervious Area Manning's n | Percent Impervious (%) |
| Amherst Street | Amherst_D_Upstream | 23.9 | 5.3 | 656.8 | 0.01 | 0.50 | 10.0 |
| | Amherst_Downstream_ABCD | 20.9 | 4.3 | 463.8 | 0.01 | 0.25 | 30.0 |
| Birch Avenue | Birch_A_Upstream | 11.6 | 4.5 | 700.1 | 0.01 | 0.35 | 20.0 |
| | Birch_AB | 9.0 | 0.5 | 100.0 | 0.01 | 0.20 | 25.0 |
| | Birch_B4_5 | 4.5 | 0.5 | 100.0 | 0.01 | 0.40 | 25.0 |
| | Birch_C_Downstream | 5.6 | 0.5 | 100.0 | 0.01 | 0.40 | 25.0 |
| | Birch_C_Upstream | 41.0 | 3.3 | 1426.7 | 0.01 | 0.40 | 10.0 |
| Bog Pond | Bog_Pond_C_E | 9.8 | 2.3 | 391.0 | 0.01 | 0.35 | 5.0 |
| | Bog_Pond_D_F | 9.3 | 2.9 | 352.0 | 0.01 | 0.20 | 25.0 |
| | Bog_Pond_G_I | 4.5 | 4.0 | 245.0 | 0.01 | 0.30 | 40.0 |
| | Bog_Pond_H | 19.5 | 3.3 | 638.9 | 0.01 | 0.35 | 30.0 |
| | Bog_Pond_I_Upstream | 5.8 | 0.7 | 430.2 | 0.01 | 0.30 | 25.0 |
| Bristol Avenue West | West_Bristol_16_19A | 3.0 | 2.6 | 203.5 | 0.01 | 0.35 | 5.0 |
| | West_Bristol_20A | 4.4 | 3.1 | 196.5 | 0.01 | 0.40 | 25.0 |
| | West_Bristol_3B | 11.1 | 1.2 | 326.8 | 0.01 | 0.45 | 10.0 |
| | West_Bristol_A1_Downstream | 4.0 | 3.8 | 164.4 | 0.01 | 0.30 | 25.0 |
| | West_Bristol_A2_Downstream | 1.8 | 4.7 | 112.7 | 0.01 | 0.30 | 10.0 |
| | West_Bristol_A3_Downstream | 1.6 | 3.0 | 110.2 | 0.01 | 0.15 | 25.0 |
| | West_Bristol_AB_Upstream | 5.1 | 6.7 | 165.1 | 0.01 | 0.32 | 55.0 |
| | West_Bristol_B_Downstream | 5.3 | 3.3 | 159.6 | 0.01 | 0.30 | 15.0 |
| | West_Bristol_B_Upstream_2 | 5.1 | 3.6 | 317.4 | 0.01 | 0.37 | 20.0 |
| | West_Bristol_Mersey_Ave | 1.4 | 2.8 | 189.5 | 0.01 | 0.20 | 60.0 |
| Bristol Avenue East | East_Bristol_8C | 2.4 | 3.1 | 143.9 | 0.01 | 0.15 | 70.0 |
| | East_Bristol_C_Downstream | 21.6 | 3.9 | 552.3 | 0.01 | 0.30 | 25.0 |
| | East_Bristol_C_Upstream | 90.6 | 5.6 | 1890.2 | 0.01 | 0.37 | 5.0 |
| | East_Bristol_C2_Downstream | 17.0 | 1.0 | 403.8 | 0.01 | 0.30 | 25.0 |
| | East_Bristol_C2_Upstream | 25.7 | 3.6 | 884.3 | 0.01 | 0.37 | 10.0 |

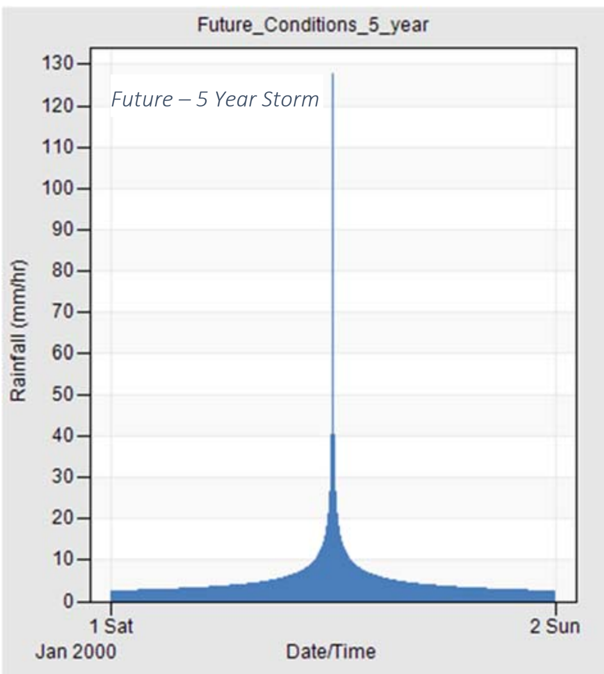
| Watershed | Identifier | Area (ha) | Average Slope (%) | Maximum Overland Flow Length (m) | Surface Roughness | | |
|---|---|---|---|---|---|---|---|
| | | | | | Impervious Area Manning's n | Pervious Area Manning's n | Percent Impervious (%) |
| | East_Bristol_C3_Downstream | 6.0 | 2.7 | 211.7 | 0.01 | 0.25 | 30.0 |
| Cobbs Ridge | Cobbs_Ridge_A | 1.8 | 0.5 | 100.0 | 0.01 | 0.20 | 25.0 |
| | Cobbs_Ridge_Downstream | 37.5 | 2.1 | 672.9 | 0.01 | 0.20 | 80.0 |
| | Cobbs_Ridge_F | 4.4 | 1.9 | 294.6 | 0.01 | 0.30 | 35.0 |
| | Cobbs_Ridge_G | 6.6 | 3.1 | 350.0 | 0.01 | 0.35 | 40.0 |
| | Cobbs_Ridge_H | 10.2 | 4.7 | 362.2 | 0.01 | 0.28 | 50.0 |
| | Cobbs_Ridge_J_1 | 14.2 | 0.2 | 575.7 | 0.01 | 0.45 | 10.0 |
| | Cobbs_Ridge_J_2 | 1.8 | 1.1 | 119.5 | 0.01 | 0.30 | 30.0 |
| Hospital Area | Hospital_A_B_C | 6.1 | 3.5 | 435.0 | 0.01 | 0.20 | 65.0 |
| | Hospital_D_Downstream | 1.4 | 3.3 | 160.0 | 0.01 | 0.22 | 35.0 |
| | Hospital_D_Upstream | 8.7 | 4.8 | 390.0 | 0.011 | 0.35 | 50.0 |
| | Hospital_E | 6.9 | 5.4 | 700.0 | 0.012 | 0.30 | 5.0 |
| Meadow Pond | Meadow_Pond_C_Upstream | 45.9 | 3.9 | 1163.4 | 0.01 | 0.50 | 15.0 |
| | Meadow_Pond_Downstream_ACD | 28.9 | 2.5 | 665.4 | 0.01 | 0.25 | 70.0 |
| | Meadow_Pond_E_Downstream | 10.3 | 4.0 | 288.7 | 0.01 | 0.30 | 40.0 |
| | Meadow_Pond_E_Upstream | 70.8 | 1.5 | 1218.1 | 0.01 | 0.60 | 10.0 |
| | Meadow_Pond_F1 | 220.0 | 0.8 | 2294.1 | 0.01 | 0.65 | 10.0 |
| | Meadow_Pond_F2 | 229.1 | 2.6 | 1504.8 | 0.01 | 0.50 | 20.0 |
| | Meadow_Pond_F3 | 54.3 | 1.1 | 1064.1 | 0.01 | 0.50 | 5.0 |
| Wolfe Street | Wolfe_B_Upstream | 21.7 | 3.8 | 1041.0 | 0.01 | 0.50 | 10.0 |
| | Wolfe_B2_Upstream | 10.2 | 5.6 | 451.6 | 0.01 | 0.35 | 30.0 |
| | Wolfe_Downstream | 8.1 | 4.0 | 421.1 | 0.01 | 0.20 | 55.0 |

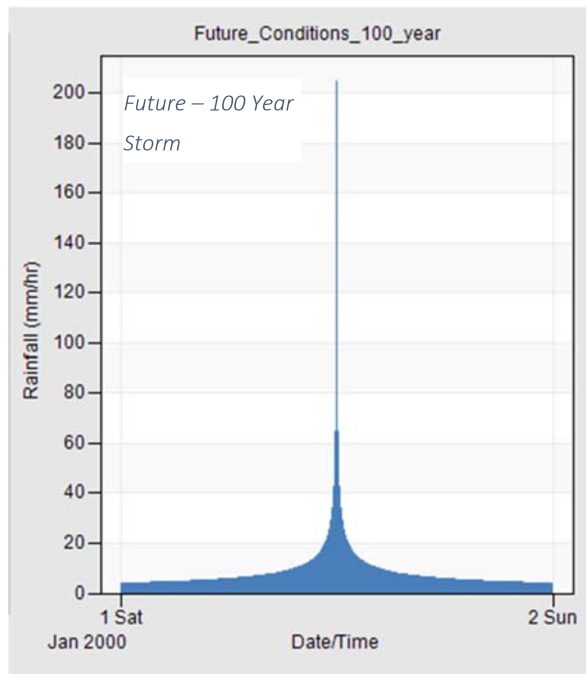
### 5.5.3 Design Storms

The Shearwater Airport climate station was used for the evaluation of the intensity of rainfall events at Liverpool due to it being the closet most representative station to the site with sufficient data. The most current IDF is based on 59 years of rainfall data (1955-2016) and is included in Appendix D. The IDF curves are the result of statistical analyses by Environment Canada to estimate extreme rainfall events to return periods of 2, 5, 10, 25, 50 or 100 years. A Chicago distribution was then used to produce 24-hour design rainfall events using the IDF curves for the Shearwater Airport climate station. The resultant 1 in 5 and 1 in 100 year design storms for both current and future climate conditions that were used for the hydrologic model are presented in the figures below.




As previously stated in Section 5.4, the 2009 EC report "Climate Change Scenarios for Atlantic Canada Utilizing a Statistical Downscaling Model" presents the analysis of several Global Climate Change models in order to estimate changes in the 24-hour rainfall amount for various return periods at several major climate stations across Nova Scotia. According to the report, rainfall in the Halifax area may increase by 30% within the next 100 years. Due to the location of Liverpool being along the coast, as well as being along the Eastern Shore allows using these results to estimate the potential effect of climate change in the study area. Therefore, climate change scenarios for future condition assessment were based on a 30% increase to the calculated design storms and to the projected extreme flows.

### 5.5.4 Results

The resultant peak runoff and runoff coefficients for each contributing watershed at the site is presented below with respect to the presented design storms.

**Table 5.4.2: Peak Runoff and Runoff Coefficients**

| Watershed | Identifier | Current Conditions | | | | Future Conditions | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 in 5 Year | | 1 in 100 Year | | 1 in 5 Year | | 1 in 100 Year | |
| | | Peak Runoff ($m^3/s$) | Runoff Coefficient | Peak Runoff ($m^3/s$) | Runoff Coefficient | Peak Runoff ($m^3/s$) | Runoff Coefficient | Peak Runoff ($m^3/s$) | Runoff Coefficient |
| **Amherst Street** | Amherst_D_Upstream | 1.2 | 0.8 | 2.2 | 0.8 | 1.7 | 0.8 | 3.0 | 0.9 |
| | Amherst_Downstream_ABCD | 2.8 | 0.9 | 4.9 | 0.9 | 3.8 | 0.9 | 6.7 | 1.0 |
| **Birch Avenue** | Birch_A_Upstream | 0.9 | 0.8 | 1.5 | 0.9 | 1.2 | 0.9 | 2.1 | 0.9 |
| | Birch_AB | 1.4 | 0.9 | 2.4 | 1.0 | 1.9 | 0.9 | 3.3 | 1.0 |
| | Birch_B4_5 | 0.5 | 0.9 | 0.8 | 0.9 | 0.6 | 0.9 | 1.1 | 0.9 |
| | Birch_C_Downstream | 1.3 | 1.0 | 2.4 | 1.0 | 1.8 | 1.0 | 3.4 | 1.0 |
| | Birch_C_Upstream | 1.6 | 0.7 | 2.9 | 0.8 | 2.2 | 0.7 | 4.0 | 0.8 |
| **Bog Pond** | Bog_Pond_C_E | 1.6 | 0.9 | 3.0 | 0.9 | 2.3 | 0.9 | 4.2 | 0.9 |
| | Bog_Pond_D_F | 1.8 | 1.0 | 3.3 | 1.0 | 2.5 | 1.0 | 4.7 | 1.0 |
| | Bog_Pond_G_I | 1.9 | 1.0 | 3.5 | 1.0 | 2.7 | 1.0 | 4.8 | 1.0 |
| | Bog_Pond_H | 1.8 | 0.8 | 3.1 | 0.9 | 2.5 | 0.9 | 4.3 | 0.9 |
| | Bog_Pond_I_Upstream | 0.4 | 0.8 | 0.8 | 0.9 | 0.6 | 0.8 | 1.1 | 0.9 |
| **Bristol Avenue West** | West_Bristol_16_19A | 0.2 | 0.8 | 0.3 | 0.9 | 0.3 | 0.9 | 0.5 | 0.9 |
| | West_Bristol_20A | 0.5 | 0.9 | 0.8 | 0.9 | 0.6 | 0.9 | 1.1 | 0.9 |
| | West_Bristol_3B | 0.6 | 0.8 | 1.0 | 0.8 | 0.8 | 0.8 | 1.4 | 0.9 |
| | West_Bristol_A1_Downstream | 0.5 | 0.9 | 0.9 | 0.9 | 0.7 | 0.9 | 1.2 | 0.9 |
| | West_Bristol_A2_Downstream | 0.2 | 0.9 | 0.3 | 0.9 | 0.3 | 0.9 | 0.5 | 0.9 |
| | West_Bristol_A3_Downstream | 0.3 | 0.9 | 0.4 | 0.9 | 0.3 | 0.9 | 0.6 | 0.9 |
| | West_Bristol_AB_Upstream | 1.0 | 0.9 | 1.7 | 1.0 | 1.3 | 0.9 | 2.2 | 1.0 |
| | West_Bristol_B_Downstream | 1.5 | 1.0 | 2.8 | 1.0 | 2.1 | 1.0 | 3.9 | 1.0 |
| | West_Bristol_B_Upstream_2 | 0.5 | 0.9 | 0.8 | 0.9 | 0.6 | 0.9 | 1.1 | 0.9 |
| | West_Bristol_Mersey_Ave | 0.3 | 0.9 | 0.5 | 1.0 | 0.4 | 1.0 | 0.6 | 1.0 |
| **Bristol Avenue East** | East_Bristol_8C | 0.5 | 1.0 | 0.9 | 1.0 | 0.7 | 1.0 | 1.2 | 1.0 |
| | East_Bristol_C_Downstream | 3.0 | 0.9 | 5.6 | 0.9 | 4.3 | 0.9 | 7.9 | 1.0 |
| | East_Bristol_C_Upstream | 2.6 | 0.7 | 4.8 | 0.7 | 3.7 | 0.7 | 6.8 | 0.8 |

| Watershed | Identifier | Current Conditions | | | | Future Conditions | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 in 5 Year | | 1 in 100 Year | | 1 in 5 Year | | 1 in 100 Year | |
| | | Peak Runoff ($m^3/s$) | Runoff Coefficient | Peak Runoff ($m^3/s$) | Runoff Coefficient | Peak Runoff ($m^3/s$) | Runoff Coefficient | Peak Runoff ($m^3/s$) | Runoff Coefficient |
| | East_Bristol_C2_Downstream | 3.4 | 0.9 | 6.6 | 1.0 | 5.0 | 0.9 | 9.4 | 1.0 |
| | East_Bristol_C2_Upstream | 1.2 | 0.8 | 2.2 | 0.8 | 1.7 | 0.8 | 3.0 | 0.8 |
| | East_Bristol_C3_Downstream | 0.8 | 0.9 | 1.3 | 0.9 | 1.0 | 0.9 | 1.8 | 0.9 |
| Cobbs Ridge | Cobbs_Ridge_A | 0.2 | 0.9 | 0.4 | 0.9 | 0.3 | 0.9 | 0.5 | 0.9 |
| | Cobbs_Ridge_Downstream | 6.4 | 1.0 | 11.6 | 1.0 | 9.0 | 1.0 | 16.1 | 1.0 |
| | Cobbs_Ridge_F | 0.5 | 0.9 | 0.9 | 0.9 | 0.7 | 0.9 | 1.2 | 0.9 |
| | Cobbs_Ridge_G | 0.8 | 0.9 | 1.5 | 0.9 | 1.1 | 0.9 | 2.0 | 0.9 |
| | Cobbs_Ridge_H | 2.1 | 1.0 | 3.6 | 1.0 | 2.8 | 1.0 | 4.9 | 1.0 |
| | Cobbs_Ridge_J_1 | 0.4 | 0.6 | 0.8 | 0.7 | 0.6 | 0.6 | 1.1 | 0.7 |
| | Cobbs_Ridge_J_2 | 0.4 | 1.0 | 0.8 | 1.0 | 0.6 | 1.0 | 1.1 | 1.0 |
| Hosptial Area | Hospital_A_B_C | 1.0 | 0.9 | 1.7 | 1.0 | 1.4 | 1.0 | 2.4 | 1.0 |
| | Hospital_D_Downstream | 1.0 | 1.0 | 1.9 | 1.0 | 1.5 | 1.0 | 2.6 | 1.0 |
| | Hospital_D_Upstream | 1.2 | 0.9 | 2.2 | 0.9 | 1.7 | 0.9 | 2.9 | 1.0 |
| | Hospital_E | 0.3 | 0.8 | 0.6 | 0.9 | 0.4 | 0.8 | 0.8 | 0.9 |
| Meadow Pond | Meadow_Pond_C_Upstream | 2.3 | 0.7 | 4.1 | 0.8 | 3.2 | 0.8 | 5.7 | 0.8 |
| | Meadow_Pond_Downstream_ACD | 8.3 | 0.7 | 15.8 | 1.0 | 12.0 | 1.0 | 22.7 | 1.0 |
| | Meadow_Pond_E_Downstream | 6.1 | 1.0 | 11.9 | 1.0 | 8.9 | 1.0 | 17.4 | 1.0 |
| | Meadow_Pond_E_Upstream | 2.3 | 0.6 | 4.1 | 0.7 | 3.2 | 0.6 | 5.7 | 0.7 |
| | Meadow_Pond_F1 | 5.1 | 0.4 | 9.8 | 0.5 | 7.4 | 0.5 | 14.1 | 0.5 |
| | Meadow_Pond_F2 | 11.4 | 0.7 | 20.8 | 0.8 | 15.9 | 0.7 | 28.8 | 0.8 |
| | Meadow_Pond_F3 | 3.8 | 0.7 | 7.7 | 0.8 | 5.7 | 0.8 | 11.3 | 0.8 |
| Wolfe Street | Wolfe_B_Upstream | 0.9 | 0.7 | 1.6 | 0.8 | 1.3 | 0.7 | 2.3 | 0.8 |
| | Wolfe_B2_Upstream | 1.5 | 0.9 | 2.6 | 0.9 | 2.0 | 0.9 | 3.6 | 1.0 |
| | Wolfe_Downstream | 2.0 | 1.0 | 3.5 | 1.0 | 2.7 | 1.0 | 4.8 | 1.0 |

The comparison of the runoffs generated for each major watershed using the Rational Method and the EPA SWMM Model for both current and future conditions are presented in Table 5.5.2 and Table 5.5.3. The difference between both runoff values for each watershed is also presented. The difference between the two methods is a result of many factors. Sources of error in determining the coefficients used within the Rational Method, as described in Section 5.4, may account for differences in variables such as runoff coefficient, flow length, and slope between the two methods. The future development estimates determined in 1993 to produce the future flows may be different then the currently assessed development of each watershed which impacts difference in runoff coefficient and time of concentration. Another major source of difference between the resultant runoffs may be attributed to the differences in methodologies. The Rational Method is a simplistic method to calculate the peak runoff of a watershed, however, this method does not account for the watersheds natural dynamic responses to a rainfall event. The EPA SWMM Model utilizes the variables within the Rational Method while also accounting for various hydrological processes such as infiltration, depression storage, as well as the varying responses of rainfall on impermeable and permeable surfaces.

**Table 5.5.2: Comparison of Runoff Results between the Rational Method and the EPA SWMM Model for the 5 Year Return Period**

| Watershed | 5 Year Return Period Peak Runoff (m3/s) | | | | | |
|---|---|---|---|---|---|---|
| | 2019 | | | Future Conditions | | |
| | Rational Method (A1) | EPA SWMM Model Method (B1) | Difference (B1-A1) | Rational Method (A2) | EPA SWMM Model Method (B2) | Difference (B2-A2) |
| Amherst Street | 5.1 | 4.0 | -1.1 | 6.7 | 5.5 | -1.2 |
| Birch Avenue | 7.2 | 5.6 | -1.6 | 9.3 | 7.8 | -1.5 |
| Bog Pond | 5.3 | 7.5 | 2.2 | 7.1 | 10.5 | 3.4 |
| Bristol Avenue West | 5.6 | 5.3 | -0.3 | 7.7 | 7.3 | -0.4 |
| Bristol Avenue East | 11.4 | 11.5 | 0.1 | 16.7 | 16.4 | -0.3 |
| Cobbs Ridge | 10.5 | 10.9 | 0.1 | 13.6 | 15.1 | 1.5 |
| Hospital Area | 2.6 | 3.6 | 1.0 | 3.4 | 4.9 | 1.5 |
| Meadow Pond | 36.9 | 39.2 | 2.3 | 58.9 | 56.2 | -2.7 |
| Wolfe Street | 4.1 | 4.3 | 0.2 | 5.6 | 6.0 | 0.4 |

**Table 5.5.3: Comparison of Runoff Results between the Rational Method and the EPA SWMM Model for the 100 Year Return Period**

| Watershed | 100 Year Return Period Runoff (m3/s) | | | | | |
|---|---|---|---|---|---|---|
| | 2019 | | | Future Conditions | | |
| | Rational Method (A1) | EPA SWMM Model Method (B1) | Difference (B1-A1) | Rational Method (A2) | EPA SWMM Model Method (B2) | Difference (B2-A2) |
| Amherst Street | 8.0 | 7.1 | -0.9 | 10.5 | 9.7 | -0.8 |
| Birch Avenue | 11.3 | 10.1 | -1.2 | 14.7 | 14.0 | -0.7 |
| Bog Pond | 8.1 | 13.7 | 5.6 | 11.1 | 19.0 | 7.9 |
| Bristol Avenue West | 8.9 | 9.4 | 0.5 | 12.2 | 12.9 | 0.7 |
| Bristol Avenue East | 19.5 | 21.4 | 1.9 | 26.6 | 30.1 | 3.5 |
| Cobbs Ridge | 16.7 | 19.5 | 2.8 | 21.6 | 26.8 | 5.2 |
| Hospital Area | 4.2 | 6.4 | 2.2 | 5.4 | 8.7 | 3.3 |
| Meadow Pond | 58.0 | 74.3 | 16.3 | 93.3 | 105.7 | 12.4 |
| Wolfe Street | 6.8 | 7.7 | 0.9 | 8.8 | 10.6 | 1.8 |

## 5.6 Low Impact Developmnet and Stromwater Best Management Practices

Low Impact Development (LID) uses a range of techniques and technologies that provide the following fundamental benefits:

1. **Control of Runoff Volume and Peak Flows.**
2. **Control of Runoff Water Quality.**
3. **Preservation of Biodiversity.**

These techniques are referred to as stormwater Best Management Practices (BMPs).

Low impact development (LID) is a stormwater management strategy that seeks to mitigate the impacts of development (increased runoff, stormwater pollution, destruction of habitat) by managing runoff as close to its source as possible. LID comprises a set of site design strategies that minimize runoff in distributed, small scale structural practices. The aim is to mimic natural or predevelopment hydrology through the processes of infiltration, evapotranspiration, harvesting, filtration and detention of stormwater. These practices can effectively remove nutrients, pathogens and metals from runoff, and they reduce the volume and intensity of stormwater flows. (U.S. Environmental Protection Agency)

The BMPs presented here are designed to enhance stormwater system and facility performance, minimize maintenance requirements and address the public safety concerns related to flooding and stormwater events.

### 5.6.1 New Development and Reclamation

The goal of Low Impact Development practices is to add value and efficiency to infrastructure required for new development without incurring great expense. Initial costs due to BMP installation are offset by the decrease in peak surface flows, flooding, associated damages and larger infrastructure requirements downstream.

New development options include:

- → Grass Swales.
- → Permeable Pavement.
- → Perforated Pipe Systems.
- → Wet Pond.
- → Dry Detention Pond.
- → Constructed Wetland.
- → Vegetative Filter Strips.

### 5.6.2 References and Recommended Design Guidelines

Low Impact Development is listed in design guidelines throughout Canada and is law in the U.S. It has also been used repeatedly in Atlantic Canada, with CBCL designing for Low Impact Development throughout the region. Notable references for guides, costing analyses and performance studies are listed below.

**LID Guides**

City of Calgary. (2014). “Complete Streets Guide.”

City of Saskatoon. (2016). “Low Impact Development: Design Guide for Saskatoon.”

Metro Vancouver. (2012). “Stormwater Source Control Design Guidelines”.

Toronto and Region Conservation Authority (TRCA). (2012). “Stormwater Management Criteria.”

Toronto and Region Conservation Authority (TRCA) & Credit Valley Conservation Authority (CVC). (2012). “Low Impact Development Stormwater Management Planning and Design Guide.”

**LID Costing Studies**

EPA. 2008. “Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices.”

Houle, J., Roseen, R., Ballestero, T., Puls, T., & Sherrard, J. (2013). “Comparison of Maintenance Cost, Labor Demands, and System Performance for LID and Conventional Stormwater Management.” Journal of Environmental Engineering. 139:7 pp. 932-938.

Toronto and Region Conservation (TRCA). (2013). “Assessment of Life Cycle Costs for Low Impact Development Stormwater Management Practices.”

United States Environmental Protecting Agency (EPA). (2007). “Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices.”

**LID Performance Studies**

LeFevre, N., Davidson, J., & Oberts, G. (2009). “Bioretention of Simulated Snowmelt: Cold Climate Performance and Design Criteria.” Cold Regions Engineering 2009. pp. 145-154

Toronto and Region Conservation Authority (TRCA). (2008). “Performance Evaluation of Permeable Pavement and a Bioretention Swale.”

Toronto and Region Conservation Authority (TRCA). (2015). “Five Year Performance Evaluation of Permeable Pavements.”

### 5.6.3 Best Management Practice: Grass Swales

Stormwater swales are also designed to maximize infiltration and mimic the natural water system by conveying, treating and attenuating runoff. During the landscaping of a green area, clearstone or gravel is placed below the topsoil. This layer allows water to easily infiltrate into the ground and drain directly into the groundwater system. The large voids between the stones also act as extra storage space for stormwater. Bushes, trees and other vegetation may be planted within the swale to slow overland flow, further increasing infiltration and sedimentation. Swales can be used to increase underground storage, promote infiltration and groundwater recharge and reduce overland flow.

Enhanced drainage swales include design features to improve contaminant removal and runoff reduction beyond that of a simple grass swale. One of the most common such feature is check dams. These are placed along the swale perpendicular to flow and encourage pooling and infiltration. In other cases, perforated pipes and underdrains are used.

Yarmouth – Starrs Road


**Enhanced Grass Swales (Source: CBCL Design)**

Swales are best suited for treating highway and residential road runoff, but are less suited to urban environments due to their size requirements.

**Notes on Enhanced Grass Swale Design:**
Enhanced grass swales are most effective in locations with high soil permeability. Ponding should not occur for more than 24 hours after storm events, as this may create mosquito habitat. During winter, these locations may be used for snow storage, but salt tolerant plants are required. Enhanced swale slopes and benching should be similar to typical grass swale design.


**Bioswale in a Corporate Setting (Source: U.S. Department of Agriculture)**

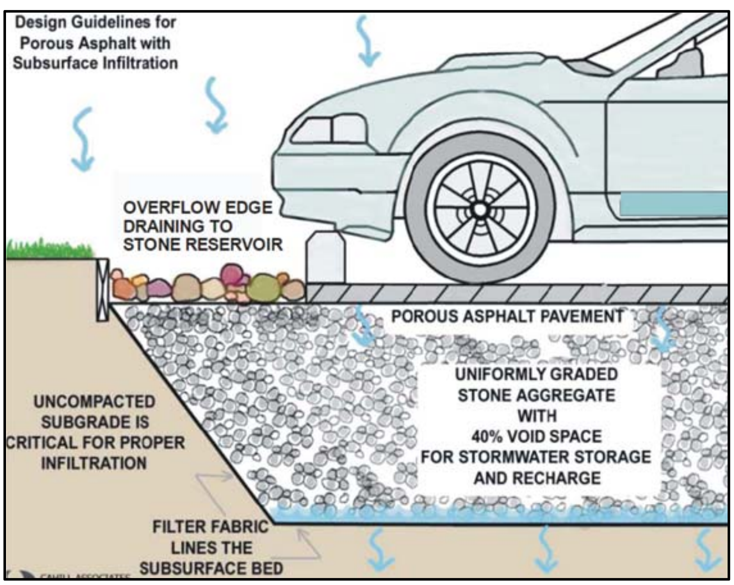
### 5.6.4 Best Management Practice: Permeable Pavemnet

Permeable pavement is an alternative to traditional pavements which allows for partial water infiltration through the pavement and into a graded stone reservoir or the underlying soil. The surface may consist of permeable concrete, porous asphalt, permeable interlocking concrete pavers, concrete grid pavers or plastic grid pavers. In cases where interlocking pavers are used, space between and within the pavers is filled with pea gravel, sand, topsoil or grass.

**Permeable Pavers in Hawthorne Street, Yarmouth (Source: CBCL Design)**

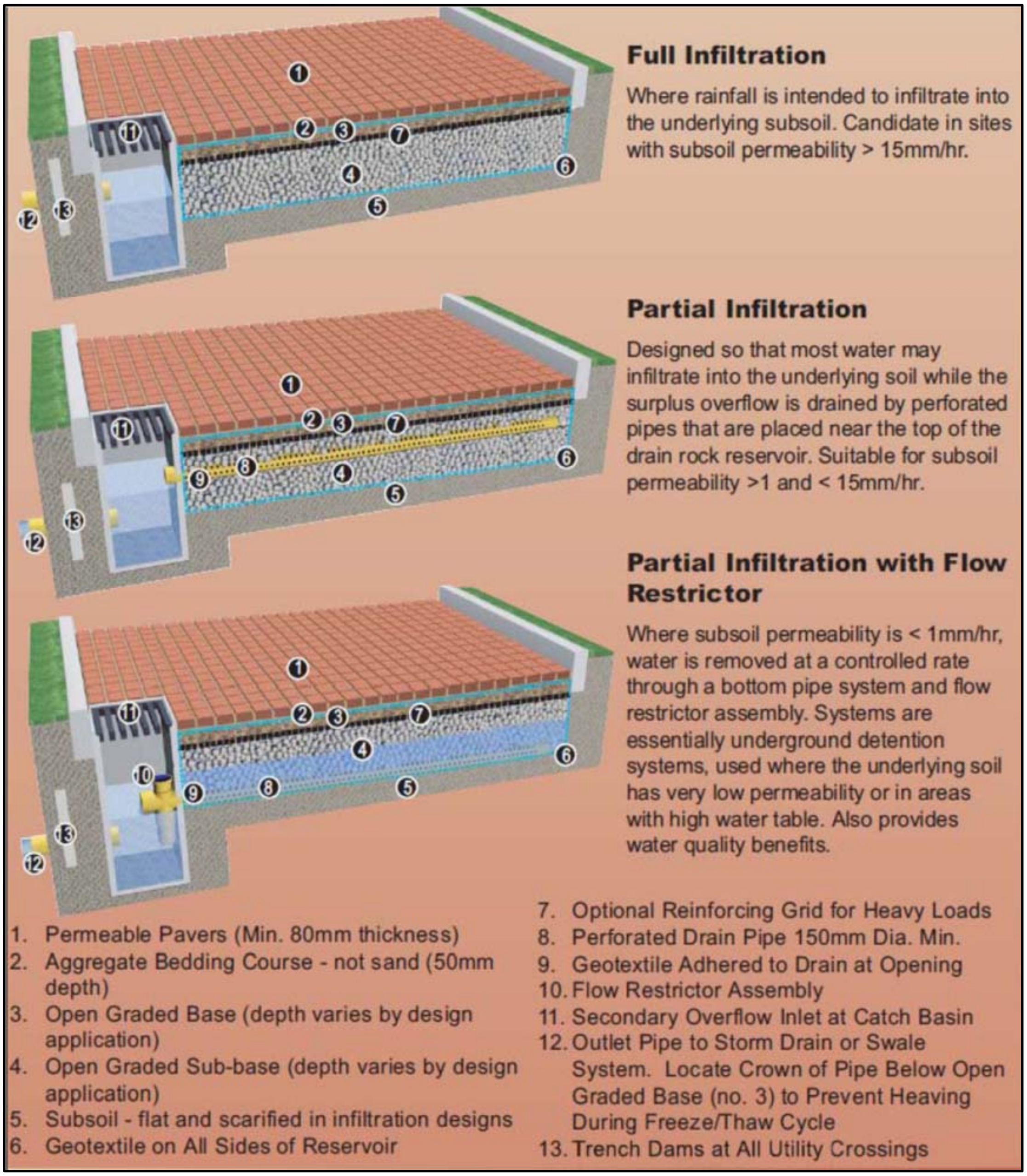
Permeable pavement works in a similar way to natural permeable surfaces, decreasing stormwater runoff by increasing infiltration. They are most suitable for applications with low to medium traffic areas. These include residential roads, alleys, driveways, walkways, plazas, low traffic parking lots and other locations with low levels of contaminants.

Permeable pavements provide added benefits in poor weather. Due to rapid drainage of the surface, snow collected on these pavements melts rapidly and the surface helps to reduce the occurrence of black ice and frozen puddles.




**Porous Asphalt with Stone Aggregate (Source: LID Toronto)**

**Notes on Permeable Pavement Design:**
Sand should not be used for deicing in winter, as this can clog up the pavement. Susceptibility to clogging can be a major concern for permeable pavements in some environments. Landscaping areas should drain away from permeable pavement to minimize the transportation of sediment onto the pavement. A geotextile should be used to separate the stone aggregate from natural soils below.

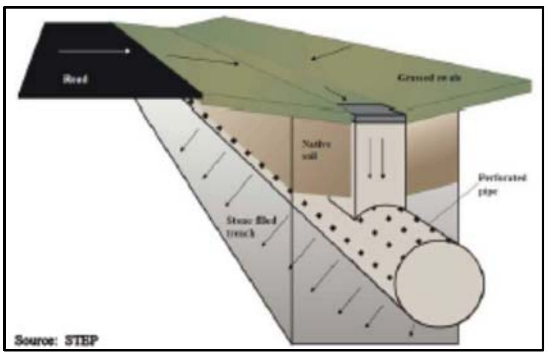


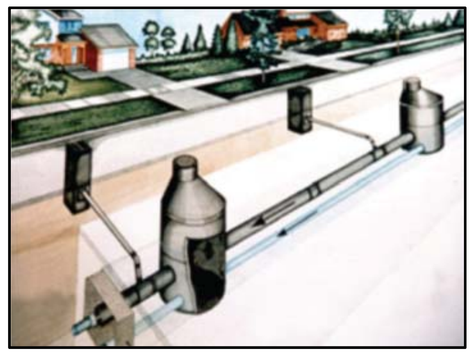

**Permeable Pavement Cross Sections (Source: GVRD 2005)**

### 5.6.5 Best Management Practice: Perforated Pipe System
Perforated pipes systems are designed both for the conveyance and infiltration of stormwater. The design is similar to traditional stormwater pipe systems. However, holes are added to the pipe and the infrastructure is bedded in graded gravel. In this way, the efficiency of the pipe system can be greatly

increased without large expense. Perforations within the pipe allow water to flow downwards out of the pipe, infiltrating through the gravel bedding and back into the ground. Even though the surface may be paved, water is still able to infiltrate and encourage groundwater recharge. Infiltration from the pipe also greatly decreases flows discharged at the pipe outlet and smaller pipes may be used. For all but very large storms, it is possible to design the system so that all rainfall infiltrates, preventing any outlet flow at all.

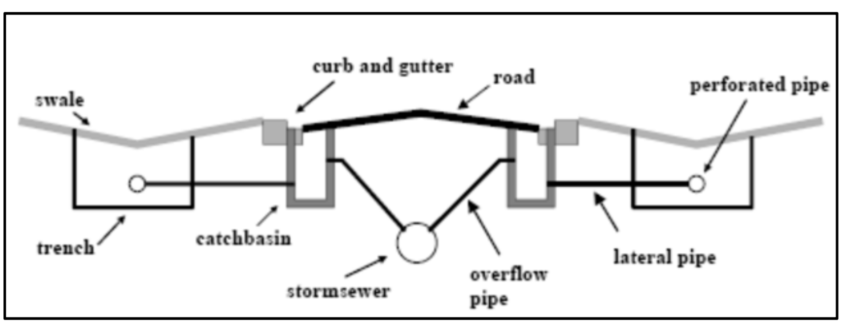
Pervious catchbasins are an extension of the permeable pipe system concept. They are normal catchbasins with larger sumps that are physically connected to an exfiltration storage zone made up of crushed stone or other porous material. The storage media is typically located beneath or beside the catchbasin. To minimize clogging and early failure of the perforated pipe system, it is necessary to pre-treat any runoff that carries a high sediment load. It can be achieved by conveying the runoff over grassed area to filter sediments prior to flowing into the pervious catchbasins. Perforated pipes are best suited to treating drainage from low to medium traffic areas with flat to gentle slopes.



**Perforated Pipe System Sketches (Source: STEP)**

**Notes on Permeable Pipe Design:**
A geotextile should be used to separate the granular bedding material from the natural soils. Perforated pipe systems can be used throughout winter, provided that the pipes are buried below the maximum frost penetration depth. Perforated pipe systems must be set back four meters from building foundations to prevent damage due to freeze/thaw cycles or flooding.

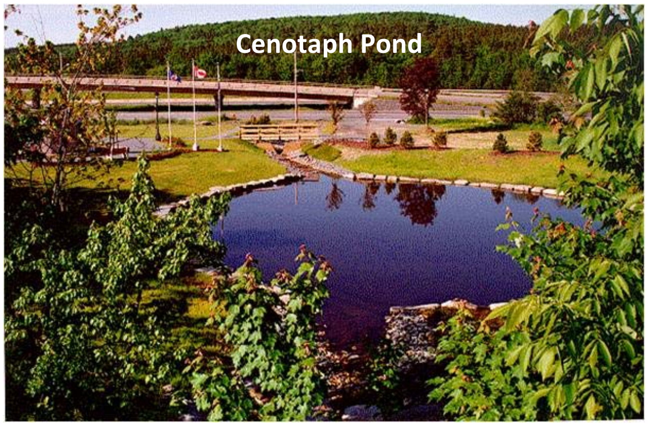



**Perforated Stormwater System with Grassed Swales (Source: LID Toronto)**

### 5.6.6 Best Management Practice: Wet Pond

Constructed wet ponds are stormwater basins that have a permanent pool for water quality treatment and additional capacity above the permanent pool for temporary runoff storage.

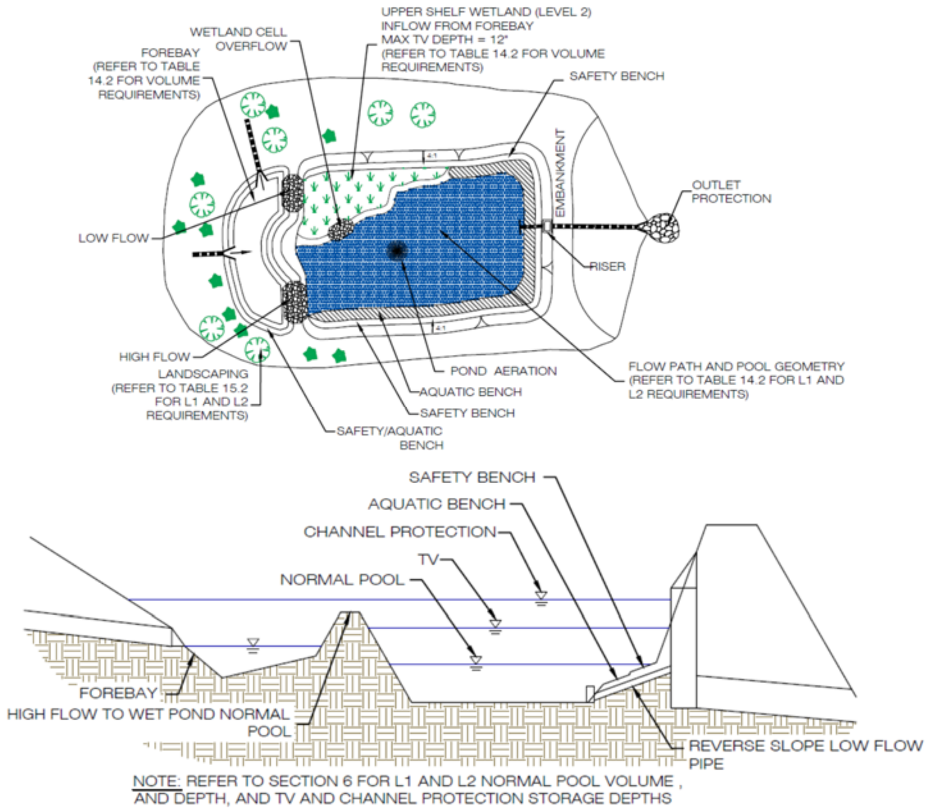
They can be designed to control discharge to predetermined levels to reduce downstream flooding and erosion. They are also among the most effective BMPs at removing stormwater pollutants. Water contained in the permanent pool mixes with and dilutes the initial polluted runoff from storm events. Additionally, plants, algae, and bacteria in the water consume these pollutants and thereby substantially reduce the total mass of pollutants released downstream. Wet ponds lend themselves to multi-purpose facilities that include fish and wildlife habitat, recreational use, and aesthetic enhancements, as well as stormwater management.




**Example of Wet Pond (Source: CBCL Design)**

**Notes on Wet Pond Design:**

Wet ponds should be designed with a length to width ratio of at least 2:1 wherever possible. A forebay at major inflow points can capture coarse sediment and minimize erosion from inflow.



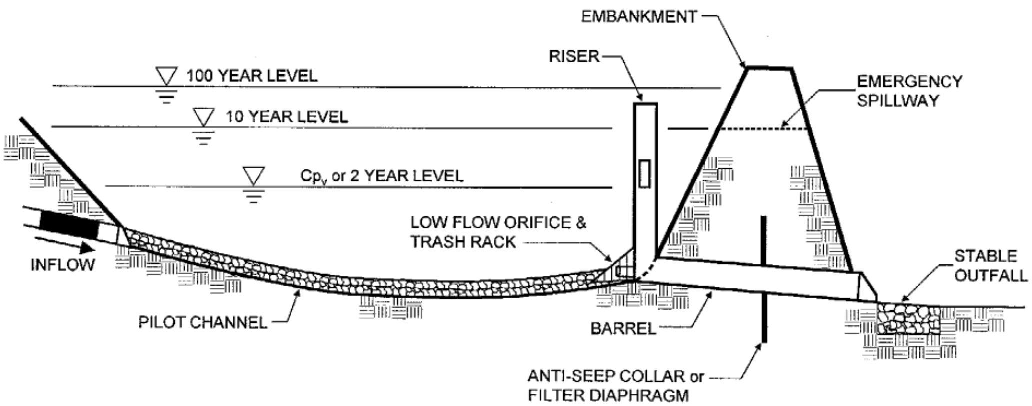

**Wet Pond Design Schematics (Source: VT EDU)**

### 5.6.7 Best Management Practice: Dry Detention Pond

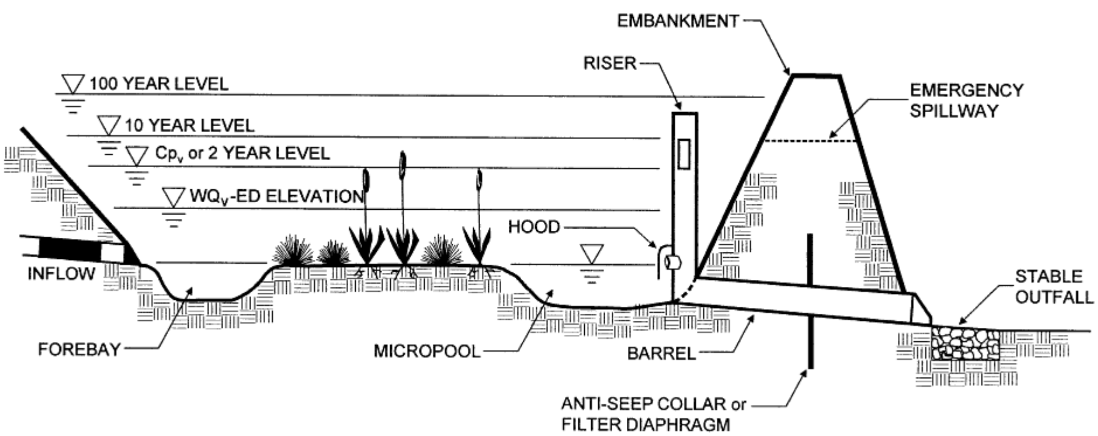
Dry detention ponds are stormwater basins that are designed to provide temporary storage of storm water runoff and impound the water for gradual release to the receiving stream or storm sewer system. Unlike wet ponds, dry detention ponds do not have a permanent pool.

Most dry ponds are designed to empty in a time period of less than 24 hours, resulting in lower contaminant removal than wet ponds. Dry ponds can provide limited settling of particulate matter, but a large portion of this material can be resuspended by subsequent runoff events. Therefore, these ponds are normally used strictly for flood control and are not recommended for water quality benefits. If water quality treatment is the intended goal of the pond, a wet or extended storage pond design should be considered.

The extended dry pond contains a water quality volume in the lower stage, and has an upper stage for detention of larger storms for flood control. The lower stages of a dry pond are controlled by outlets designed to detain the storm water runoff for the water quality volume for a minimum duration of 24-hours, which allow sediment particles and associated pollutants to settle out. Higher stages in the pond detain the peak rates of runoff from larger storms for flood and erosion control.




**Example of Dry Detention Pond (Source: BMPs BC)**




**Example of Extended Dry Detention Pond (Source: BMPs BC)**


**Example of Dry Detention Pond in Fredericton (Source: CBCL Design)**


**Example of Halifax Water “Red Book” Dry Detention Pond in Burnside (Source: CBCL Design)**

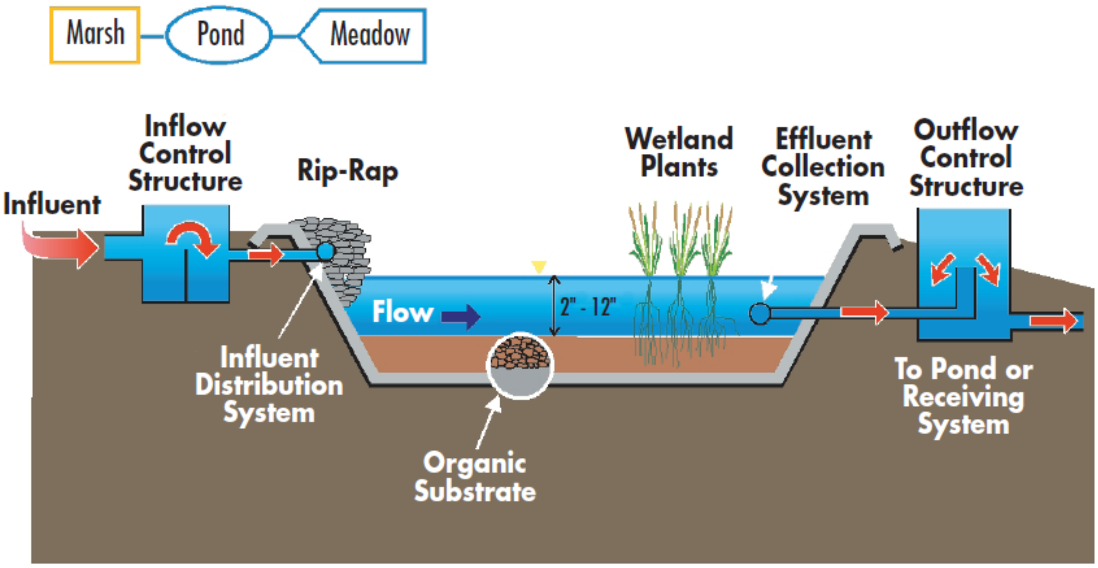
**Notes on Dry Pond Design:**
Dry detention ponds can perform well in cold climate, but as a general rule dry ponds should be implemented for drainage areas greater than 10 acres. A minimum detention time of 24 hours should be targeted in all instances. If it is possible, a detention time of 48 hours should be employed to improve suspended solids removal.

### 5.6.8 Best Managemnet Practice: Contructed Wetland

Constructed wetlands are shallow pools developed specifically for storm or waste water treatment that create growing conditions suitable for wetland plants. Constructed wetlands are designed to provide water quality benefits by minimizing pollution prior to its entry into receiving waters. Also, they can be used to manage stormwater runoff peak flows and make reductions in overall runoff quantity. Quantity reductions can be achieved through infiltration of stormwater to the water table, and some delays in peak flows.

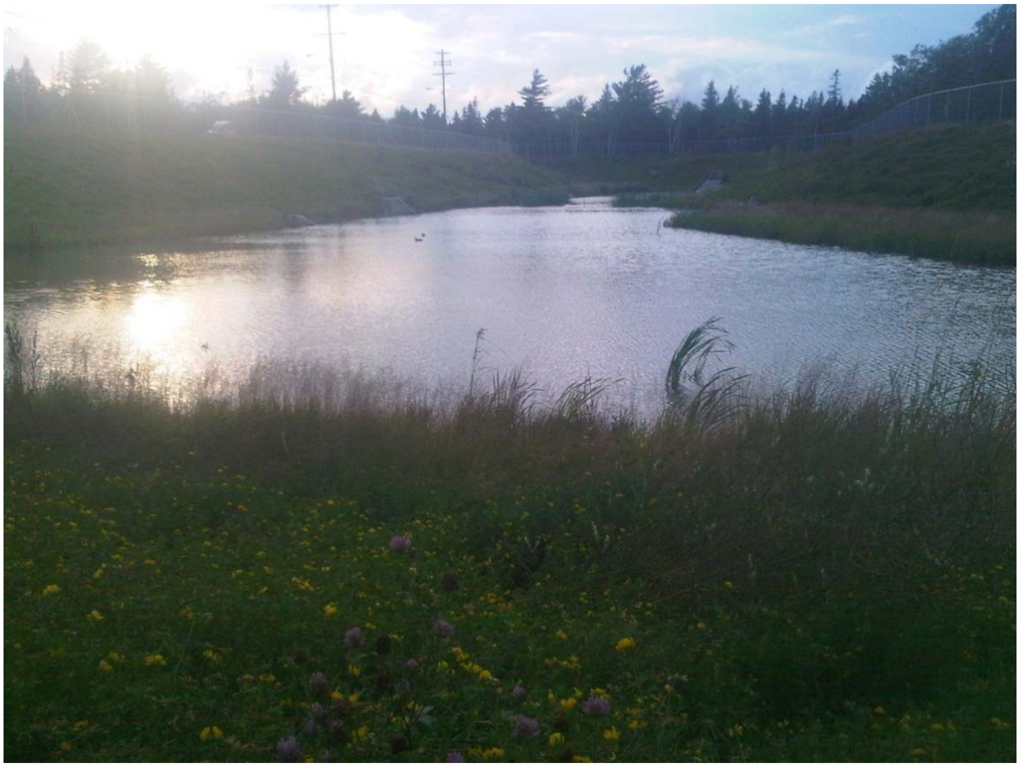
Stormwater quality management is typically the reason why constructed wetlands are considered as a stormwater management practice. Properly constructed and maintained wetlands can provide very high removal rates of pollutants from stormwater. Removal of pollutants is accomplished through adsorption, wetland plant uptake, retention, gravitational settling, physical filtration and microbial decomposition, thus improving runoff quality.


**Plan View of Constructed Wetland (Source: VT EDU)**




**Typical Cross-Section of Constructed Wetland (Source: US Department of Energy)**

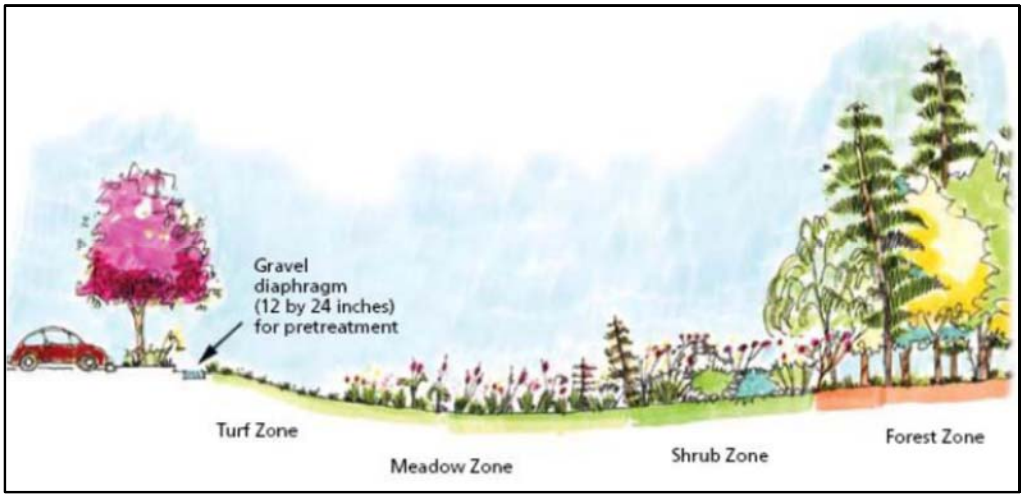
**Notes on Constructed Wetland Design:**
The contributing drainage area must be large enough to sustain a permanent water level within the wetland. The area required for constructed wetland is generally 3-5% of its drainage area.



**Example of Constructed Wetland (Source: CBCL Design)**

### 5.6.9 Best Management Practice: Vegetative Filter Strips

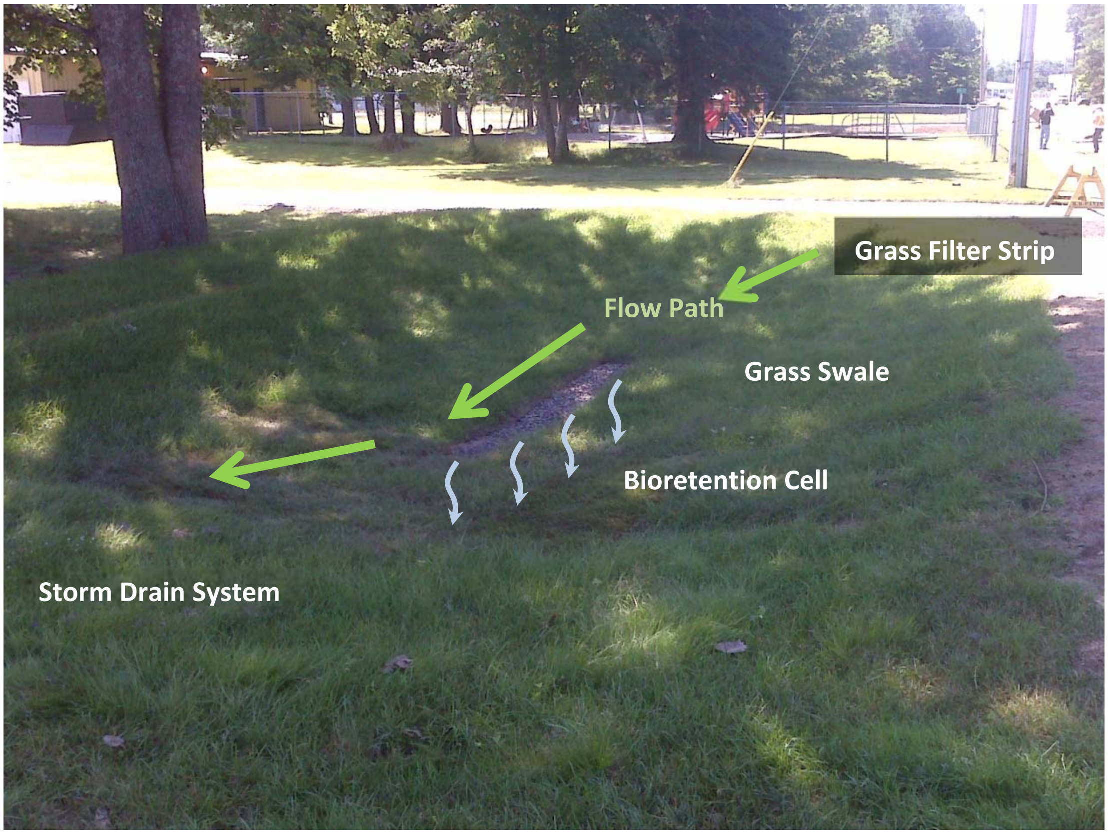
Densely vegetated areas with gentle slopes can be designed to treat runoff of from surrounding impervious surfaces. These vegetated filter strips slow runoff, filtering out particulates, increasing infiltration and providing temporary depression storage. Strips may be comprised of shrubs, trees, grasses or native vegetation.




**Multi-zone Filter Strip (Source: LID Toronto)**

Vegetated filter strips are most commonly used to treat runoff from roads, highways, low traffic parking lots and downspouts. They are best used in combination with other BMPs. It should be noted that the same salinity, ponding and mosquito concerns associated with rain gardens also apply to vegetative strips.

**Garden along Hawthorne Street, Yarmouth**
**(Source: CBCL Design)**




**Combined BMP Treatment Train / Rain Garden (Source: CBCL Design)**

# Chapter 6 Conclusion/Recommendation

## 6.1 Long Term Sea Level

The table below is extracted from Table 2.2.3 in Chapter 2 and shows the projected extreme water levels (HHWLT plus storm surge) accounting for sea level rise to the year 2100:

**Table 6.1.1: Projected Total Extreme Water Levels (Storm Surge + HHWLT)**

| Extreme Values by Return Period [years] | Meters above CGVD28 (2020) | Meters above CGVD28 (2050) | Meters above CGVD28 (2070) | Meters above CGVD28 (2100) |
|---|---|---|---|---|
| 100-yr | 2.4 | 2.6 | 2.9 | 3.4 |
| 50-yr | 2.3 | 2.6 | 2.8 | 3.3 |

## 6.2 Development Levels

Based on the long term sea level predictions, it is recommended that the Municipality review planning regulations and consider limiting development within any area below at least 3.4m CGVD28. A plan should be developed on how to assess and address existing infrastructure within this development level on a case by case basis throughout Liverpool.

## 6.3 Downtown Liverpool Recommendations

For the purposes of mitigating flooding risks in the Downtown Liverpool area, during a 1 in 100 year storm, under present climatic conditions, a minimum design elevation of 2.4m CGVD28 was selected. A higher design elevation would, of course, result in protection for a larger area but at a dramatically higher cost. It was therefore decided to use a lower and more achievable design elevation with an understanding that a plan must be developed that will include mitigation measures for all properties under 3.4m CGVD28.

The cost to mitigate risks to a higher elevation will rise dramatically as it will impact a much greater area, but the cost of damages to infrastructure for floods exceeding this elevation will also be dramatically higher. It is recommended that this be considered in future master planning for Liverpool.

Based on our analysis of potential flood mitigation measures the parking lot and the surrounding Downtown Liverpool area to a high-water level of 2.4m, it was found that the seawall concept was much more costly than the other options and carries significant challenges and disadvantages. The primary issue is the space required for stormwater storage which would either eliminate the parking lot or be very costly. The geotechnical concerns underlying the existing parking lot also create some unknowns and create a potential for significant cost overruns for the options that involve constructing a seawall or raising the parking lot.

The results of this assessment indicate that the most feasible approach is to plan to relocate buildings and their occupants to higher ground (Concept 4). This could include raising Water Street (Concept 3), however, the limited benefit of this option once the buildings in questions are removed may not outweigh the cost.

## 6.4 Prioritization for the Community of Liverpool

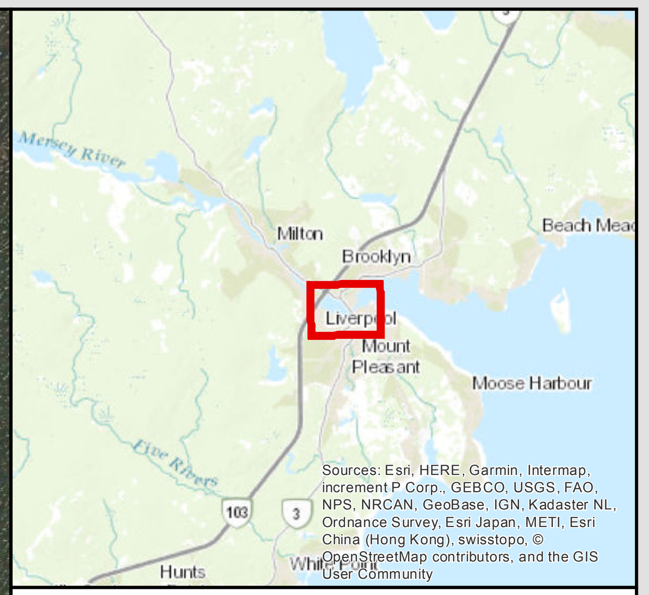
The priority list provided in Chapter 3 also provides some guidance as to what regions the Municipality should address first. Though each region has long-term and near-term recommendations, this study can conclude, with confidence, that the Downtown Liverpool region should be addressed first and foremost. Priority should also be given to the Liverpool Fire Hall and residential properties around the Union Street open channel and along the water; at the end of Mersey Road, on Cowie Street and Main Street near Amherst Street, and on the eastern end of Main Street. Beyond the businesses located around the Downtown Liverpool region, the Municipality should also consult with other major businesses that appear to be prone to coastal flooding about their future development plans. These businesses include Mersey Seafoods, Lane's Privateer Inn & Restaurant, Sobeys, Tim Horton's, and South Shore Chevrolet. While some properties appear to be more at risk than others, it would be valuable to determine what the long-term plans are for each business.

## 6.5 Closure

While Liverpool faces many challenges due to global sea level rise, proper mitigation measures could be implemented in a methodical process. The update to the stormwater management plan, coastal flood maps, priority list and mitigation measures of infrastructure regions, and the concept options presented for Downtown Liverpool can all form a basis for developing a mitigation plan to address Liverpool's infrastructure in regard to climate change.

| | |
|---|---|
| Prepared by:<br>Suvir Pursnani, P.Eng<br>Civil Engineer, Municipal | Reviewed by:<br>Colin Fisher, P.Eng.<br>Senior Civil Engineer, Municipal |

# APPENDIX A – Community of Liverpool Coastal Still Water Floodline Maps


Legend

- Building
- Commercial
- Residential
- Industrial
- Institutional
- Conservation
- Recreational / Open Space

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Land Use Plan

| **CBCL Project # 181109.00** | |
|---|---|
| **Date: 01/08/2019** | **Scale @ 22"x34"** 1:2,769 |
| **Drawn: RM** | **Revisions** |
| **Checked: SP** | |
| **Approved: CF** | |
| **Sheet: 2 of 16** | |

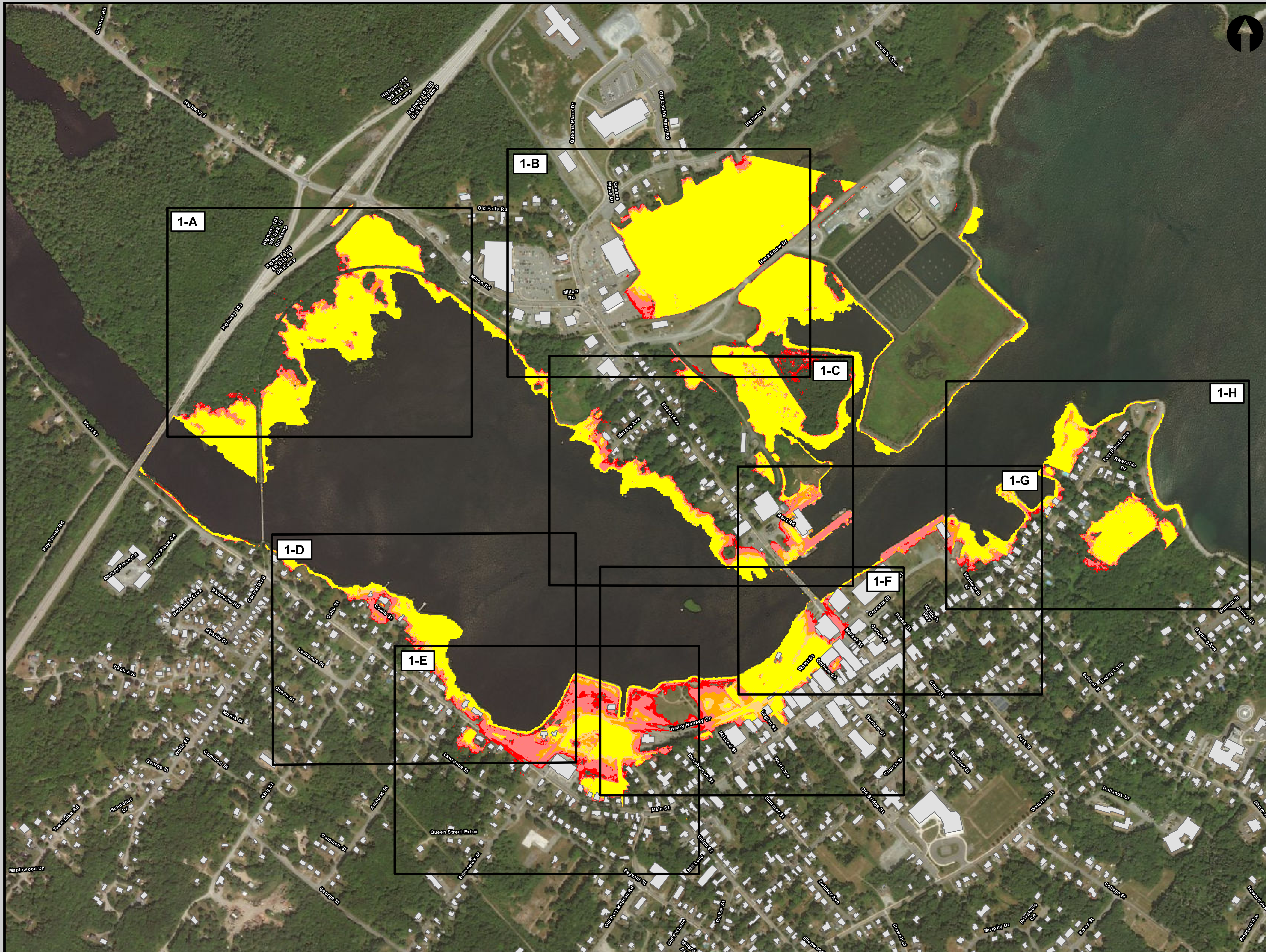
Notes:

• Water levels are based on the still-water elevations and do not take into account tidal amplification.
• Flood lines show all locations below the projected still-water elevations.
• Surface information (LiDAR, 2015) provided by NSCC – Applied Geomatics Resource Group on May 1, 2019
Vertical Datum: CGVD 2013
Horizontal Datum: NAD83(CSRS) / UTM zone 20N

0 65 130 260 m

Coordinate System: NAD 1983 UTM Zone 20N
Units: Meter

K:\Projects\181109.00 Liverpool Coastal Flooding Mitigation Study\20 CAD\08 GIS\layout\181109 - MXD01 - LIVERPOOL COASTAL FLOODING MITIGATION STUDY - LAND USE MAP.mxd 08/07/2019 4:43:35 PM





Map Extents
Building
Existing-2yr
Existing-5yr
Existing-10yr
Existing-50yr
Existing-100yr

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Current (2019) Sea Level
Multiple Storm Surge Events

| | |
|---|---|
| Drawn: RM | Map: 1 |
| Checked: SP | CBCL Project #: 181109.00 |
| Date: 21/06/2019 | Scale @ 11"x17" 1:7,510 |

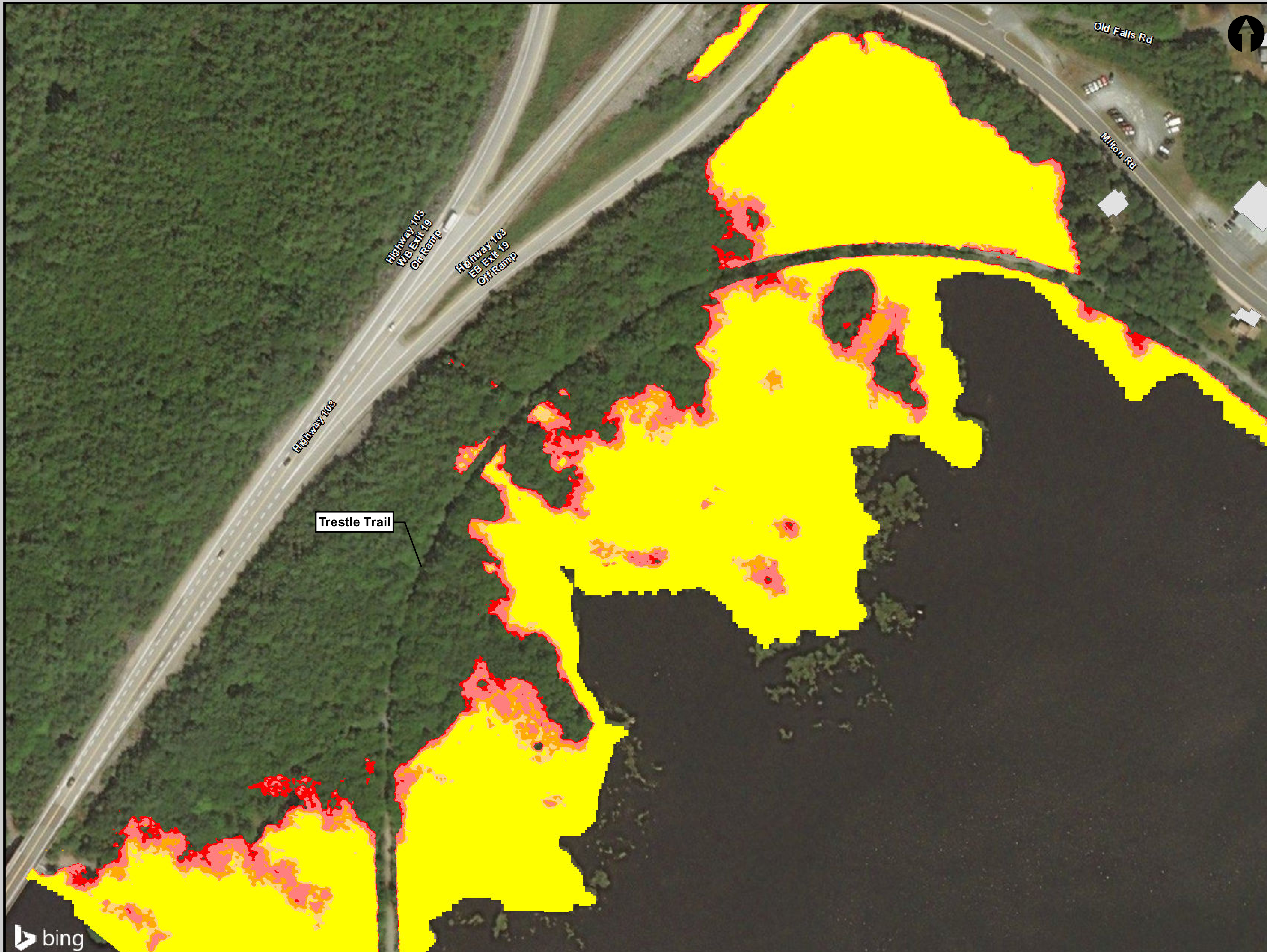
Notes:
- Water levels are based on the still-water elevations and do not take into account tidal amplification.
- Flood lines show all locations below the projected still-water elevations.
- Surface information (LiDAR, 2015) provided by NSCC – Applied Geomatics Resource Group on May 1, 2019

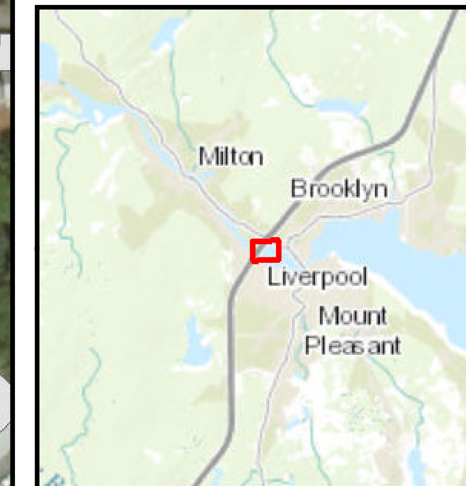
Vertical Datum: CGVD 2013

0 0.1 0.2 0.4 Km

Coordinate System: NAD 1983 UTM Zone 20N

K:\Projects\181109.00 Liverpool Coastal Flooding Mitigation Study\20 CAD\08 GIS\layout\181109 - MXD18 - LIVERPOOL COASTAL FLOODING MITIGATION STUDY - CURRENT FLOOD MAP.mxd




- Building
- Existing-2yr
- Existing-5yr
- Existing-10yr
- Existing-50yr
- Existing-100yr

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Current (2019) Sea Level
Multiple Storm Surge Events

| | |
|---|---|
| **Drawn: RM** | **Map: 1-A** |
| **Checked: SP** | **CBCL Project #: 181109.00** |
| **Date: 21/06/2019** | **Scale @ 11"x17" 1:1,800** |

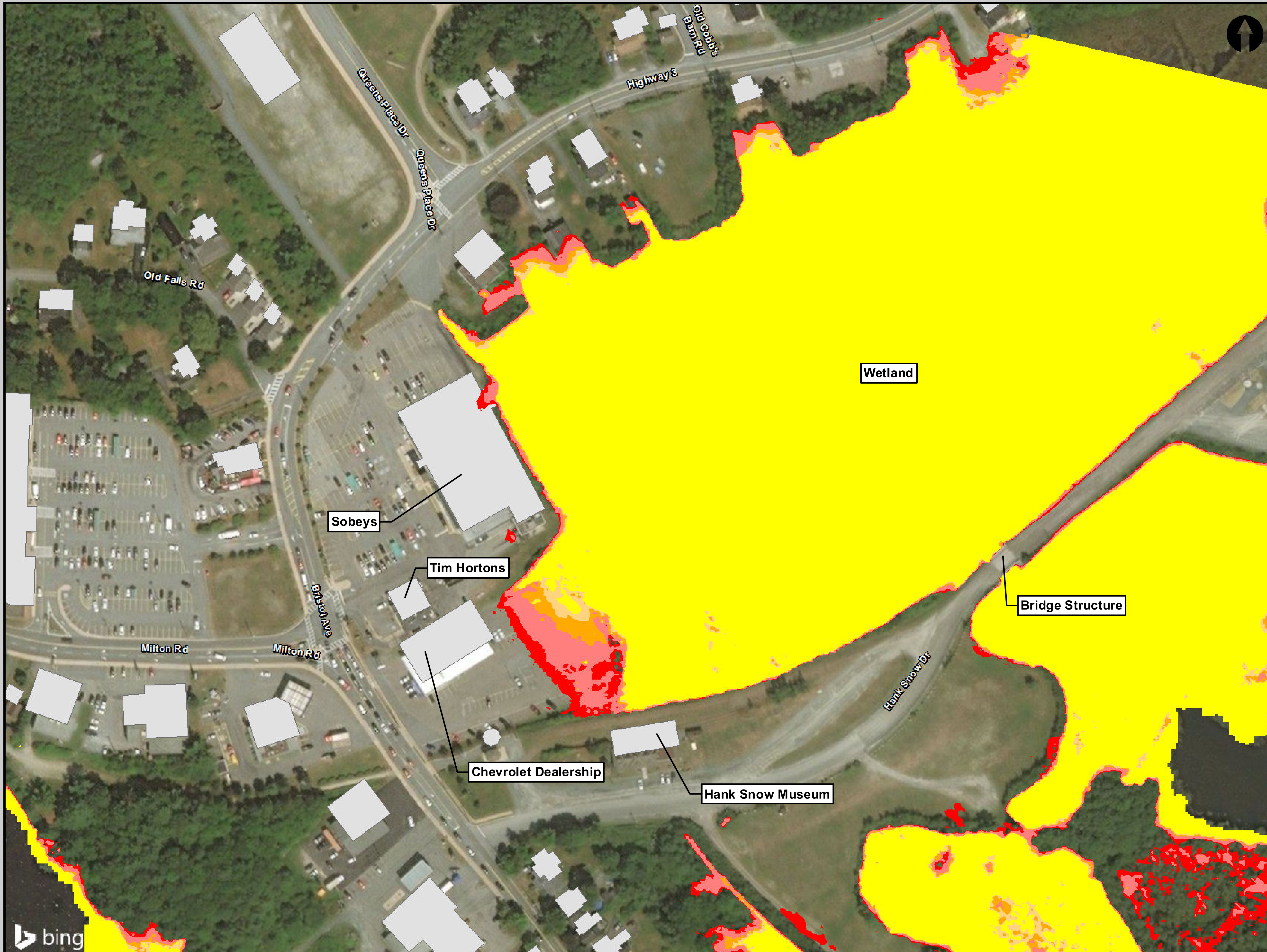
Notes:
- Water levels are based on the still-water elevations and do not take into account tidal amplification.
- Flood lines show all locations below the projected still-water elevations.
- Surface information (LiDAR, 2015) provided by NSCC – Applied Geomatics Resource Group on May 1, 2019

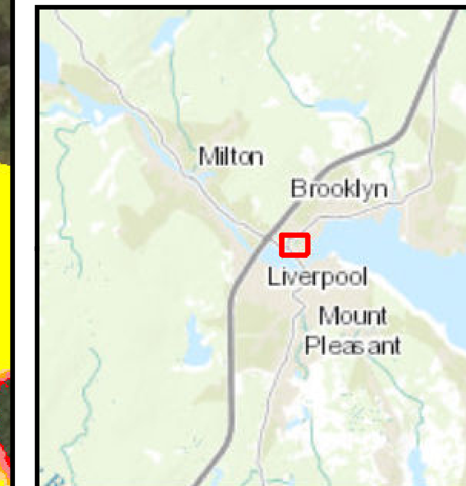
Vertical Datum: CGVD 2013

0 20 40 80 Meters

Coordinate System: NAD 1983 UTM Zone 20N

K:\Projects\181109.00 Liverpool Coastal Flooding Mitigation Study\20 CAD\08 GIS\layout\181109 - MXD18 - LIVERPOOL COASTAL FLOODING MITIGATION STUDY - CURRENT FLOOD MAP (MAP A).mxd




- Building
- Existing-2yr
- Existing-5yr
- Existing-10yr
- Existing-50yr
- Existing-100yr

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Current (2019) Sea Level
Multiple Storm Surge Events

| | |
|---|---|
| **Drawn: RM** | **Map: 1-B** |
| **Checked: SP** | **CBCL Project #: 181109.00** |
| **Date: 21/06/2019** | **Scale @ 11"x17" 1:1,800** |

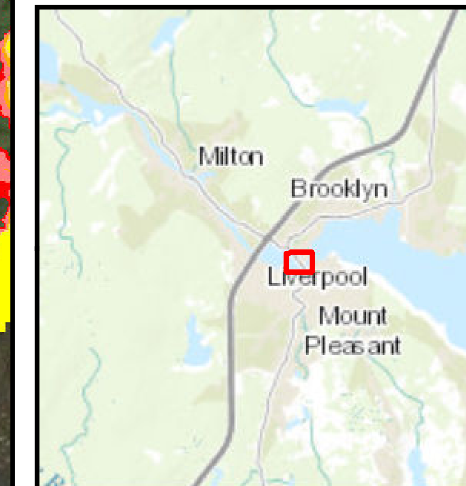
Notes:
- Water levels are based on the still-water elevations and do not take into account tidal amplification.
- Flood lines show all locations below the projected still-water elevations.
- Surface information (LiDAR, 2015) provided by NSCC – Applied Geomatics Resource Group on May 1, 2019

Vertical Datum: CGVD 2013

0 20 40 80 Meters

Coordinate System: NAD 1983 UTM Zone 20N

K:\Projects\181109.00 Liverpool Coastal Flooding Mitigation Study\20 CAD\08 GIS\layout\181109 - MXD18 - LIVERPOOL COASTAL FLOODING MITIGATION STUDY - CURRENT FLOOD MAP (MAP B).mxd


- Building
- Existing-2yr
- Existing-5yr
- Existing-10yr
- Existing-50yr
- Existing-100yr

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Current (2019) Sea Level
Multiple Storm Surge Events

| | |
|---|---|
| **Drawn: RM** | **Map: 1- C** |
| **Checked: SP** | **CBCL Project #: 181109.00** |
| **Date: 21/06/2019** | **Scale @ 11"x17" 1:1,800** |

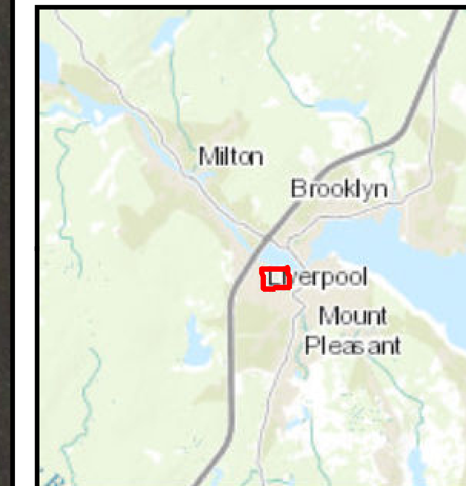
Notes:
- Water levels are based on the still-water elevations and do not take into account tidal amplification.
- Flood lines show all locations below the projected still-water elevations.
- Surface information (LiDAR, 2015) provided by NSCC – Applied Geomatics Resource Group on May 1, 2019

Vertical Datum: CGVD 2013

0 20 40 80 Meters

Coordinate System: NAD 1983 UTM Zone 20N

K:\Projects\181109.00 Liverpool Coastal Flooding Mitigation Study\20 CAD\08 GIS\layout\181109 - MXD18 - LIVERPOOL COASTAL FLOODING MITIGATION STUDY - CURRENT FLOOD MAP (MAP C).mxd


Building
Existing-2yr
Existing-5yr
Existing-10yr
Existing-50yr
Existing-100yr

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Current (2019) Sea Level
Multiple Storm Surge Events

| | |
|---|---|
| **Drawn: RM** | **Map: 1-D** |
| **Checked: SP** | **CBCL Project #: 181109.00** |
| **Date: 21/06/2019** | **Scale @ 11"x17" 1:1,800** |

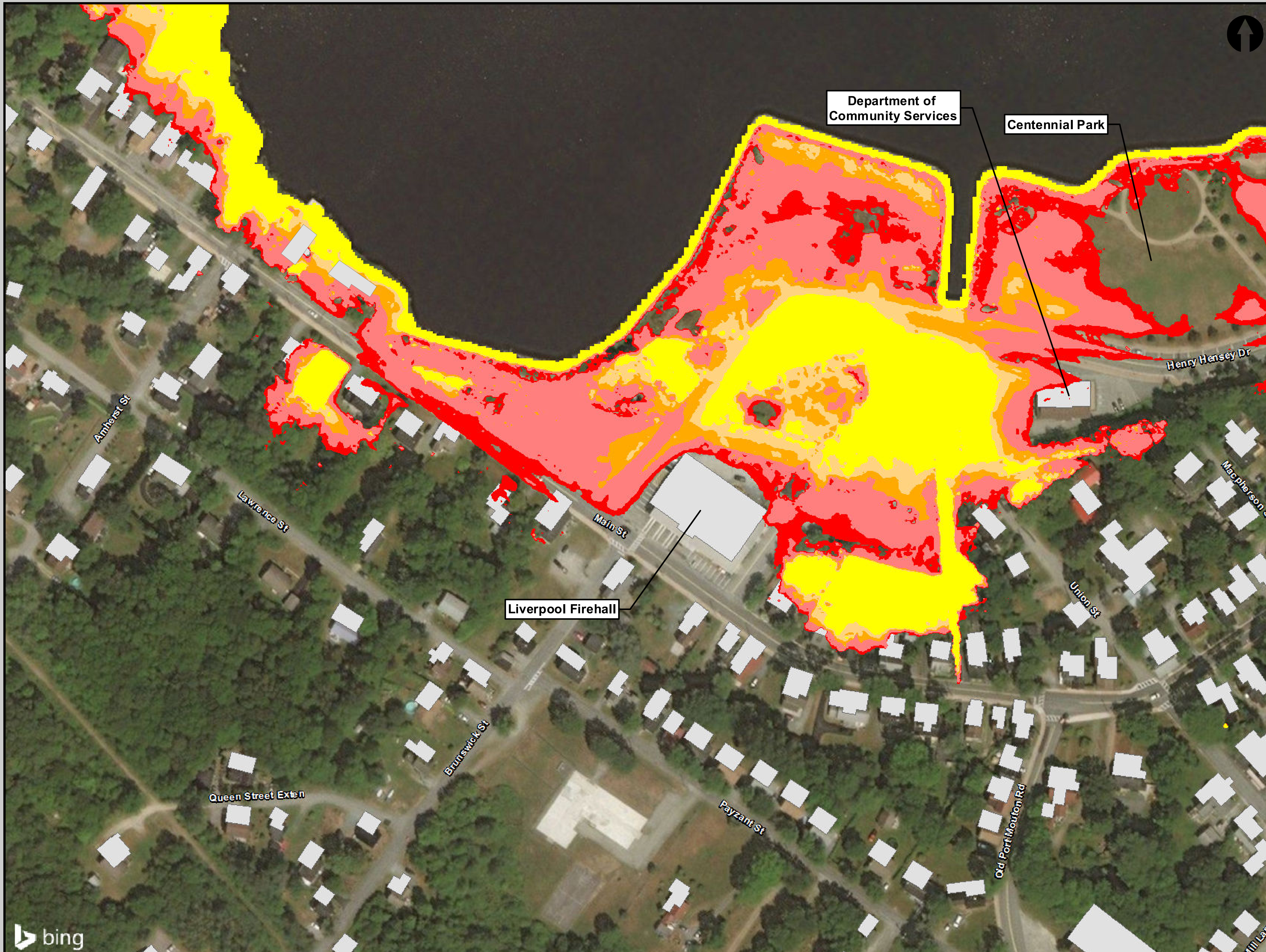
Notes:
- Water levels are based on the still-water elevations and do not take into account tidal amplification.
- Flood lines show all locations below the projected still-water elevations.
- Surface information (LiDAR, 2015) provided by NSCC – Applied Geomatics Resource Group on May 1, 2019

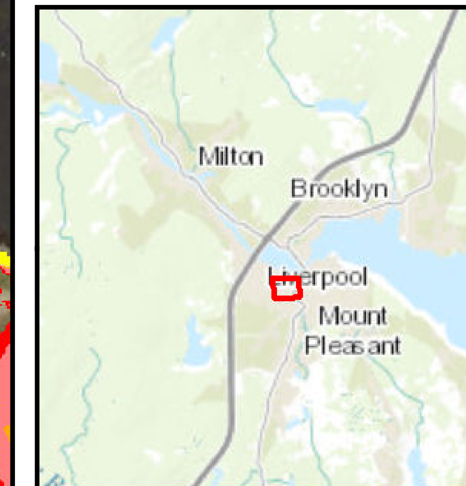
Vertical Datum: CGVD 2013

0 20 40 80 Meters

Coordinate System: NAD 1983 UTM Zone 20N

K:\Projects\181109.00 Liverpool Coastal Flooding Mitigation Study\20 CAD\08 GIS\layout\181109 - MXD18 - LIVERPOOL COASTAL FLOODING MITIGATION STUDY - CURRENT FLOOD MAP (MAP D).mxd




- Building
- Existing-2yr
- Existing-5yr
- Existing-10yr
- Existing-50yr
- Existing-100yr

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**Coastal Flooding Mitigation Study**

Current (2019) Sea Level
Multiple Storm Surge Events

| | |
|---|---|
| **Drawn: RM** | **Map: 1-E** |
| **Checked: SP** | **CBCL Project #: 181109.00** |
| **Date: 21/06/2019** | **Scale @ 11"x17" 1:1,800** |

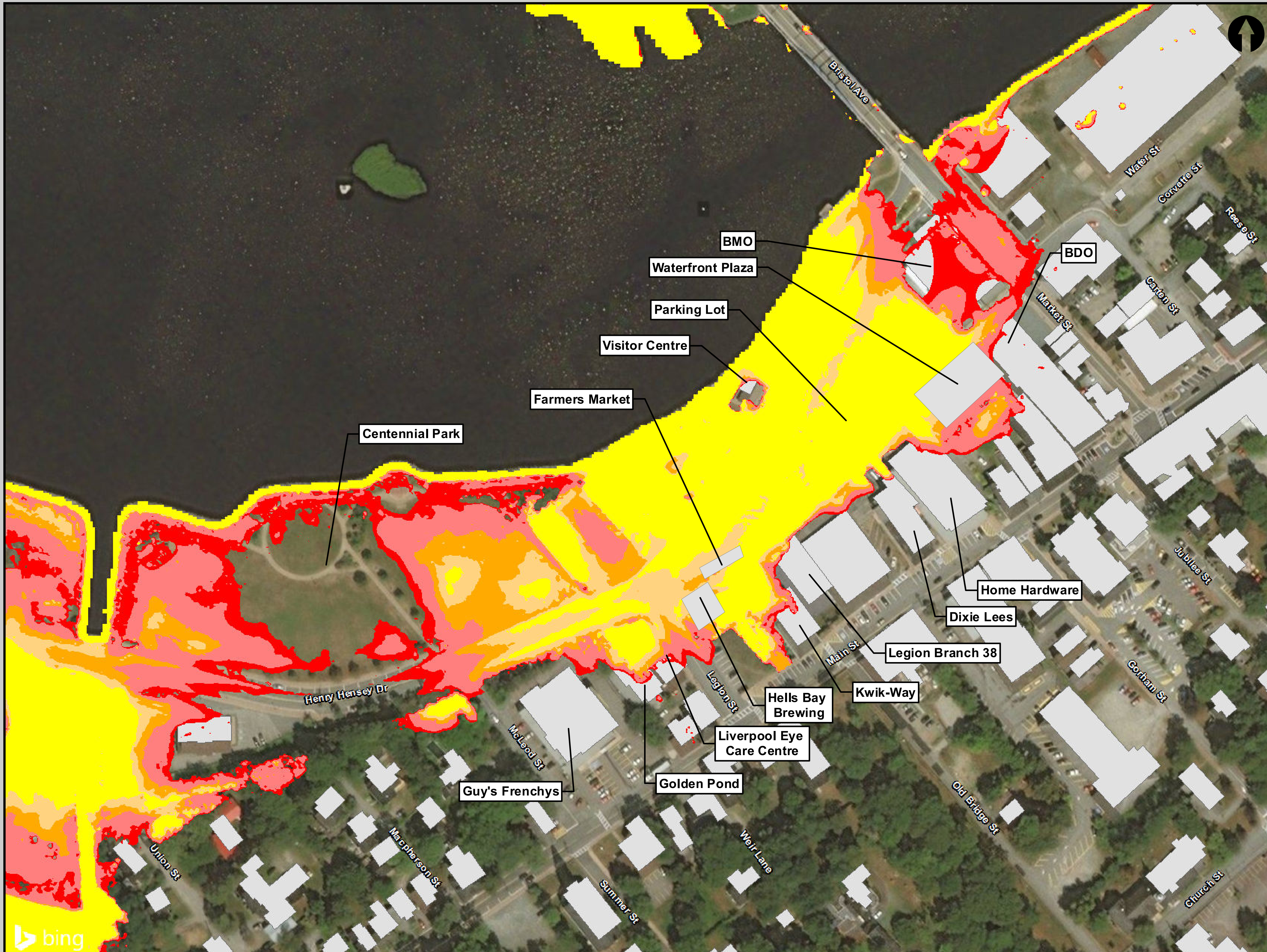
Notes:
- Water levels are based on the still-water elevations and do not take into account tidal amplification.
- Flood lines show all locations below the projected still-water elevations.
- Surface information (LiDAR, 2015) provided by NSCC – Applied Geomatics Resource Group on May 1, 2019

Vertical Datum: CGVD 2013

0 20 40 80 Meters

Coordinate System: NAD 1983 UTM Zone 20N

K:\Projects\181109.00 Liverpool Coastal Flooding Mitigation Study\20 CAD\08 GIS\layout\181109 - MXD18 - LIVERPOOL COASTAL FLOODING MITIGATION STUDY - CURRENT FLOOD MAP (MAP E).mxd





Building
Existing-2yr
Existing-5yr
Existing-10yr
Existing-50yr
Existing-100yr

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Current (2019) Sea Level
Multiple Storm Surge Events

| | |
|---|---|
| **Drawn: RM** | **Map: 1-F** |
| **Checked: SP** | **CBCL Project #: 181109.00** |
| **Date: 21/06/2019** | **Scale @ 11"x17" 1:1,800** |

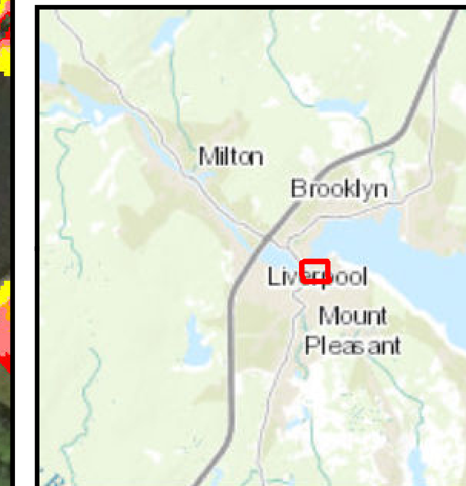
Notes:
- Water levels are based on the still-water elevations and do not take into account tidal amplification.
- Flood lines show all locations below the projected still-water elevations.
- Surface information (LiDAR, 2015) provided by NSCC – Applied Geomatics Resource Group on May 1, 2019

Vertical Datum: CGVD 2013

0 20 40 80 Meters

Coordinate System: NAD 1983 UTM Zone 20N

K:\Projects\181109.00 Liverpool Coastal Flooding Mitigation Study\20 CAD\08 GIS\layout\181109 - MXD18 - LIVERPOOL COASTAL FLOODING MITIGATION STUDY - CURRENT FLOOD MAP (MAP F).mxd


- Building
- Existing-2yr
- Existing-5yr
- Existing-10yr
- Existing-50yr
- Existing-100yr

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Current (2019) Sea Level
Multiple Storm Surge Events

| | |
|---|---|
| Drawn: RM | Map: 1-G |
| Checked: SP | CBCL Project #: 181109.00 |
| Date: 21/06/2019 | Scale @ 11"x17" 1:1,800 |

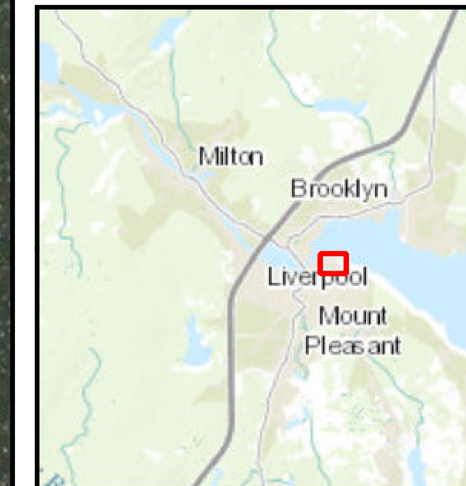
Notes:
- Water levels are based on the still-water elevations and do not take into account tidal amplification.
- Flood lines show all locations below the projected still-water elevations.
- Surface information (LiDAR, 2015) provided by NSCC – Applied Geomatics Resource Group on May 1, 2019

Vertical Datum: CGVD 2013

0 20 40 80 Meters

Coordinate System: NAD 1983 UTM Zone 20N

K:\Projects\181109.00 Liverpool Coastal Flooding Mitigation Study\20 CAD\08 GIS\layout\181109 - MXD18 - LIVERPOOL COASTAL FLOODING MITIGATION STUDY - CURRENT FLOOD MAP (MAP G).mxd


- Building
- Existing-2yr
- Existing-5yr
- Existing-10yr
- Existing-50yr
- Existing-100yr

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Current (2019) Sea Level
Multiple Storm Surge Events

| | |
|---|---|
| Drawn: RM | Map: 1-H |
| Checked: SP | CBCL Project #: 181109.00 |
| Date: 21/06/2019 | Scale @ 11"x17" 1:1,800 |

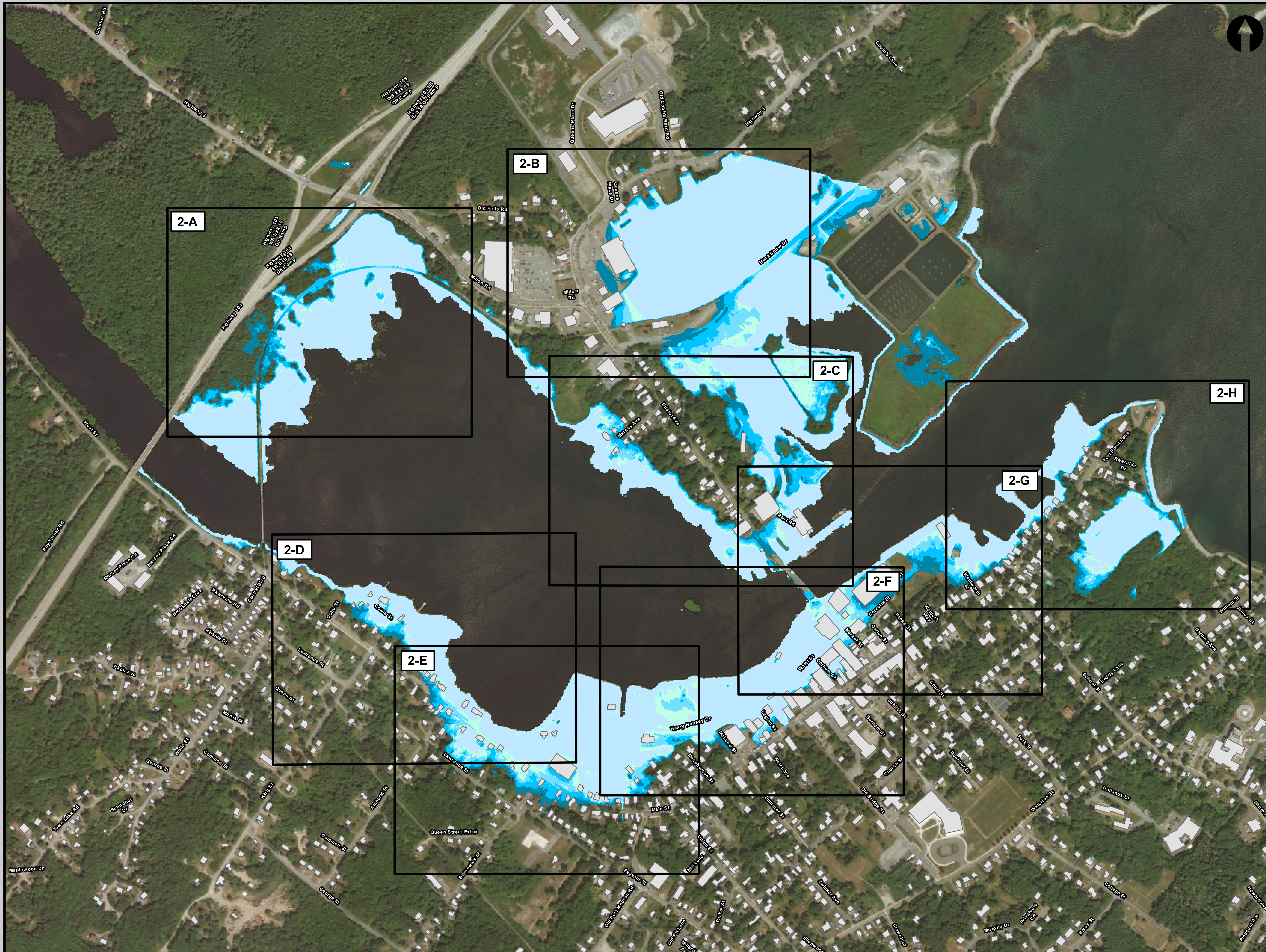
Notes:
- Water levels are based on the still-water elevations and do not take into account tidal amplification.
- Flood lines show all locations below the projected still-water elevations.
- Surface information (LiDAR, 2015) provided by NSCC – Applied Geomatics Resource Group on May 1, 2019

Vertical Datum: CGVD 2013

0 20 40 80 Meters

Coordinate System: NAD 1983 UTM Zone 20N

K:\Projects\181109.00 Liverpool Coastal Flooding Mitigation Study\20 CAD\08 GIS\layout\181109 - MXD18 - LIVERPOOL COASTAL FLOODING MITIGATION STUDY - CURRENT FLOOD MAP (MAP H).mxd





Map Extents
Building
2020-100yr
2040-100yr
2060-100yr
2080-100yr
2100-100yr

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**Coastal Flooding Mitigation Study**

Future Sea Level Rise
100-year Storm Surge Events

| | |
|---|---|
| Drawn: RM | Map: 2 |
| Checked: SP | CBCL Project #: 181109.00 |
| Date: 21/06/2019 | Scale @ 11"x17" 1:7,510 |

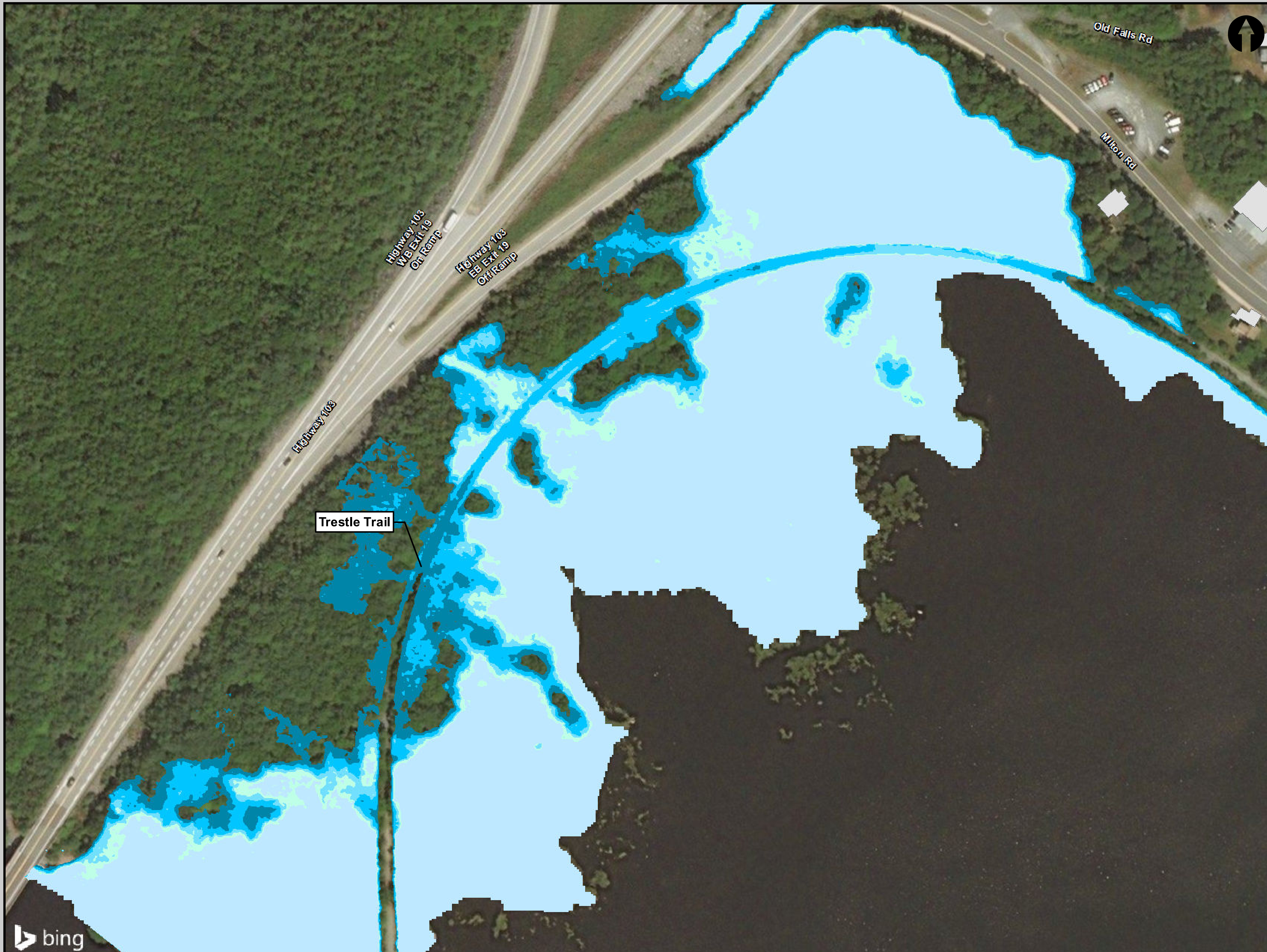
Notes:
- Water levels are based on the still-water elevations and do not take into account tidal amplification.
- Flood lines show all locations below the projected still-water elevations.
- Surface information (LiDAR, 2015) provided by NSCC – Applied Geomatics Resource Group on May 1, 2019

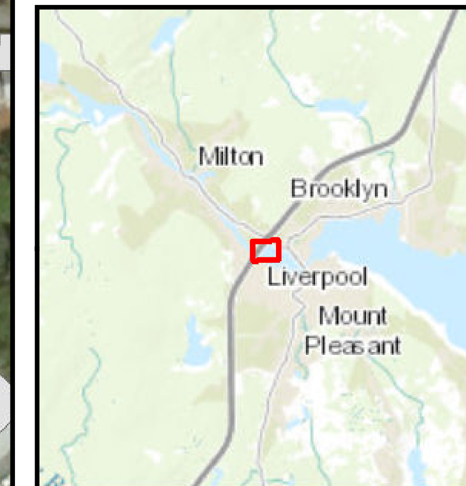
Vertical Datum: CGVD 2013

0 0.1 0.2 0.4 Km

Coordinate System: NAD 1983 UTM Zone 20N

K:\Projects\181109.00 Liverpool Coastal Flooding Mitigation Study\20 CAD\08 GIS\layout\181109 - MXD19 - LIVERPOOL COASTAL FLOODING MITIGATION STUDY - FUTURE FLOOD MAP.mxd




- Building
- 2020-100yr
- 2040-100yr
- 2060-100yr
- 2080-100yr
- 2100-100yr

CBCL LIMITED
Consulting Engineers

**Town of Liverpool**
**Coastal Flooding Mitigation Study**

Future Sea Level Rise
100-year Storm Surge Events

| | |
|---|---|
| **Drawn: RM** | **Map: 2-A** |
| **Checked: SP** | **CBCL Project #: 181109.00** |
| **Date: 21/06/2019** | **Scale @ 11"x17" 1:1,800** |

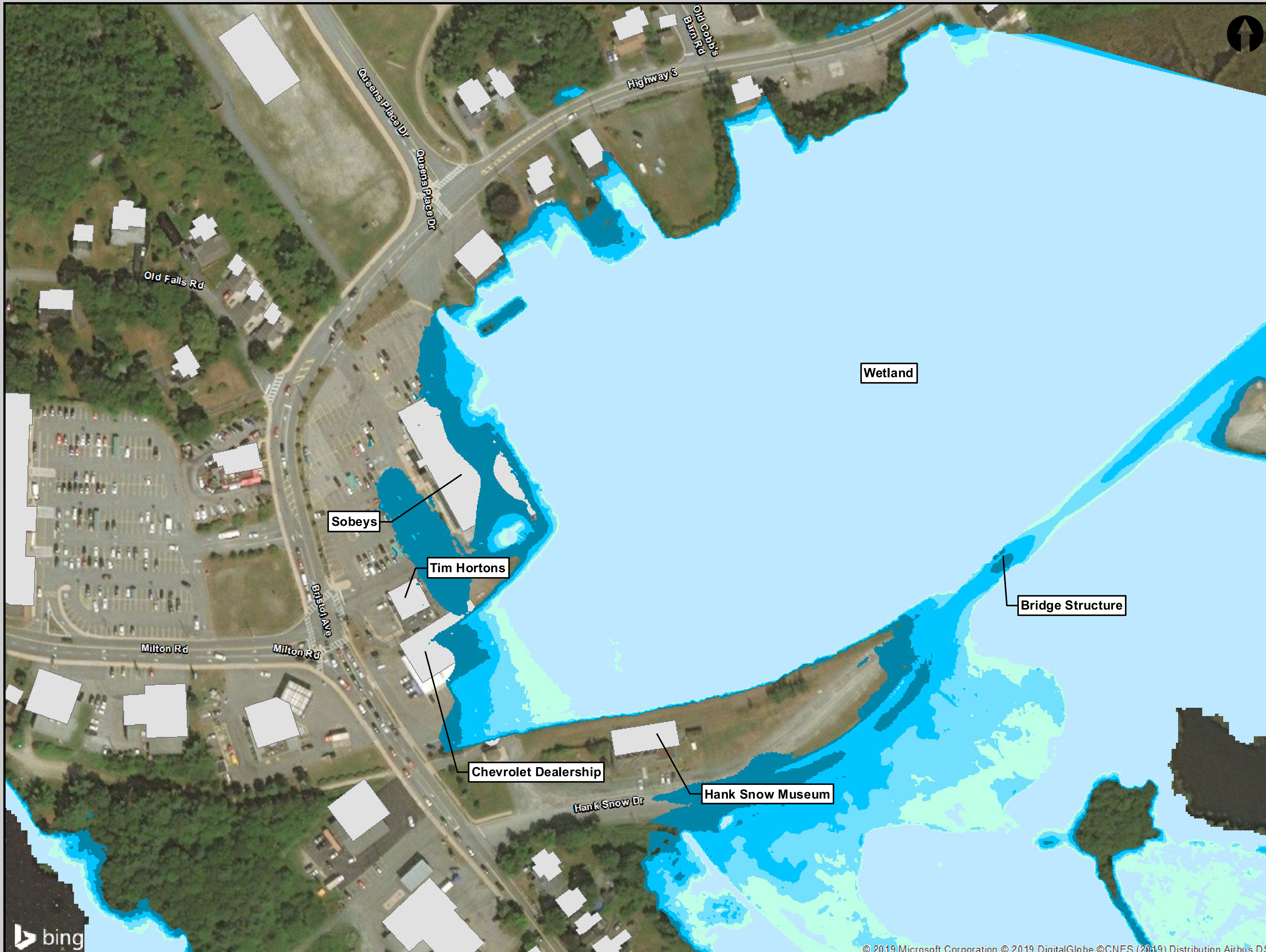
Notes:
- Water levels are based on the still-water elevations and do not take into account tidal amplification.
- Flood lines show all locations below the projected still-water elevations.
- Surface information (LiDAR, 2015) provided by NSCC – Applied Geomatics Resource Group on May 1, 2019

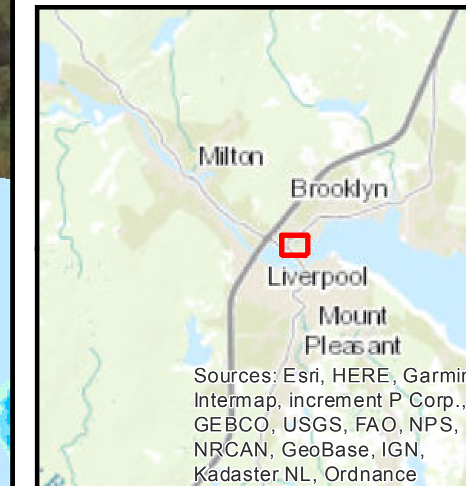
Vertical Datum: CGVD 2013

0 20 40 80 Meters

Coordinate System: NAD 1983 UTM Zone 20N

K:\Projects\181109.00 Liverpool Coastal Flooding Mitigation Study\20 CAD\08 GIS\layout\181109 - MXD19 - LIVERPOOL COASTAL FLOODING MITIGATION STUDY - FUTURE FLOOD MAP (MAP A).mxd




- Building
- 2020-100yr
- 2040-100yr
- 2060-100yr
- 2080-100yr
- 2100-100yr

CBCL LIMITED
Consulting Engineers

**Town of Liverpool**
**Coastal Flooding Mitigation Study**

Future Sea Level Rise
100-year Storm Surge Events

| | |
|---|---|
| **Drawn: RM** | **Map: 2-B** |
| **Checked: SP** | **CBCL Project #: 181109.00** |
| **Date: 21/06/2019** | **Scale @ 11"x17" 1:1,800** |

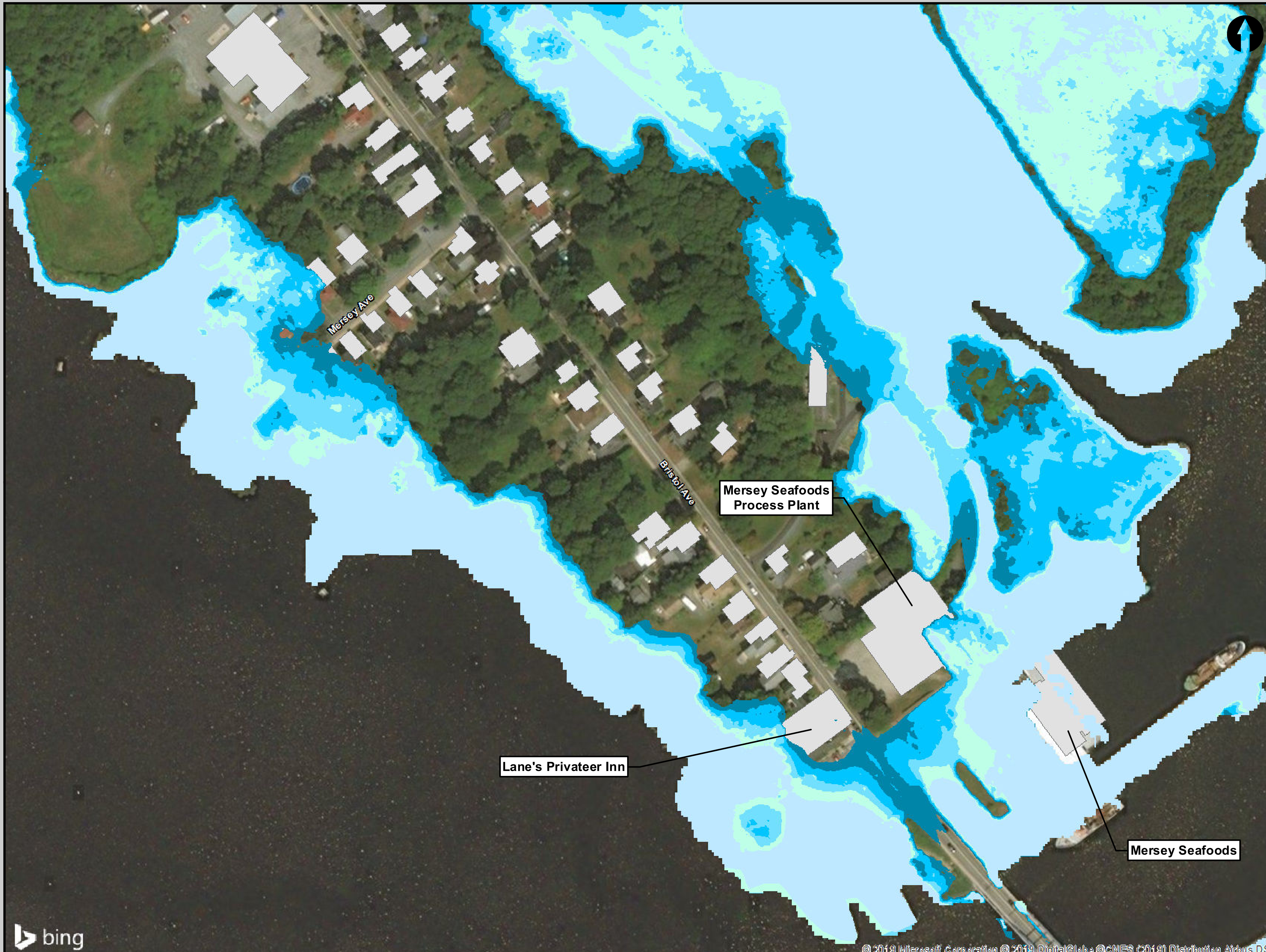
Notes:
- Water levels are based on the still-water elevations and do not take into account tidal amplification.
- Flood lines show all locations below the projected still-water elevations.
- Surface information (LiDAR, 2015) provided by NSCC – Applied Geomatics Resource Group on May 1, 2019

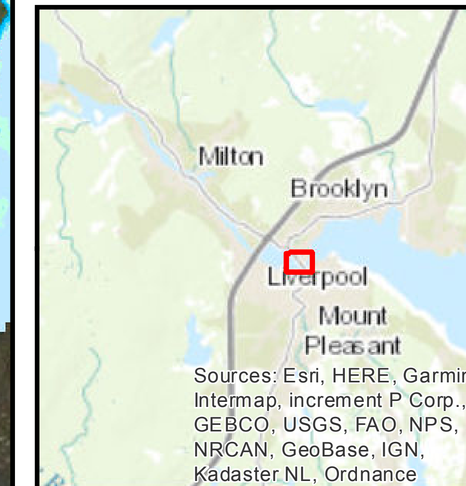
Vertical Datum: CGVD 2013

0 20 40 80 Meters

Coordinate System: NAD 1983 UTM Zone 20N

K:\Projects\181109.00 Liverpool Coastal Flooding Mitigation Study\20 CAD\08 GIS\layout\181109 - MXD19 - LIVERPOOL COASTAL FLOODING MITIGATION STUDY - FUTURE FLOOD MAP (MAP B).mxd




- Building
- 2020-100yr
- 2040-100yr
- 2060-100yr
- 2080-100yr
- 2100-100yr

CBCL LIMITED
Consulting Engineers

**Town of Liverpool**
**Coastal Flooding Mitigation Study**

Future Sea Level Rise
100-year Storm Surge Events

| | |
|---|---|
| **Drawn: RM** | **Map: 2- C** |
| **Checked: SP** | **CBCL Project #: 181109.00** |
| **Date: 21/06/2019** | **Scale @ 11"x17" 1:1,800** |

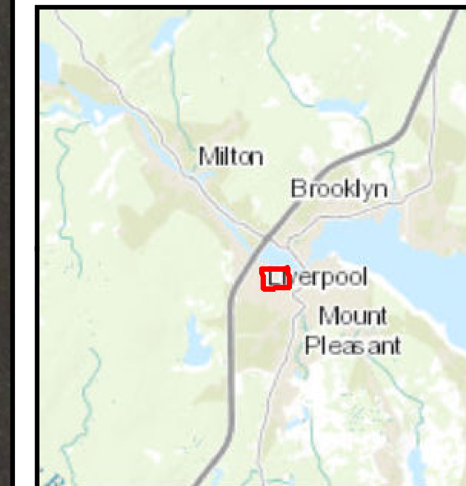
Notes:
- Water levels are based on the still-water elevations and do not take into account tidal amplification.
- Flood lines show all locations below the projected still-water elevations.
- Surface information (LiDAR, 2015) provided by NSCC – Applied Geomatics Resource Group on May 1, 2019

Vertical Datum: CGVD 2013

0 20 40 80 Meters

Coordinate System: NAD 1983 UTM Zone 20N

K:\Projects\181109.00 Liverpool Coastal Flooding Mitigation Study\20 CAD\08 GIS\layout\181109 - MXD19 - LIVERPOOL COASTAL FLOODING MITIGATION STUDY - FUTURE FLOOD MAP (MAP C).mxd


Building
2020-100yr
2040-100yr
2060-100yr
2080-100yr
2100-100yr

CBCL LIMITED
Consulting Engineers

**Town of Liverpool**
**Coastal Flooding Mitigation Study**

Future Sea Level Rise
100-year Storm Surge Events

| | |
|---|---|
| **Drawn: RM** | **Map: 2-D** |
| **Checked: SP** | **CBCL Project #: 181109.00** |
| **Date: 21/06/2019** | **Scale @ 11"x17" 1:1,800** |

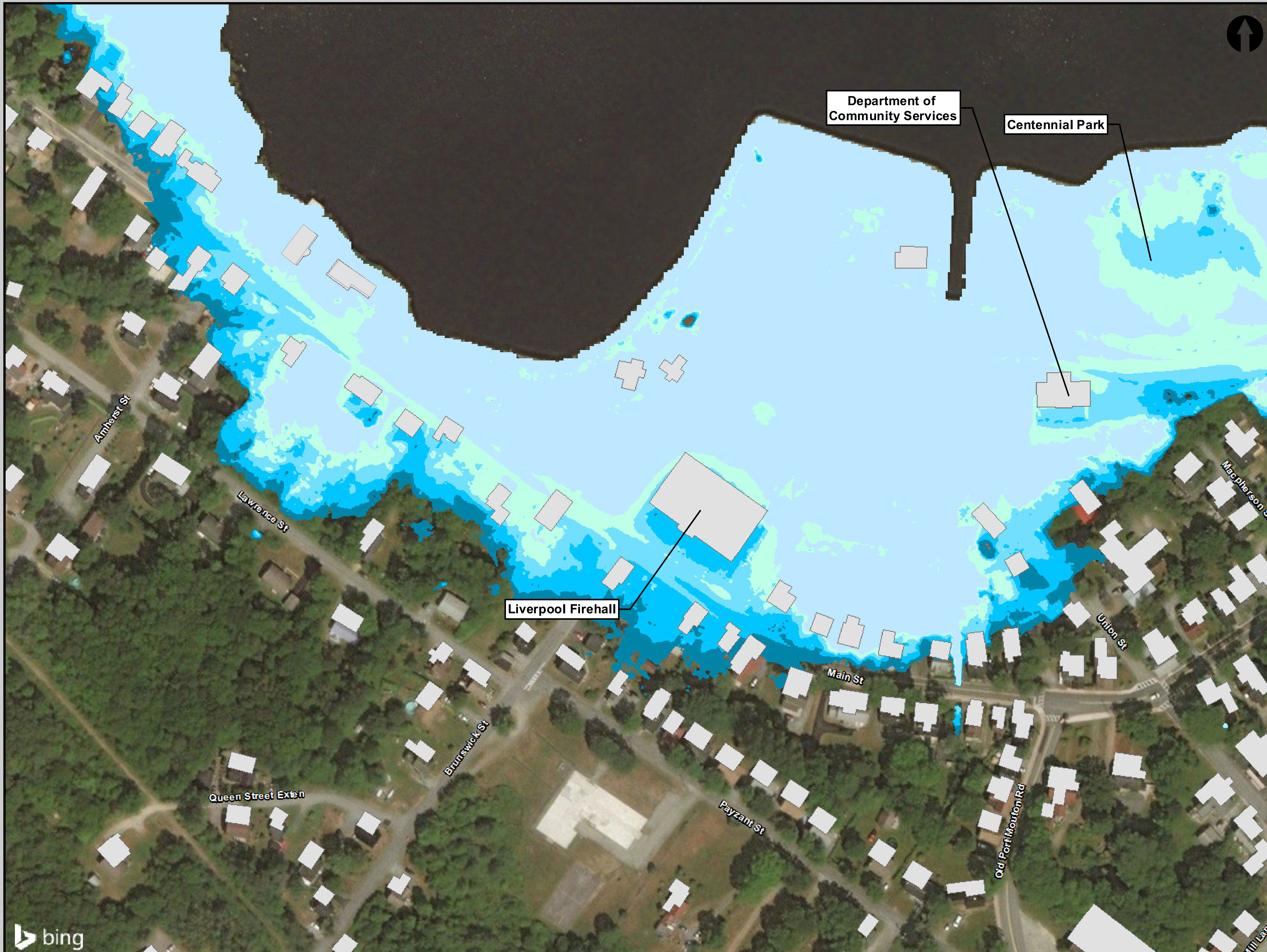
Notes:
- Water levels are based on the still-water elevations and do not take into account tidal amplification.
- Flood lines show all locations below the projected still-water elevations.
- Surface information (LiDAR, 2015) provided by NSCC – Applied Geomatics Resource Group on May 1, 2019

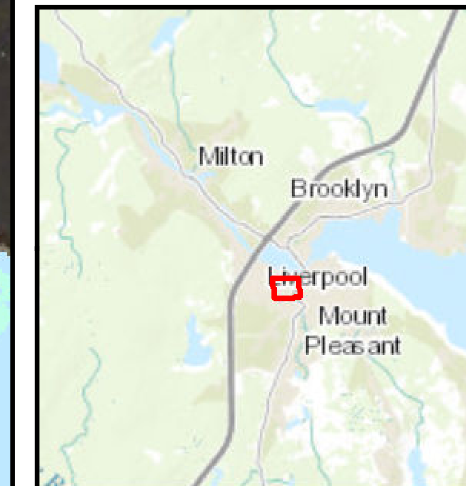
Vertical Datum: CGVD 2013

0 20 40 80 Meters

Coordinate System: NAD 1983 UTM Zone 20N

K:\Projects\181109.00 Liverpool Coastal Flooding Mitigation Study\20 CAD\08 GIS\layout\181109 - MXD19 - LIVERPOOL COASTAL FLOODING MITIGATION STUDY - FUTURE FLOOD MAP (MAP D).mxd




Building
2020-100yr
2040-100yr
2060-100yr
2080-100yr
2100-100yr

CBCL LIMITED
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**Town of Liverpool**
**Coastal Flooding Mitigation Study**

Future Sea Level Rise
100-year Storm Surge Events

| | |
|---|---|
| Drawn: RM | Map: 2-E |
| Checked: SP | CBCL Project #: 181109.00 |
| Date: 21/06/2019 | Scale @ 11"x17" 1:1,800 |

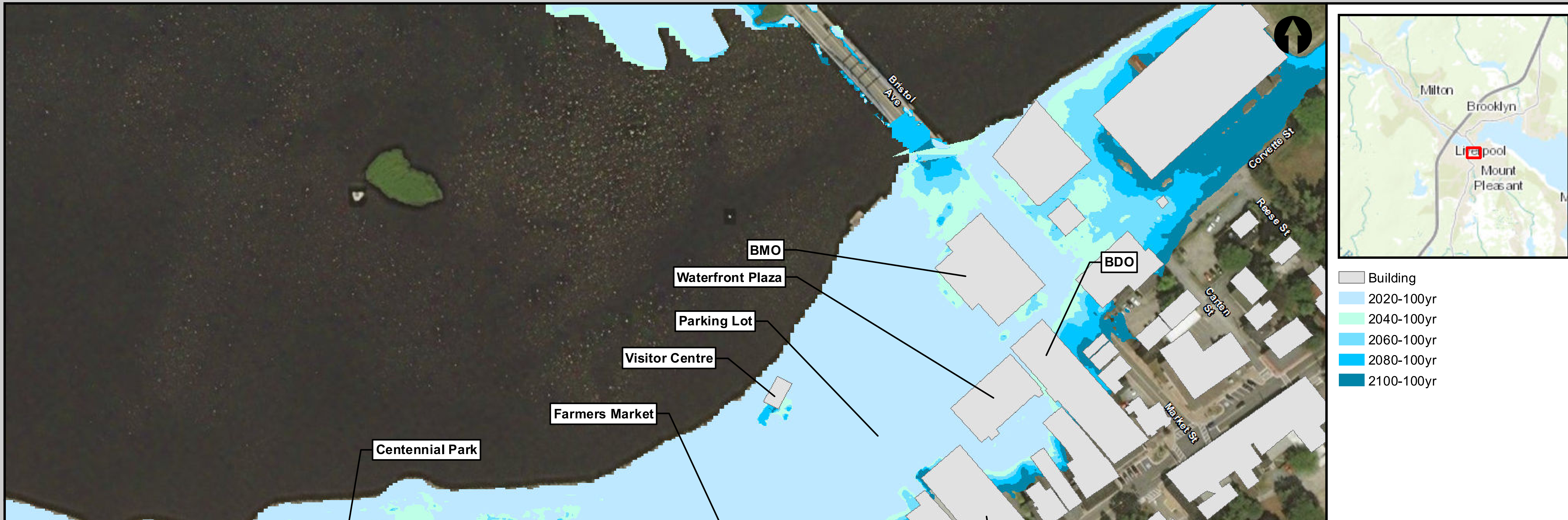
Notes:
- Water levels are based on the still-water elevations and do not take into account tidal amplification.
- Flood lines show all locations below the projected still-water elevations.
- Surface information (LiDAR, 2015) provided by NSCC – Applied Geomatics Resource Group on May 1, 2019

Vertical Datum: CGVD 2013

0 20 40 80 Meters

Coordinate System: NAD 1983 UTM Zone 20N

K:\Projects\181109.00 Liverpool Coastal Flooding Mitigation Study\20 CAD\08 GIS\layout\181109 - MXD19 - LIVERPOOL COASTAL FLOODING MITIGATION STUDY - FUTURE FLOOD MAP (MAP E).mxd




CBCL LIMITED
Consulting Engineers

**Town of Liverpool**
**Coastal Flooding Mitigation Study**

Future Sea Level Rise
100-year Storm Surge Events

| | |
|---|---|
| **Drawn: RM** | **Map: 2-F** |
| **Checked: SP** | **CBCL Project #: 181109.00** |
| **Date: 21/06/2019** | **Scale @ 11"x17" 1:1,800** |

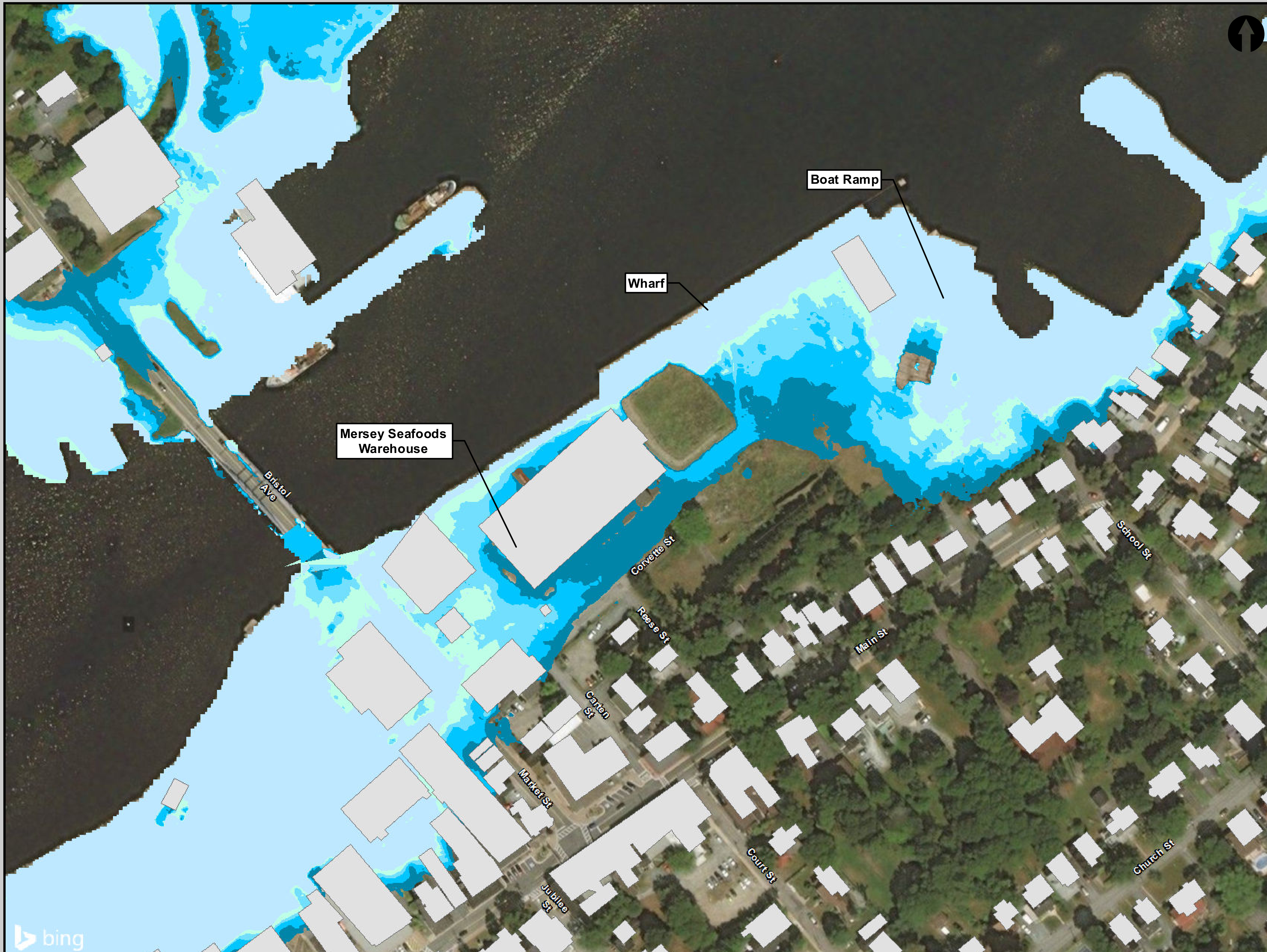
Notes:
- Water levels are based on the still-water elevations and do not take into account tidal amplification.
- Flood lines show all locations below the projected still-water elevations.
- Surface information (LiDAR, 2015) provided by NSCC – Applied Geomatics Resource Group on May 1, 2019

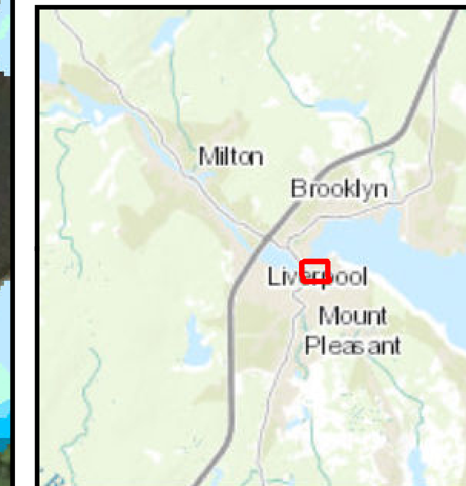
Vertical Datum: CGVD 2013

0 20 40 80 Meters

Coordinate System: NAD 1983 UTM Zone 20N

K:\Projects\181109.00 Liverpool Coastal Flooding Mitigation Study\20 CAD\08 GIS\layout\181109 - MXD19 - LIVERPOOL COASTAL FLOODING MITIGATION STUDY - FUTURE FLOOD MAP (MAP F).mxd




- Building
- 2020-100yr
- 2040-100yr
- 2060-100yr
- 2080-100yr
- 2100-100yr

CBCL LIMITED
Consulting Engineers

**Town of Liverpool**
**Coastal Flooding Mitigation Study**

Future Sea Level Rise
100-year Storm Surge Events

| | |
|---|---|
| Drawn: RM | Map: 2-G |
| Checked: SP | CBCL Project #: 181109.00 |
| Date: 21/06/2019 | Scale @ 11"x17" 1:1,800 |

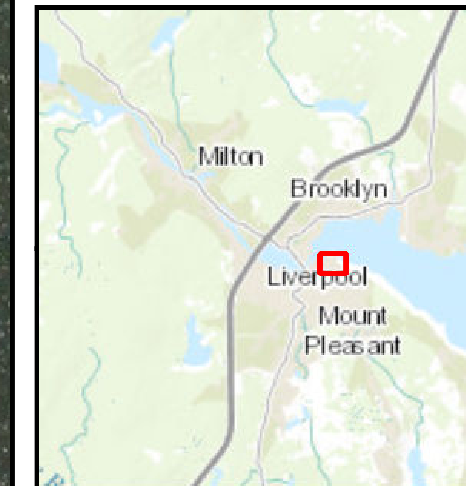
Notes:
- Water levels are based on the still-water elevations and do not take into account tidal amplification.
- Flood lines show all locations below the projected still-water elevations.
- Surface information (LiDAR, 2015) provided by NSCC – Applied Geomatics Resource Group on May 1, 2019

Vertical Datum: CGVD 2013

0 20 40 80 Meters

Coordinate System: NAD 1983 UTM Zone 20N

K:\Projects\181109.00 Liverpool Coastal Flooding Mitigation Study\20 CAD\08 GIS\layout\181109 - MXD19 - LIVERPOOL COASTAL FLOODING MITIGATION STUDY - FUTURE FLOOD MAP (MAP G).mxd


- Building
- 2020-100yr
- 2040-100yr
- 2060-100yr
- 2080-100yr
- 2100-100yr

CBCL LIMITED
Consulting Engineers

**Town of Liverpool**
**Coastal Flooding Mitigation Study**

Future Sea Level Rise
100-year Storm Surge Events

| | |
|---|---|
| Drawn: RM | Map: 2-H |
| Checked: SP | CBCL Project #: 181109.00 |
| Date: 21/06/2019 | Scale @ 11"x17" 1:1,800 |

Notes:
- Water levels are based on the still-water elevations and do not take into account tidal amplification.
- Flood lines show all locations below the projected still-water elevations.
- Surface information (LiDAR, 2015) provided by NSCC – Applied Geomatics Resource Group on May 1, 2019

Vertical Datum: CGVD 2013

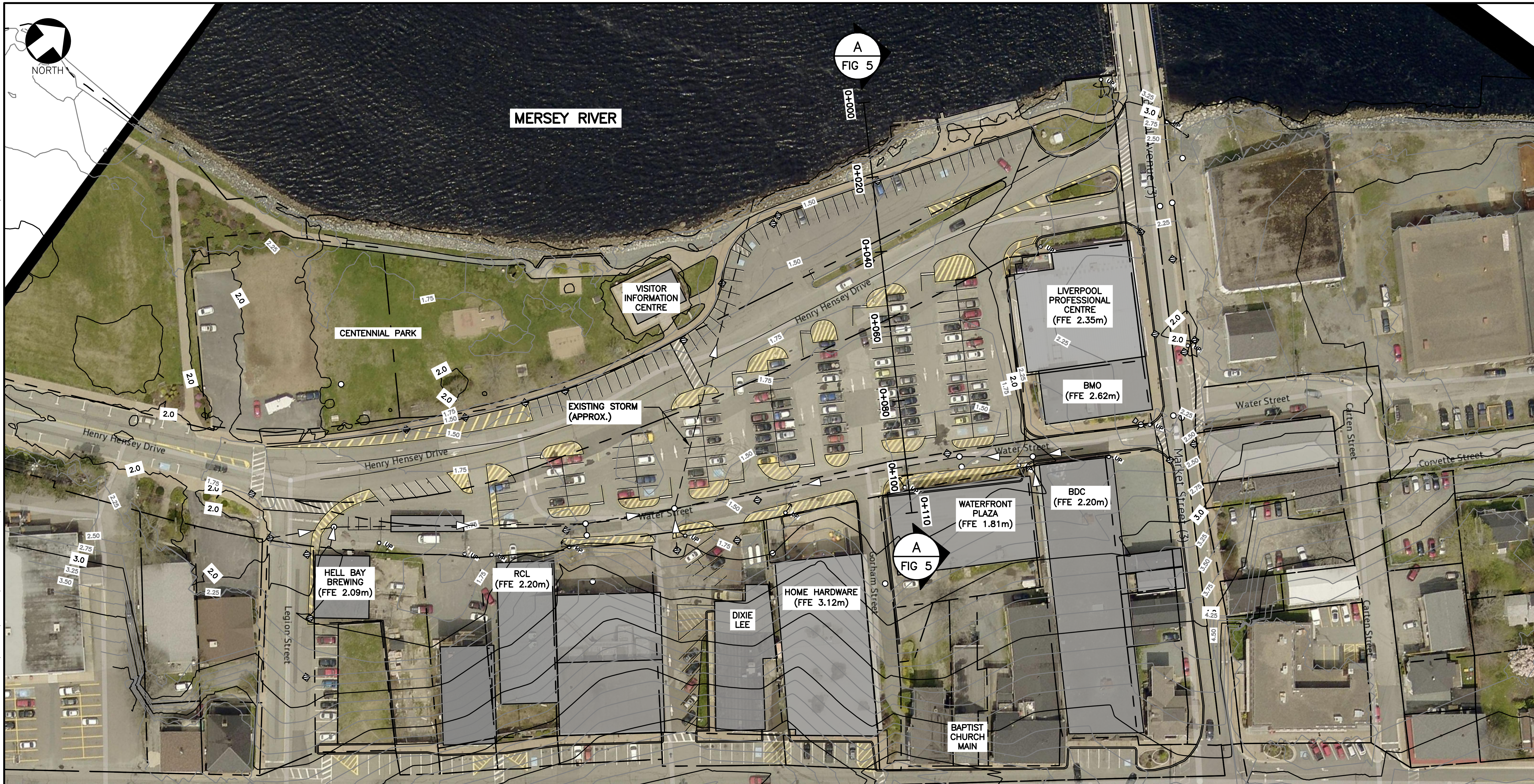
0 20 40 80 Meters

Coordinate System: NAD 1983 UTM Zone 20N

K:\Projects\181109.00 Liverpool Coastal Flooding Mitigation Study\20 CAD\08 GIS\layout\181109 - MXD19 - LIVERPOOL COASTAL FLOODING MITIGATION STUDY - FUTURE FLOOD MAP (MAP H).mxd

# APPENDIX B – Downtown Liverpool Concept Plans

DRAWING NAME: K:\PROJECTS\181109.00 LIVERPOOL COASTAL FLOODING MITIGATION STUDY\20 CAD\01 CIVIL\04 DRAWING SHEETS\181109.00 -SITE PLAN-FIG 1-SHEET.DWG LAYOUT NAME: FIG 1 PLOT DATE:February 7, 2019 12:21:53 PM CAD OPERATOR: CMMOLOKE




## LEGEND

| | | | |
|---|---|---|---|
| — — — | PROPERTY LINE (EX.) | ——20.0—— | MAJOR CONTOUR (EX.) |
| - - - ▷ | STORM SEWER (EX.) | ——20.0—— | MAJOR CONTOUR (PR.) |
| ▨ | STORM CATCHBASIN (EX.) | ——19.0—— | MINOR CONTOUR (EX.) |
| ○ | STORM MH (EX.) | ——19.0—— | MINOR CONTOUR (PR.) |
| ○—UP→ | UTILITY POLE (EX.) | × 19.00 | SPOT ELEVATION (PR.) |
| ╥╥╥╥ | TOP OF SLOPE (PR.) | | |
| – – – – | BOTTOM OF SLOPE (EX.) | | |
| — — — | BOTTOM OF SLOPE (PR.) | | |

## PLAN
1:1000

| No. | Description |
|---|---|
| | |

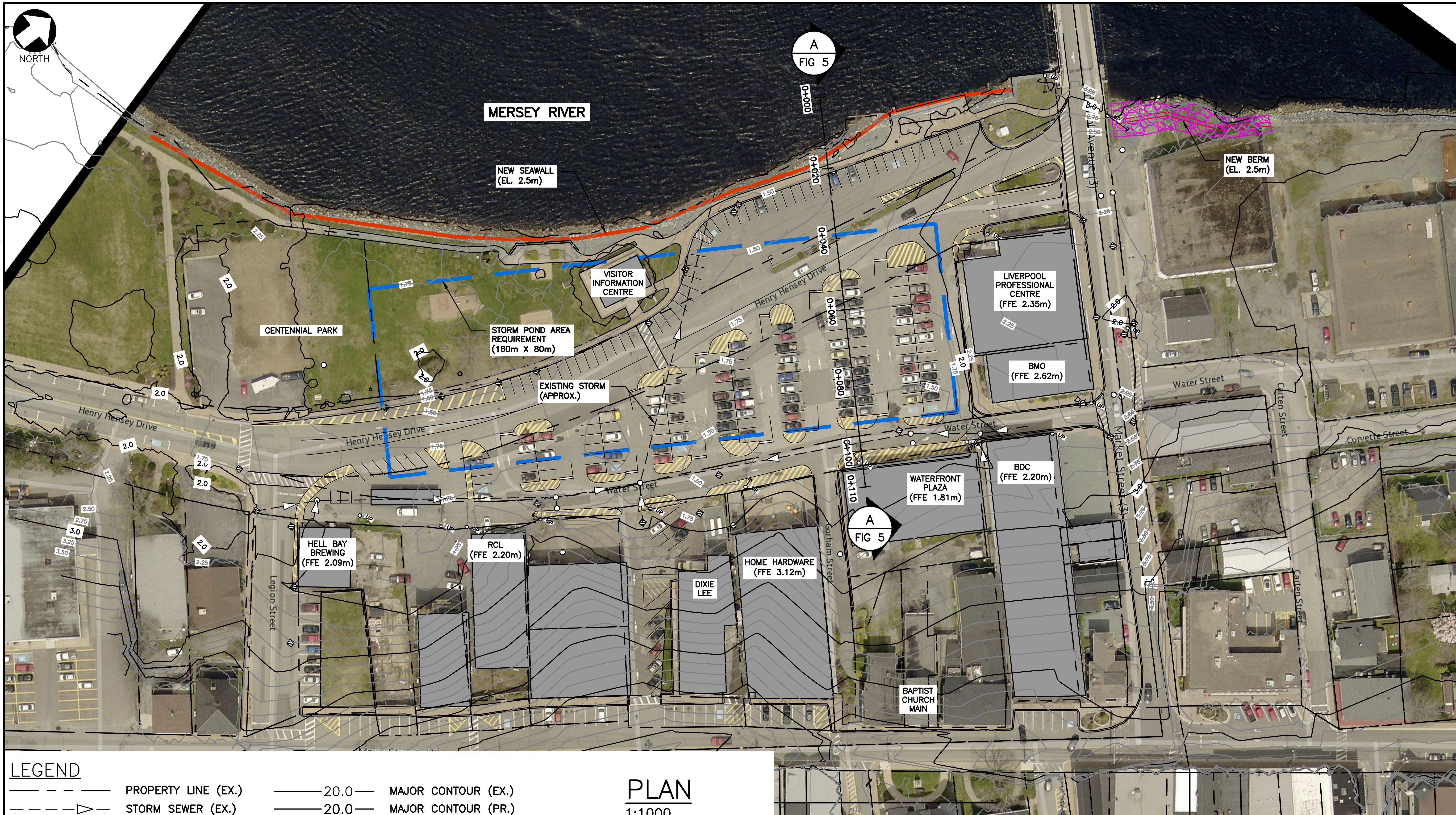
| Date | Scale | Designed | Drawn | Checked | Approved | CBCL No. | Contract |
|---|---|---|---|---|---|---|---|
| FEB 7/2019 | AS NOTED | SP | RM | CF | ---- | 181109.00 | |

CBCL LIMITED Consulting Engineers

LIVERPOOL FLOOD MITIGATION STUDY

EXISTING CONDITIONS

Drawing
# FIG 1




LEGEND

| | | | |
|---|---|---|---|
| | PROPERTY LINE (EX.) | 20.0 | MAJOR CONTOUR (EX.) |
| | STORM SEWER (EX.) | 20.0 | MAJOR CONTOUR (PR.) |
| | STORM CATCHBASIN (EX.) | 19.0 | MINOR CONTOUR (EX.) |
| | STORM MH (EX.) | 19.0 | MINOR CONTOUR (PR.) |
| UP | UTILITY POLE (EX.) | × 19.00 | SPOT ELEVATION (PR.) |
| | TOP OF SLOPE (PR.) | | |
| | BOTTOM OF SLOPE (EX.) | | |
| | BOTTOM OF SLOPE (PR.) | | |

PLAN
1:1000

| No. | Description |
|---|---|
| | |

| Date | Scale | Designed | Drawn | Checked | Approved | CBCL No. | Contract |
|---|---|---|---|---|---|---|---|
| FEB 7/2019 | AS NOTED | SP | RM | CF | | 181109.00 | |

CBCL LIMITED
Consulting Engineers

LIVERPOOL FLOOD MITIGATION STUDY

CONCEPT #1 – SEAWALL

Drawing
FIG 2

DRAWING NAME: K:\PROJECTS\181109.00 LIVERPOOL COASTAL FLOODING MITIGATION STUDY\20 CAD\01 CIVIL\04 DRAWING SHEETS\181109.00 –SITE PLAN–FIG 2–SHEET.DWG LAYOUT NAME: CONCEPT #1 – SEAWALL PLOT DATE: February 7, 2019 12:22:50 PM CAD OPERATOR:

DRAWING NAME: K:\PROJECTS\181109.00 LIVERPOOL COASTAL FLOODING MITIGATION STUDY\20 CAD\01 CIVIL\04 DRAWING SHEETS\181109.00 -SITE PLAN-FIG 3-SHEET.DWG LAYOUT NAME: CONCEPT #2 – RAISING PARKING LOT PLOT DATE: February 7, 2019 12:23:32 PM


## LEGEND

| | |
|---|---|
| PROPERTY LINE (EX.) | 20.0 MAJOR CONTOUR (EX.) |
| STORM SEWER (EX.) | 20.0 MAJOR CONTOUR (PR.) |
| STORM CATCHBASIN (EX.) | 19.0 MINOR CONTOUR (EX.) |
| STORM MH (EX.) | 19.0 MINOR CONTOUR (PR.) |
| UP UTILITY POLE (EX.) | × 19.00 SPOT ELEVATION (PR.) |
| TOP OF SLOPE (PR.) | |
| BOTTOM OF SLOPE (EX.) | |
| BOTTOM OF SLOPE (PR.) | |

## PLAN

1:1000

| No. | Description |
|---|---|

| Date | Scale | Designed | Drawn | Checked | Approved | CBCL No. | Contract |
|---|---|---|---|---|---|---|---|
| FEB 7/2019 | AS NOTED | SP | RM | CF | | 181109.00 | |

CBCL LIMITED Consulting Engineers

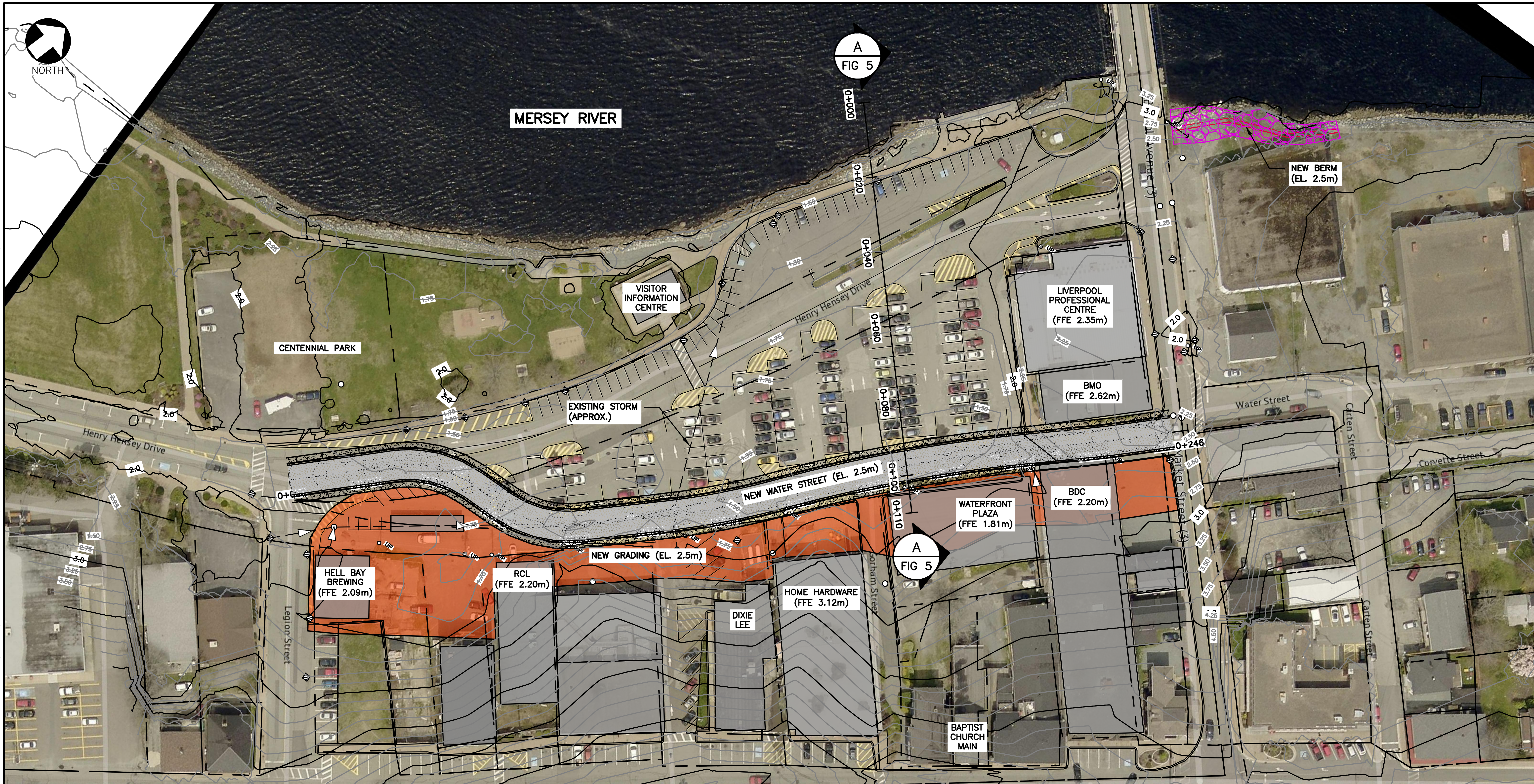
LIVERPOOL FLOOD MITIGATION STUDY

CONCEPT #2 – RAISING PARKING LOT

Drawing

# FIG 3

DRAWING NAME: K:\PROJECTS\181109.00 LIVERPOOL COASTAL FLOODING MITIGATION STUDY\20 CAD\01 CIVIL\04 DRAWING SHEETS\181109.00 -SITE PLAN-FIG 4-SHEET.DWG LAYOUT NAME: CONCEPT #3 - RAISING WATER STREET PLOT DATE: February 7, 2019 12:24:10 PM




## LEGEND

| | |
|---|---|
| — — — — | PROPERTY LINE (EX.) |
| — — — ▷ — | STORM SEWER (EX.) |
| ▨ | STORM CATCHBASIN (EX.) |
| ○ | STORM MH (EX.) |
| ○— UP → | UTILITY POLE (EX.) |
| ┬┬┬┬┬┬ | TOP OF SLOPE (PR.) |
| — — — — | BOTTOM OF SLOPE (EX.) |
| — — — — | BOTTOM OF SLOPE (PR.) |
| —20.0— | MAJOR CONTOUR (EX.) |
| —20.0— | MAJOR CONTOUR (PR.) |
| —19.0— | MINOR CONTOUR (EX.) |
| —19.0— | MINOR CONTOUR (PR.) |
| × 19.00 | SPOT ELEVATION (PR.) |

## PLAN
1:1000

| No. | Description |
|---|---|

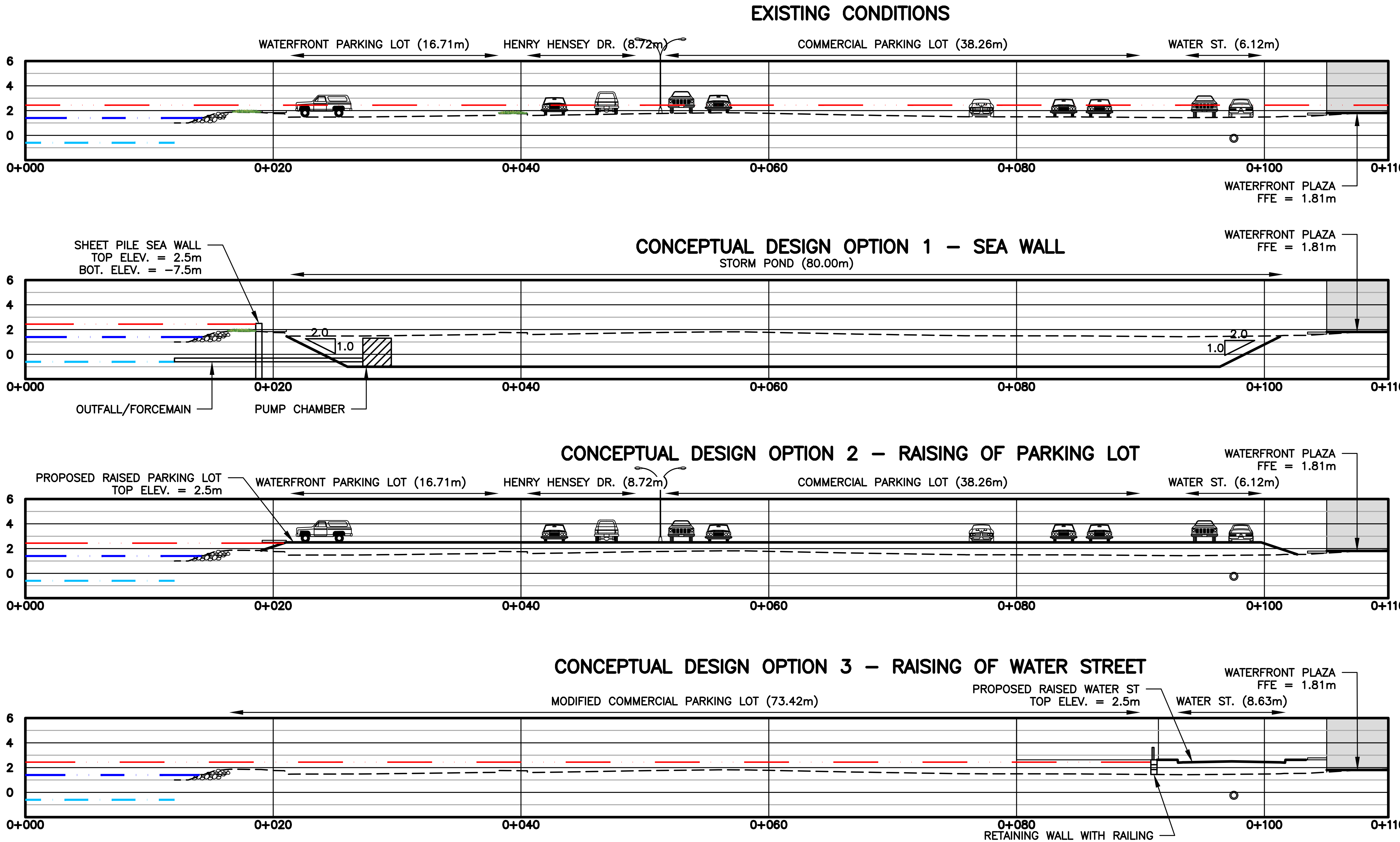
| Date | Scale | Designed | Drawn | Checked | Approved | CBCL No. | Contract |
|---|---|---|---|---|---|---|---|
| FEB 7/2019 | AS NOTED | SP | RM | CF | | 181109.00 | |

CBCL LIMITED
Consulting Engineers

LIVERPOOL FLOOD MITIGATION STUDY

CONCEPT #3 – RAISING WATER STREET

Drawing
# FIG 4




# CROSS SECTIONS

1:300

STORM PIPE

DESIGN LINE (2.44m)

HHWLT LINE (1.40m)

LLWLT LINE (-0.60m)

| No. | Description |
|---|---|
| | |

| Date | Scale | Designed | Drawn | Checked | Approved | CBCL No. | Contract |
|---|---|---|---|---|---|---|---|
| FEB 7/2019 | AS NOTED | SP | RM | CF | | 181109.00 | |

CBCL LIMITED
Consulting Engineers

LIVERPOOL FLOOD MITIGATION STUDY

CROSS SECTIONS

Drawing

**FIG 5**

DRAWING NAME: K:\PROJECTS\181109.00 LIVERPOOL COASTAL FLOODING MITIGATION STUDY\20 CAD\01 CIVIL\04 DRAWING SHEETS\181109.00 -CROSS SECTIONS-SHEET.DWG LAYOUT NAME: CROSS SECTIONS PLOT DATE: February-07-19 8:40:39 AM CAD OPERATOR: RMAYER

# APPENDIX C – Downtown Liverpool Concept Options Cost Estimates

CBCL LIMITED
Consulting Engineers

# OPINION OF PROBABLE CONSTRUCTION COST

## Town of Liverpool Flood Mitigation Improvements Study

## Option #1 - Seawall



| | |
|---|---|
| DATE: | February 5, 2019 |
| CBCL FILE No.: | 181109.00 |
| PREPARED BY: | SP/CM/CF/AT |
| EST. DESCRIPTION : | Class D |

| Item No. | Description | Unit | Est. Qty | Unit Price | Amount |
|---|---|---|---|---|---|
| 1 | Insurance, Bonds, Equipment, Pre-Construction Management | LS | 1 | $ 150,000 | $150,000 |
| 2 | Environmental Protection | LS | 1 | $ 25,000 | $25,000 |
| 3 | Seawall (10m Deep Sheetpile c/w cap stone and exterior decorative finish) | m | 2,800 | $1,000.0 | $2,800,000 |
| 4 | Armour Stone (seaward side of seawall) | $m^3$ | 8,400 | $100.0 | $840,000 |
| 5 | Storage Tank / Unlined Pond (Incl. excavation) | $m^3$ | 30,000 | $12.00 | $360,000 |
| 6 | Control House c/w CIP Chamber | LS | 1 | $250,000 | $250,000 |
| 7 | 36" HDPE Submerged Outfall Pipe | m | 150 | $2,000 | $300,000 |
| 8 | 24" HDPE Gravity Outfall | m | 100 | $1,500 | $150,000 |
| 9 | 4 Pump System | Ea | 4 | $236,000 | $944,000 |
| 10 | Pump Installation Including Mechanical & Electrical | LS | 1 | $420,000 | $420,000 |
| 11 | Emergency Genset | Ea | 1 | $100,000 | $100,000 |
| 12 | Reinstate Landscaping, Sod Tank Slopes | LS | 1 | $220,000 | $220,000 |
| 13 | New Curbs, Sidewalks, Asphalt | LS | 1 | $400,000 | $400,000 |
| 14 | Prime Contractor Overhead & Fees | | | 15% | Included in Units |
| | **TOTAL CONSTRUCTION COST (Exluding Contingency Allowances)** | | | | **$6,960,000** |
| | **CONTINGENCIES and ALLOWANCES** | | | | |
| A | Design Development Contingency **(See Note 2)** | | | 20% | $1,392,000 |
| B | Construction Contingency **(See Note 3)** | | | 10% | $700,000 |
| C | Escalation / Inflation **(Based on 2019 Dollars)** | | | | Not Included |
| D | Location Factor | | | | Included |
| | **TOTAL CONSTRUCTION BUDGET without HST** | | | | **$9,052,000** |



THIS OPINION OF PROBABLE COSTS IS PRESENTED ON THE BASIS OF EXPERIENCE, QUALIFICATIONS, AND BEST JUDGEMENT. IT HAS BEEN PREPARED IN ACCORDANCE WITH ACCEPTABLE PRINCIPLES AND PRACTICES. MARKET TRENDS, NON-COMPETITIVE BIDDING SITUATIONS, UNFORSEEN LABOUR AND MATERIAL ADJUSTMENTS AND THE LIKE ARE BEYOND THE CONTROL OF CBCL LIMITED. AS SUCH WE CANNOT WARRANT OR GUARANTEE THAT ACTUAL COSTS WILL NOT VARY FROM THE OPINION PROVIDED.

| | |
|---|---|
| **Note 1** | The summary shall only provide costs, allowances, contingencies and factors related to construction. No engineering design fees |
| **Note 2** | A Design Development Contingency is to allow for growth of quanties, increase material costs as the work is better defined in the future |
| **Note 3** | A Construction Contingency is to allow for the cost of additional work that is over and above the Original Construction Contract Price |

Form CBCL 034.Rev 1

**OPINION OF PROBABLE CONSTRUCTION COST**

**Town of Liverpool Flood Mitigation**

**Improvements Study**

**Option #2 - Raised Parking Lot**



| | |
|---|---|
| **DATE:** | February 5, 2019 |
| **CBCL FILE No.:** | 181109.00 |
| **PREPARED BY:** | SP/CM/CF/AT |
| **EST. DESCRIPTION :** | Class D |

| Item No. | Description | Unit | Est. Qty | Unit Price | Amount |
|---|---|---|---|---|---|
| 1 | Insurance, Bonds, Equipment, Pre-Construction Management | LS | 1 | $ 52,000 | $52,000 |
| **2.0** | **Full Demolition** | | | | |
| 2.1 | Building - Waterfront Plaza (Full Demo - 1 story) | $m^2$ | 840 | $29.76 | $25,000 |
| 2.2 | Building - Hell Bay Brewing (Full Demo - 1 Story) | $m^2$ | 250 | $60.00 | $15,000 |
| **3.0** | **Partial Demolition & Renovation** | | | | |
| 3.1 | Building - BDC (Partial - 2 Storeys) | $m^2$ | 600 | $217 | $130,000 |
| 3.2 | Building - Royal Canadian Legion (Partial - 1 Story) | $m^2$ | 150 | $597 | $90,000 |
| **4.0** | **Removals** | | | | |
| 4.1 | Asphalt | $m^2$ | 1,800 | $25.00 | $45,000 |
| 4.2 | Concrete | $m^2$ | 70 | $200.00 | $14,000 |
| 5 | Common Fill | $m^3$ | 8,400 | $20.00 | $168,000 |
| 6 | Asphalt c/w Gravels | $m^2$ | 12,000 | $80.00 | $960,000 |
| 7 | Concrete Sidewalk c/w Gravels | $m^2$ | 350 | $110.00 | $38,500 |
| 8 | Tie-In Berm | $m^3$ | 3,800 | $20.00 | $76,000 |
| 9 | Raise Catchbasins/Manholes (Approx. 0.7m) | Ea | 12 | $1,500.00 | $18,000 |
| 10 | Relocate/Re-Use Light Standards Including Foundations | Ea. | 4 | $3,000.00 | $12,000 |
| | **TOTAL CONSTRUCTION COST (Exluding Contingency Allowances)** | | | | **$1,640,000** |
| | **CONTINGENCIES and ALLOWANCES** | | | | |
| A | Design Development Contingency **(See Note 2)** | | | 15% | $246,000 |
| B | Construction Contingency **(See Note 3)** | | | 10% | $164,000 |
| C | Escalation / Inflation **(Based on 2019 Dollars)** | | | | Not Included |
| D | Location Factor | | | | Included |
| | **TOTAL CONSTRUCTION BUDGET without HST** | | | | **$2,050,000** |



**SEPARATE BUDGETS to Relocate Business:**

| | | |
|---|---|---|
| 1. Hell Bay Brewing | **ADD** | **$ 520,000** |
| 2. Royal Canadian Legion (Partial) | **ADD** | **$ 290,000** |
| 3. Salvation Army Thrift Store (Partial) | **ADD** | **$ 616,000** |
| 4. Waterfront Plaza | **ADD** | **$ 982,000** |
| 5. Liverpool Professional Centre | **ADD** | **??** |
| 6. Bank of Montreal Building | **ADD** | **??** |

THIS OPINION OF PROBABLE COSTS IS PRESENTED ON THE BASIS OF EXPERIENCE, QUALIFICATIONS, AND BEST JUDGEMENT. IT HAS BEEN PREPARED IN ACCORDANCE WITH ACCEPTABLE PRINCIPLES AND PRACTICES. MARKET TRENDS, NON-COMPETITIVE BIDDING SITUATIONS, UNFORSEEN LABOUR AND MATERIAL ADJUSTMENTS AND THE LIKE ARE BEYOND THE CONTROL OF CBCL LIMITED. AS SUCH WE CANNOT WARRANT OR GUARANTEE THAT ACTUAL COSTS WILL NOT VARY FROM THE OPINION PROVIDED.

| | |
|---|---|
| **Note 1** | The summary shall only provide costs, allowances, contingencies and factors related to construction. No engineering design fees |
| **Note 2** | A Design Development Contingency is to allow for growth of quanties, increase material costs as the work is better defined in the future |
| **Note 3** | A Construction Contingency is to allow for the cost of additional work that is over and above the Original Construction Contract Price |

**Form CBCL 034.Rev 1**

OPINION OF PROBABLE CONSTRUCTION COST

**Town of Liverpool Flood Mitigation Improvements Study**

**Option #3 - Raised Water Street**



| | |
|---|---|
| **DATE:** | February 5, 2019 |
| **CBCL FILE No.:** | 181109.00 |
| **PREPARED BY:** | SP/CM/CF/AT |
| **EST. DESCRIPTION :** | Class D |

| Item No. | Description | Unit | Est. Qty | Unit Price | Est. Cost |
|---|---|---|---|---|---|
| 1 | Insurance, Bonds, Equipment, Pre-Construction Management | LS | 1 | $ 33,000 | $33,000 |
| **2.0** | **Full Demolition** | | | | |
| 2.1 | Building - Waterfront Plaza (Full Demo - 1 story) | $m^2$ | 840 | $29.76 | $25,000 |
| 2.2 | Building - Hell Bay Brewing (Full Demo - 1 Story) | $m^2$ | 250 | $60.00 | $15,000 |
| **3.0** | **Partial Demolition & Renovation** | | | | |
| 3.1 | Building - BDC (Partial - 2 Storeys) | $m^2$ | 600 | $217 | $130,000 |
| 3.2 | Building - Royal Canadian Legion (Partial - 1 Story) | $m^2$ | 150 | $597 | $90,000 |
| **4.0** | **Removals** | | | | |
| 4.1 | Asphalt | $m^3$ | 338 | $25.00 | $8,000 |
| 4.2 | Concrete | $m^3$ | 36 | $200.00 | $7,000 |
| 5 | Common Fill | $m^3$ | 1,911 | $20.00 | $38,000 |
| 6 | Asphalt c/w Gravels | $m^2$ | 2,250 | $80.00 | $180,000 |
| 7 | Concrete Sidewalk c/w Gravels | $m^2$ | 720 | $110.00 | $79,000 |
| 8 | Concrete Curb | m | 520 | $90.00 | $47,000 |
| 9 | Tie-In Berm | $m^3$ | 3,800 | $20.00 | $76,000 |
| 10 | Raise Catchbasins/Manholes (Approx. 0.7m) | Ea | 12 | $1,500.00 | $18,000 |
| 11 | Relocate/Re-Use Light Standards Including Foundations | Ea. | 4 | $3,000.00 | $12,000 |
| 12 | Block Retaining Wall (0.7m high) | m | 200 | $600.00 | $120,000 |
| | **TOTAL CONSTRUCTION COST (Exluding Contingency Allowances)** | | | | **$880,000** |
| | **CONTINGENCIES and ALLOWANCES** | | | | |
| A | Design Development Contingency **(See Note 2)** | | | 15% | $132,000 |
| B | Construction Contingency **(See Note 3)** | | | 10% | $88,000 |
| C | Escalation / Inflation **(Based on 2019 Dollars)** | | | | Not Included |
| D | Location Factor | | | | Included |
| | **TOTAL CONSTRUCTION BUDGET without HST** | | | | **$1,100,000** |



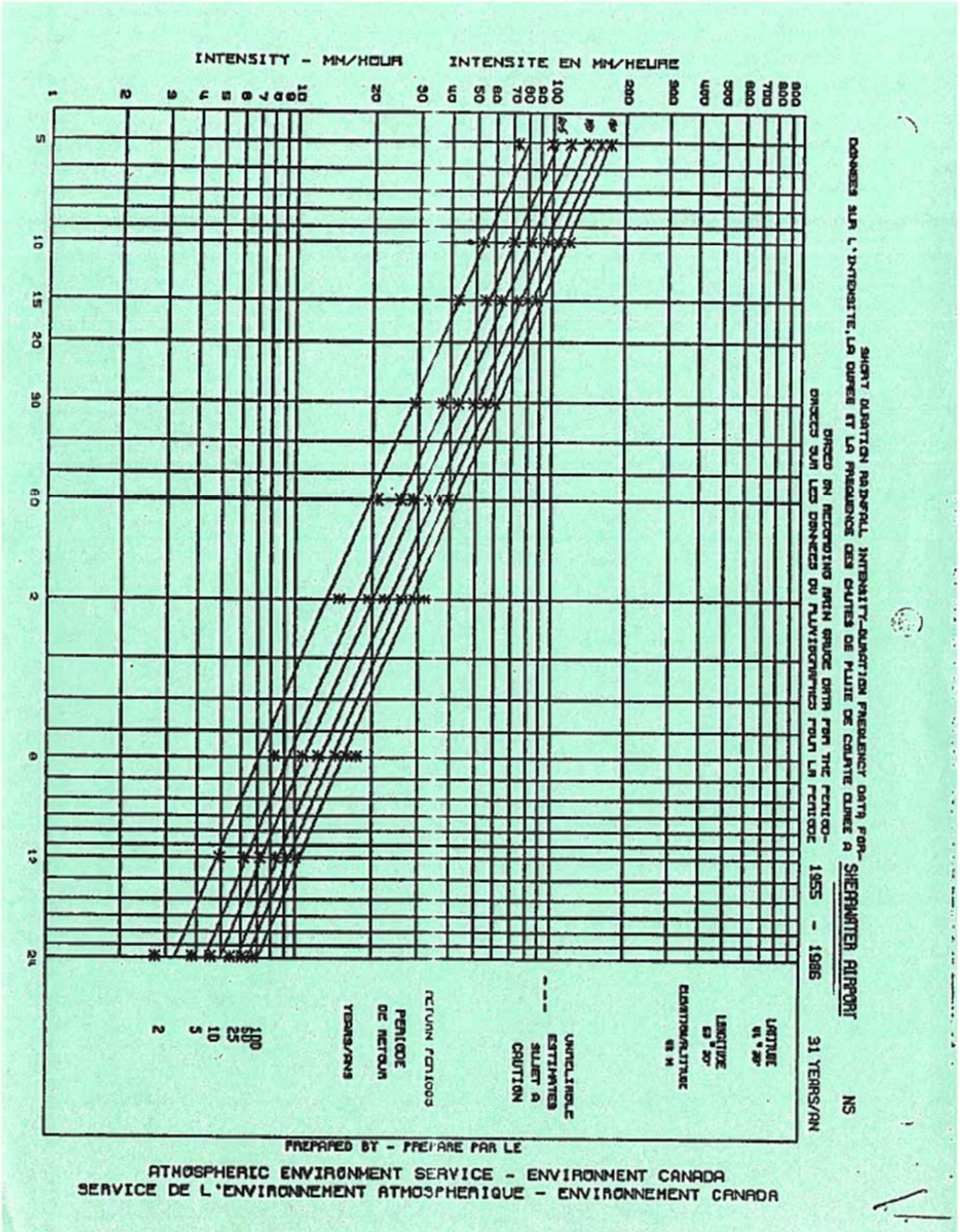
**SEPARATE BUDGETS to Relocate Business:**

| | | |
|---|---|---|
| 1. Hell Bay Brewing | **ADD** | **$ 520,000** |
| 2. Royal Canadian Legion (Partial) | **ADD** | **$ 380,000** |
| 3. Salvation Army Thrift Store (Partial) | **ADD** | **$ 616,000** |
| 4. Waterfront Plaza | **ADD** | **$ 982,000** |
| 5. Liverpool Professional Centre | **ADD** | **??** |
| 6. Bank of Montreal Building | **ADD** | **??** |

THIS OPINION OF PROBABLE COSTS IS PRESENTED ON THE BASIS OF EXPERIENCE, QUALIFICATIONS, AND BEST JUDGEMENT. IT HAS BEEN PREPARED IN ACCORDANCE WITH ACCEPTABLE PRINCIPLES AND PRACTICES. MARKET TRENDS, NON-COMPETITIVE BIDDING SITUATIONS, UNFORSEEN LABOUR AND MATERIAL ADJUSTMENTS AND THE LIKE ARE BEYOND THE CONTROL OF CBCL LIMITED. AS SUCH WE CANNOT WARRANT OR GUARANTEE THAT ACTUAL COSTS WILL NOT VARY FROM THE OPINION PROVIDED.

| | |
|---|---|
| **Note 1** | The summary shall only provide costs, allowances, contingencies and factors related to construction. No engineering design fees |
| **Note 2** | A Design Development Contingency is to allow for growth of quanties, increase material costs as the work is better defined in the future |
| **Note 3** | A Construction Contingency is to allow for the cost of additional work that is over and above the Original Construction Contract Price |

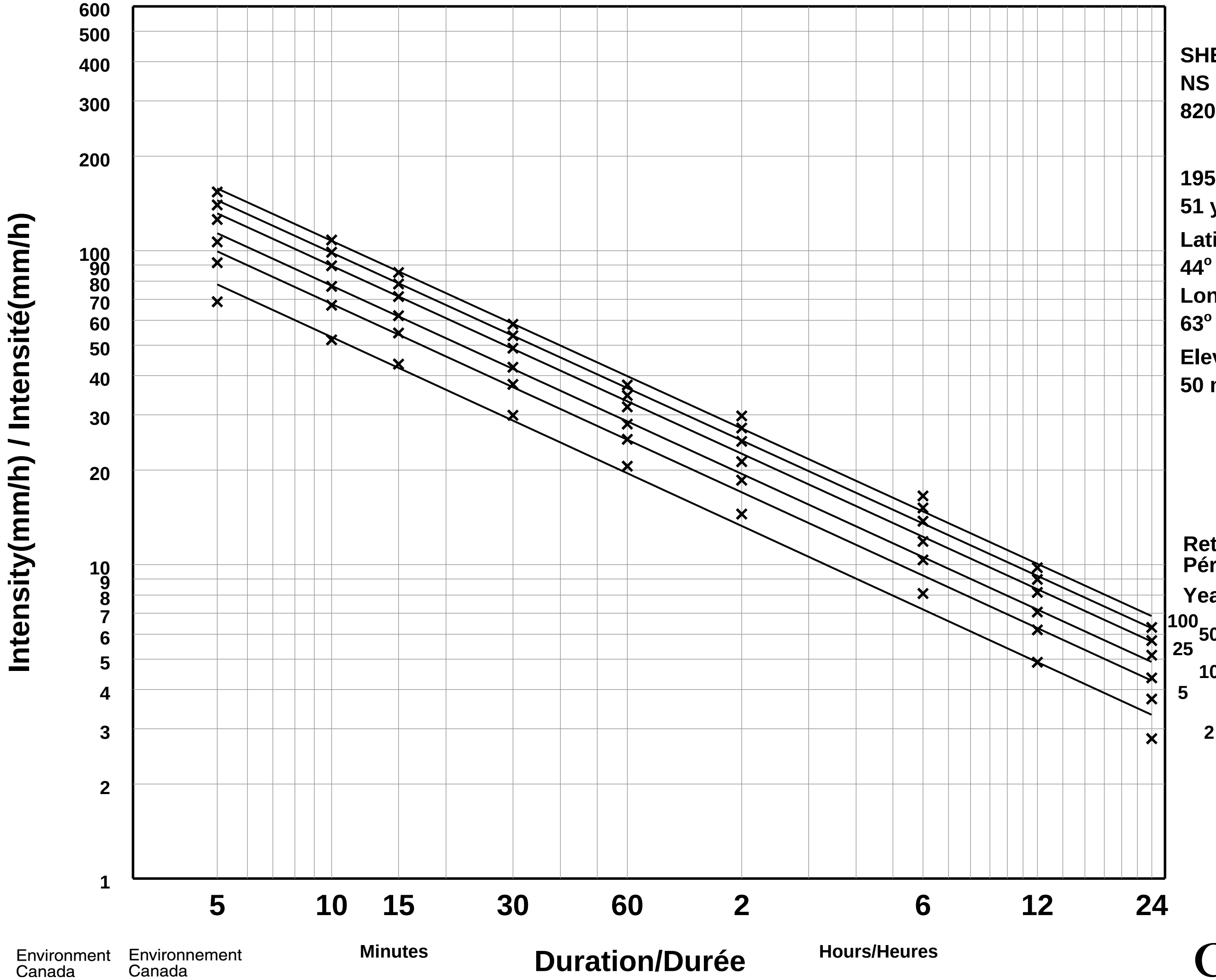
# APPENDIX D – Intensity Duration Frequency Curves


INTENSITY - MM/HOUR
INTENSITE EN MM/HEURE
SHORT DURATION RAINFALL INTENSITY-DURATION FREQUENCY DATA FOR-
SHEARWATER AIRPORT
NS
1955 - 1986
31 YEARS/AN
PREPARED BY - PREPARE PAR LE
ATMOSPHERIC ENVIRONMENT SERVICE - ENVIRONMENT CANADA
SERVICE DE L'ENVIRONNEMENT ATMOSPHERIQUE - ENVIRONNEMENT CANADA

# Short Duration Rainfall Intensity−Duration−Frequency Data

2010/04/13

# Données sur l'intensité, la durée et la fréquence des chutes de pluie de courte durée




**SHEARWATER A**
**NS**
**8205090**

**1955 − 2006**
**51 years / ans**
**Latitude**
**44° 38'N**
**Longitude**
**63° 30'W**
**Elevation / Altitude**
**50 m**

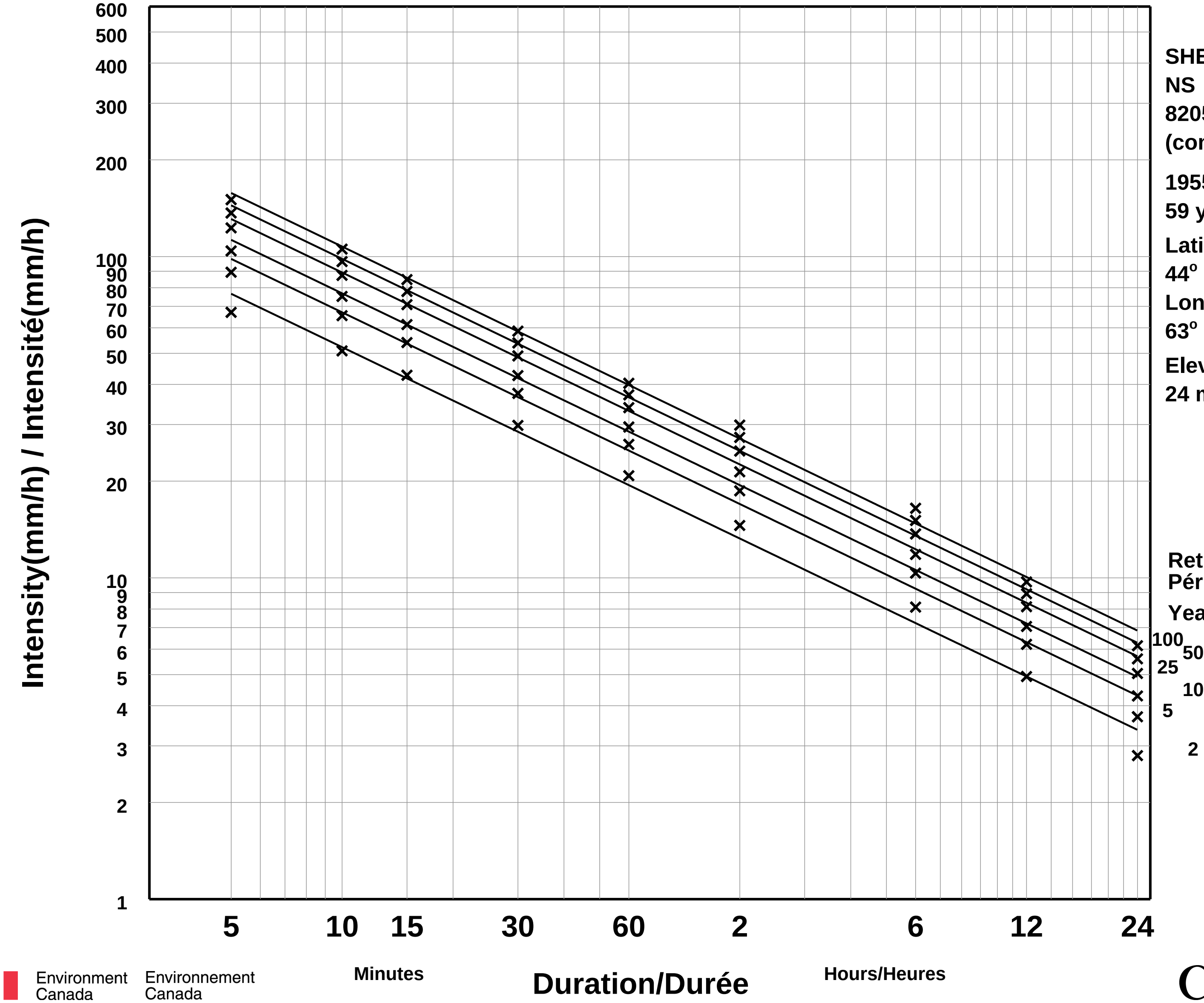
Environment Canada | Environnement Canada

Canada

# Short Duration Rainfall Intensity−Duration−Frequency Data

2019/02/27

# Données sur l’intensité, la durée et la fréquence des chutes de pluie de courte durée




SHEARWATER RCS
NS
8205092
(composite)

1955 − 2016
59 years / ans

Latitude
44° 38’N
Longitude
63° 31’W

Elevation / Altitude
24 m

Environment Canada Environnement Canada

Canada

# APPENDIX E – Hydrologic Analysis (Watershed Characteristics and Runoff)

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Return Period | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Amherst Street 1A | 0.40 | 5.5 | 59.0 | 0.76 | 0.76 | Nearly Bare Ground | 0.71 | 0.08 | 5.00 | 0.09 | 0.15 | 0.08 | 0.13 | 0.11 | 0.17 |
| Amherst Street 2A | 0.36 | 3 | 37.0 | 0.87 | 0.86 | Nearly Bare Ground | 0.52 | 0.08 | 5.00 | 0.09 | 0.15 | 0.09 | 0.14 | 0.11 | 0.18 |
| Amherst Street 3A | 0.36 | 4.9 | 106.2 | 0.48 | 0.46 | Nearly Bare Ground | 0.67 | 0.08 | 5.00 | 0.05 | 0.08 | 0.05 | 0.07 | 0.06 | 0.10 |
| Amherst Street 4A | 0.12 | 6.6 | 30.0 | 1.00 | 1.00 | Nearly Bare Ground | 0.78 | 0.08 | 5.00 | 0.04 | 0.06 | 0.03 | 0.05 | 0.04 | 0.07 |
| Amherst Street 5A | 0.57 | 5.4 | 75.4 | 0.44 | 0.44 | Nearly Bare Ground | 0.70 | 0.08 | 5.00 | 0.07 | 0.12 | 0.07 | 0.11 | 0.09 | 0.14 |
| Amherst Street 1B | 1.98 | 4.6 | 449.0 | 0.80 | 0.79 | Nearly Bare Ground | 0.65 | 0.19 | 11.52 | 0.29 | 0.48 | 0.27 | 0.43 | 0.36 | 0.56 |
| Amherst Street 2B | 0.97 | 6.2 | 40.4 | 0.47 | 0.46 | Nearly Bare Ground | 0.75 | 0.08 | 5.00 | 0.13 | 0.22 | 0.12 | 0.20 | 0.16 | 0.25 |
| Amherst Street 3B | 0.20 | 8.8 | 121.3 | 0.62 | 0.62 | Nearly Bare Ground | 0.90 | 0.08 | 5.00 | 0.04 | 0.06 | 0.03 | 0.05 | 0.04 | 0.07 |
| Amherst Street 1C | 0.57 | 2.9 | 125.3 | 0.46 | 0.46 | Nearly Bare Ground | 0.52 | 0.08 | 5.00 | 0.08 | 0.13 | 0.07 | 0.11 | 0.09 | 0.15 |
| Amherst Street 2C | 0.16 | 4.8 | 67.8 | 0.66 | 0.66 | Nearly Bare Ground | 0.66 | 0.08 | 5.00 | 0.03 | 0.05 | 0.03 | 0.05 | 0.04 | 0.06 |
| Amherst Street 3C | 0.08 | 1.8 | 33.9 | 0.24 | 0.26 | Nearly Bare Ground | 0.41 | 0.08 | 5.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Amherst Street 4C | 0.20 | 5.8 | 122.1 | 0.33 | 0.31 | Nearly Bare Ground | 0.73 | 0.08 | 5.00 | 0.02 | 0.03 | 0.02 | 0.03 | 0.02 | 0.04 |
| Amherst Street 5C | 0.08 | 4.4 | 52.1 | 0.24 | 0.24 | Nearly Bare Ground | 0.64 | 0.08 | 5.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Amherst Street 6C | 0.57 | 7.2 | 15.8 | 0.34 | 0.33 | Nearly Bare Ground | 0.81 | 0.08 | 5.00 | 0.06 | 0.09 | 0.05 | 0.08 | 0.07 | 0.11 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Return Period | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Amherst Street 7C | 0.81 | 5.7 | 190.2 | 0.36 | 0.36 | Nearly Bare Ground | 0.72 | 0.08 | 5.00 | 0.08 | 0.14 | 0.08 | 0.13 | 0.10 | 0.16 |
| Amherst Street 1D | 0.16 | 8.8 | 56.5 | 0.66 | 0.66 | Nearly Bare Ground | 0.90 | 0.08 | 5.00 | 0.03 | 0.05 | 0.03 | 0.05 | 0.04 | 0.06 |
| Amherst Street 2D | 0.40 | 4.8 | 134.5 | 0.48 | 0.47 | Nearly Bare Ground | 0.66 | 0.08 | 5.00 | 0.06 | 0.09 | 0.05 | 0.08 | 0.07 | 0.11 |
| Amherst Street 3D | 0.65 | 6.4 | 236.3 | 0.32 | 0.31 | Nearly Bare Ground | 0.77 | 0.09 | 5.14 | 0.06 | 0.10 | 0.06 | 0.09 | 0.07 | 0.11 |
| Amherst Street 4D | 1.25 | 5 | 152.9 | 0.32 | 0.31 | Nearly Bare Ground | 0.68 | 0.08 | 5.00 | 0.12 | 0.19 | 0.11 | 0.17 | 0.14 | 0.22 |
| Amherst Street 5D | 0.45 | 6.8 | 60.1 | 0.48 | 0.48 | Nearly Bare Ground | 0.79 | 0.08 | 5.00 | 0.06 | 0.10 | 0.06 | 0.09 | 0.08 | 0.12 |
| Amherst Street 6D | 0.20 | 2.3 | 185.0 | 1.00 | 1.00 | Nearly Bare Ground | 0.46 | 0.11 | 6.71 | 0.05 | 0.08 | 0.05 | 0.07 | 0.07 | 0.10 |
| Amherst Street 7D | 0.65 | 5.7 | 377.3 | 1.00 | 1.00 | Nearly Bare Ground | 0.72 | 0.14 | 8.70 | 0.16 | 0.26 | 0.13 | 0.21 | 0.19 | 0.30 |
| Amherst Street 8D | 0.81 | 5.2 | 216.0 | 0.46 | 0.45 | Nearly Bare Ground | 0.69 | 0.09 | 5.22 | 0.11 | 0.18 | 0.10 | 0.16 | 0.13 | 0.20 |
| Amherst Street 9D | 0.45 | 4.6 | 106.9 | 0.48 | 0.47 | Nearly Bare Ground | 0.65 | 0.08 | 5.00 | 0.06 | 0.10 | 0.06 | 0.09 | 0.08 | 0.12 |
| Amherst Street 10D | 0.36 | 4.3 | 37.4 | 0.34 | 0.33 | Nearly Bare Ground | 0.63 | 0.08 | 5.00 | 0.04 | 0.06 | 0.03 | 0.05 | 0.04 | 0.07 |
| Amherst Street 11D | 0.65 | 3.3 | 150.7 | 0.45 | 0.45 | Nearly Bare Ground | 0.55 | 0.08 | 5.00 | 0.08 | 0.14 | 0.08 | 0.13 | 0.10 | 0.16 |
| Amherst Street 12D | 0.28 | 5.9 | 120.3 | 0.44 | 0.43 | Nearly Bare Ground | 0.74 | 0.08 | 5.00 | 0.04 | 0.06 | 0.03 | 0.05 | 0.04 | 0.07 |
| Amherst Street 13D | 0.16 | 6.2 | 41.6 | 0.42 | 0.39 | Nearly Bare Ground | 0.75 | 0.08 | 5.00 | 0.02 | 0.03 | 0.02 | 0.03 | 0.02 | 0.04 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Return Period | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Amherst Street 14D | 0.12 | 3.8 | 27.6 | 0.71 | 0.67 | Nearly Bare Ground | 0.59 | 0.08 | 5.00 | 0.03 | 0.04 | 0.02 | 0.04 | 0.03 | 0.05 |
| Amherst Street 15D | 0.08 | 2.5 | 28.7 | 0.48 | 0.43 | Nearly Bare Ground | 0.48 | 0.08 | 5.00 | 0.01 | 0.02 | 0.01 | 0.02 | 0.01 | 0.02 |
| Amherst Street 16D | 0.08 | 5 | 23.1 | 0.48 | 0.48 | Nearly Bare Ground | 0.68 | 0.08 | 5.00 | 0.01 | 0.02 | 0.01 | 0.02 | 0.01 | 0.02 |
| Amherst Street 17D | 0.69 | 3.9 | 142.6 | 0.65 | 0.63 | Nearly Bare Ground | 0.60 | 0.08 | 5.00 | 0.13 | 0.21 | 0.12 | 0.19 | 0.16 | 0.25 |
| Amherst Street 18D | 0.36 | 4.2 | 115.5 | 0.48 | 0.48 | Nearly Bare Ground | 0.62 | 0.08 | 5.00 | 0.05 | 0.08 | 0.05 | 0.08 | 0.06 | 0.10 |
| Amherst Street 19D | 0.12 | 1.5 | 48.1 | 0.40 | 0.40 | Nearly Bare Ground | 0.37 | 0.08 | 5.00 | 0.01 | 0.02 | 0.01 | 0.02 | 0.02 | 0.03 |
| Amherst Street 20D | 1.21 | 4.4 | 345.7 | 0.58 | 0.57 | Nearly Bare Ground | 0.64 | 0.15 | 9.07 | 0.15 | 0.24 | 0.14 | 0.22 | 0.18 | 0.28 |
| Amherst Street 21D | 1.13 | 4.2 | 220.1 | 0.48 | 0.42 | Nearly Bare Ground | 0.62 | 0.10 | 5.91 | 0.14 | 0.21 | 0.13 | 0.19 | 0.18 | 0.24 |
| Amherst Street 22D | 0.81 | 4.5 | 201.7 | 0.31 | 0.31 | Nearly Bare Ground | 0.64 | 0.09 | 5.23 | 0.07 | 0.12 | 0.07 | 0.11 | 0.09 | 0.14 |
| Amherst Street 23D | 0.57 | 4.7 | 60.3 | 0.48 | 0.46 | Nearly Bare Ground | 0.66 | 0.08 | 5.00 | 0.08 | 0.13 | 0.07 | 0.11 | 0.10 | 0.15 |
| Amherst Street 24D | 0.61 | 4.4 | 112.4 | 0.52 | 0.52 | Forest with heavy ground litter & meadow | 0.16 | 0.20 | 11.90 | 0.06 | 0.09 | 0.05 | 0.09 | 0.07 | 0.11 |
| Amherst Street 25D | 0.40 | 4.9 | 139.8 | 0.77 | 0.77 | Forest with heavy ground litter & meadow | 0.17 | 0.23 | 14.02 | 0.05 | 0.08 | 0.05 | 0.08 | 0.06 | 0.10 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | Return Period | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Amherst Street 26D | 1.05 | 5.8 | 133.4 | 0.78 | 0.76 | Forest with heavy ground litter & meadow | 0.18 | 0.20 | 12.29 | 0.14 | 0.24 | 0.14 | 0.21 | 0.18 | 0.28 |
| Amherst Street 27D | 0.81 | 8.9 | 247.3 | 0.64 | 0.64 | Forest with heavy ground litter & meadow | 0.22 | 0.31 | 18.39 | 0.07 | 0.12 | 0.07 | 0.11 | 0.09 | 0.14 |
| Amherst Street 28D | 2.10 | 6.8 | 613.5 | 1.00 | 1.00 | Forest with heavy ground litter & meadow | 0.20 | 0.87 | 52.21 | 0.17 | 0.28 | 0.16 | 0.25 | 0.21 | 0.33 |
| Amherst Street 29D | 1.21 | 7.4 | 333.4 | 1.00 | 1.00 | Forest with heavy ground litter & meadow | 0.20 | 0.45 | 27.19 | 0.20 | 0.32 | 0.13 | 0.21 | 0.24 | 0.38 |
| Amherst Street 30D | 3.60 | 7.1 | 455.5 | 0.90 | 0.89 | Forest with heavy ground litter & meadow | 0.20 | 0.63 | 37.93 | 0.31 | 0.50 | 0.29 | 0.46 | 0.38 | 0.59 |
| Amherst Street 31D | 2.91 | 7 | 443.8 | 0.89 | 0.87 | Forest with heavy ground litter & meadow | 0.20 | 0.62 | 37.22 | 0.25 | 0.40 | 0.23 | 0.37 | 0.30 | 0.48 |
| Amherst Street 32D | 0.20 | 2.3 | 47.1 | 0.40 | 0.40 | Forest with heavy ground litter & meadow | 0.11 | 0.12 | 6.91 | 0.02 | 0.03 | 0.02 | 0.03 | 0.02 | 0.04 |
| Amherst Street 33D | 0.24 | 6.8 | 78.0 | 0.37 | 0.34 | Forest with heavy ground litter & meadow | 0.20 | 0.11 | 6.63 | 0.02 | 0.03 | 0.02 | 0.03 | 0.03 | 0.04 |
| Amherst Street 34D | 4.82 | 6.5 | 468.5 | 0.93 | 0.93 | Forest with heavy ground litter & meadow | 0.19 | 0.68 | 40.78 | 0.40 | 0.67 | 0.39 | 0.61 | 0.50 | 0.79 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Return Period | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Amherst Street 35D | 5.54 | 7.7 | 555.3 | 0.96 | 0.94 | Forest with heavy ground litter & meadow | 0.21 | 0.74 | 44.39 | 0.46 | 0.75 | 0.43 | 0.68 | 0.56 | 0.89 |
| Amherst Street 36D | 1.38 | 9.1 | 217.8 | 0.62 | 0.61 | Forest with heavy ground litter & meadow | 0.23 | 0.27 | 16.01 | 0.13 | 0.21 | 0.12 | 0.19 | 0.16 | 0.25 |
| Amherst Street 37D | 1.86 | 7.1 | 290.3 | 0.74 | 0.73 | Forest with heavy ground litter & meadow | 0.20 | 0.40 | 24.17 | 0.17 | 0.27 | 0.16 | 0.25 | 0.21 | 0.32 |
| Amherst Street 1E | 0.77 | 5.8 | 60.2 | 0.49 | 0.47 | Nearly Bare Ground | 0.73 | 0.08 | 5.00 | 0.11 | 0.18 | 0.10 | 0.16 | 0.13 | 0.21 |
| Amherst Street 2E | 0.16 | 3.3 | 38.0 | 0.54 | 0.54 | Nearly Bare Ground | 0.55 | 0.08 | 5.00 | 0.03 | 0.04 | 0.02 | 0.04 | 0.03 | 0.05 |
| Amherst Street 3E | 0.24 | 3.2 | 67.4 | 0.48 | 0.48 | Nearly Bare Ground | 0.54 | 0.08 | 5.00 | 0.03 | 0.06 | 0.03 | 0.05 | 0.04 | 0.07 |
| Amherst Street 4E | 0.28 | 4.5 | 67.7 | 0.51 | 0.49 | Nearly Bare Ground | 0.64 | 0.08 | 5.00 | 0.04 | 0.07 | 0.04 | 0.06 | 0.05 | 0.08 |
| Amherst Street 5E | 0.65 | 2.8 | 107.4 | 0.43 | 0.43 | Nearly Bare Ground | 0.51 | 0.08 | 5.00 | 0.08 | 0.14 | 0.08 | 0.12 | 0.10 | 0.16 |
| Amherst Street 1F | 0.32 | 4.5 | 53.8 | 0.39 | 0.38 | Nearly Bare Ground | 0.64 | 0.08 | 5.00 | 0.04 | 0.06 | 0.03 | 0.05 | 0.04 | 0.07 |
| Amherst Street 2F | 0.20 | 5.2 | 61.4 | 0.38 | 0.40 | Nearly Bare Ground | 0.69 | 0.08 | 5.00 | 0.02 | 0.04 | 0.02 | 0.04 | 0.03 | 0.05 |
| Amherst Street 3F | 0.32 | 5.3 | 85.9 | 0.39 | 0.38 | Nearly Bare Ground | 0.70 | 0.08 | 5.00 | 0.04 | 0.06 | 0.03 | 0.05 | 0.04 | 0.07 |
| Birch Avenue 1A | 0.32 | 4.2 | 128.7 | 0.63 | 0.61 | Nearly Bare Ground | 0.62 | 0.08 | 5.00 | 0.06 | 0.10 | 0.06 | 0.09 | 0.07 | 0.11 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Return Period | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Birch Avenue 2A | 0.69 | 3.5 | 189.0 | 0.60 | 0.59 | Nearly Bare Ground | 0.57 | 0.09 | 5.56 | 0.11 | 0.19 | 0.11 | 0.17 | 0.14 | 0.22 |
| Birch Avenue 3A | 0.65 | 3.6 | 177.1 | 0.58 | 0.57 | Nearly Bare Ground | 0.57 | 0.09 | 5.14 | 0.11 | 0.18 | 0.10 | 0.16 | 0.13 | 0.21 |
| Birch Avenue 4A | 0.89 | 4.5 | 211.4 | 0.61 | 0.60 | Nearly Bare Ground | 0.64 | 0.09 | 5.49 | 0.15 | 0.25 | 0.14 | 0.22 | 0.18 | 0.29 |
| Birch Avenue 5A | 0.12 | 10 | 66.9 | 0.64 | 0.64 | Nearly Bare Ground | 0.96 | 0.08 | 5.00 | 0.02 | 0.04 | 0.02 | 0.03 | 0.03 | 0.04 |
| Birch Avenue 6A | 1.13 | 3.1 | 208.6 | 0.65 | 0.64 | Nearly Bare Ground | 0.53 | 0.11 | 6.52 | 0.19 | 0.31 | 0.17 | 0.27 | 0.23 | 0.36 |
| Birch Avenue 7A | 1.09 | 2.8 | 288.2 | 0.76 | 0.75 | Nearly Bare Ground | 0.51 | 0.16 | 9.48 | 0.17 | 0.28 | 0.16 | 0.25 | 0.21 | 0.33 |
| Birch Avenue 8A | 0.24 | 7.1 | 35.8 | 0.68 | 0.67 | Nearly Bare Ground | 0.81 | 0.08 | 5.00 | 0.05 | 0.08 | 0.04 | 0.07 | 0.06 | 0.09 |
| Birch Avenue 9A | 0.28 | 2.9 | 80.0 | 0.61 | 0.61 | Nearly Bare Ground | 0.52 | 0.08 | 5.00 | 0.05 | 0.08 | 0.05 | 0.08 | 0.06 | 0.10 |
| Birch Avenue 10A | 0.24 | 3.8 | 60.1 | 0.56 | 0.55 | Nearly Bare Ground | 0.59 | 0.08 | 5.00 | 0.04 | 0.07 | 0.04 | 0.06 | 0.05 | 0.08 |
| Birch Avenue 11A | 11.98 | 4.8 | 724.8 | 0.98 | 0.96 | Nearly Bare Ground | 0.66 | 0.30 | 18.21 | 1.66 | 2.73 | 1.57 | 2.47 | 2.04 | 3.21 |
| Birch Avenue 1B | 0.53 | 7.1 | 151.5 | 0.61 | 0.59 | Nearly Bare Ground | 0.81 | 0.08 | 5.00 | 0.09 | 0.15 | 0.09 | 0.14 | 0.11 | 0.18 |
| Birch Avenue 2B | 2.43 | 5.4 | 396.2 | 0.76 | 0.75 | Nearly Bare Ground | 0.70 | 0.16 | 9.39 | 0.38 | 0.62 | 0.36 | 0.56 | 0.46 | 0.73 |
| Birch Avenue 3B | 0.77 | 11.3 | 204.5 | 0.45 | 0.44 | Nearly Bare Ground | 1.02 | 0.08 | 5.00 | 0.10 | 0.17 | 0.10 | 0.15 | 0.12 | 0.19 |
| Birch Avenue 4B | 1.54 | 8.9 | 180.7 | 0.45 | 0.44 | Nearly Bare Ground | 0.90 | 0.08 | 5.00 | 0.20 | 0.33 | 0.19 | 0.30 | 0.25 | 0.39 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Return Period | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Birch Avenue 5B | 3.12 | 9.6 | 378.0 | 0.50 | 0.50 | Nearly Bare Ground | 0.94 | 0.11 | 6.72 | 0.39 | 0.64 | 0.37 | 0.57 | 0.47 | 0.75 |
| Birch Avenue 1C | 0.08 | 35 | 19.2 | 0.36 | 0.36 | Nearly Bare Ground | 1.79 | 0.08 | 5.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 |
| Birch Avenue 2C | 0.28 | 5.4 | 70.0 | 0.34 | 0.33 | Nearly Bare Ground | 0.70 | 0.08 | 5.00 | 0.03 | 0.05 | 0.03 | 0.04 | 0.03 | 0.05 |
| Birch Avenue 3C | 0.45 | 8.3 | 183.6 | 0.33 | 0.31 | Nearly Bare Ground | 0.87 | 0.08 | 5.00 | 0.04 | 0.07 | 0.04 | 0.06 | 0.05 | 0.08 |
| Birch Avenue 4C | 0.93 | 7.3 | 122.0 | 0.59 | 0.58 | Nearly Bare Ground | 0.82 | 0.08 | 5.00 | 0.16 | 0.27 | 0.15 | 0.24 | 0.20 | 0.31 |
| Birch Avenue 5C | 0.32 | 5.9 | 144.9 | 0.51 | 0.53 | Forest with heavy ground litter & meadow | 0.18 | 0.22 | 13.24 | 0.03 | 0.05 | 0.03 | 0.04 | 0.03 | 0.06 |
| Birch Avenue 6C | 0.32 | 5.9 | 85.5 | 0.33 | 0.34 | Nearly Bare Ground | 0.74 | 0.08 | 5.00 | 0.03 | 0.05 | 0.03 | 0.05 | 0.04 | 0.06 |
| Birch Avenue 7C | 0.32 | 2.8 | 41.8 | 0.36 | 0.34 | Nearly Bare Ground | 0.51 | 0.08 | 5.00 | 0.03 | 0.05 | 0.03 | 0.05 | 0.04 | 0.06 |
| Birch Avenue 8C | 0.36 | 3.5 | 72.6 | 0.47 | 0.45 | Forest with heavy ground litter & meadow | 0.14 | 0.14 | 8.62 | 0.04 | 0.06 | 0.03 | 0.05 | 0.04 | 0.07 |
| Birch Avenue 9C | 0.16 | 3.8 | 43.6 | 0.36 | 0.36 | Nearly Bare Ground | 0.59 | 0.08 | 5.00 | 0.02 | 0.03 | 0.02 | 0.03 | 0.02 | 0.03 |
| Birch Avenue 10C | 1.13 | 4.8 | 144.2 | 0.44 | 0.44 | Nearly Bare Ground | 0.66 | 0.08 | 5.00 | 0.15 | 0.24 | 0.14 | 0.22 | 0.18 | 0.28 |
| Birch Avenue 11C | 0.32 | 3.8 | 105.4 | 0.45 | 0.43 | Nearly Bare Ground | 0.59 | 0.08 | 5.00 | 0.04 | 0.07 | 0.04 | 0.06 | 0.05 | 0.08 |
| Birch Avenue 12C | 18.01 | 3.6 | 780.1 | 0.56 | 0.55 | Nearly Bare Ground | 0.57 | 0.38 | 22.63 | 1.27 | 2.09 | 1.20 | 1.90 | 1.56 | 2.46 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Return Period | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Birch Avenue 13C | 0.12 | 4.8 | 30.3 | 0.31 | 0.33 | Forest with heavy ground litter & meadow | 0.16 | 0.08 | 5.00 | 0.01 | 0.02 | 0.01 | 0.02 | 0.01 | 0.02 |
| Birch Avenue 14C | 0.16 | 2.5 | 52.5 | 0.37 | 0.37 | Forest with heavy ground litter & meadow | 0.12 | 0.12 | 7.38 | 0.01 | 0.02 | 0.01 | 0.02 | 0.02 | 0.03 |
| Birch Avenue 15C | 0.61 | 6.2 | 213.9 | 0.64 | 0.65 | Forest with heavy ground litter & meadow | 0.19 | 0.32 | 19.07 | 0.05 | 0.09 | 0.05 | 0.08 | 0.07 | 0.11 |
| Birch Avenue 16C | 0.89 | 6.4 | 209.2 | 0.65 | 0.65 | Forest with heavy ground litter & meadow | 0.19 | 0.31 | 18.35 | 0.08 | 0.14 | 0.08 | 0.12 | 0.10 | 0.16 |
| Birch Avenue 17C | 2.83 | 4.4 | 419.9 | 0.95 | 0.94 | Forest with heavy ground litter & meadow | 0.16 | 0.74 | 44.46 | 0.23 | 0.38 | 0.23 | 0.35 | 0.29 | 0.45 |
| Birch Avenue 18C | 0.45 | 2.1 | 48.2 | 0.35 | 0.34 | Nearly Bare Ground | 0.44 | 0.08 | 5.00 | 0.05 | 0.07 | 0.04 | 0.07 | 0.05 | 0.09 |
| Birch Avenue 19C | 0.65 | 2.9 | 112.8 | 0.57 | 0.56 | Nearly Bare Ground | 0.52 | 0.08 | 5.00 | 0.11 | 0.18 | 0.10 | 0.16 | 0.13 | 0.21 |
| Birch Avenue 20C | 1.70 | 4.8 | 43.4 | 0.33 | 0.33 | Forest with heavy ground litter & meadow | 0.16 | 0.08 | 5.00 | 0.16 | 0.27 | 0.15 | 0.24 | 0.20 | 0.31 |
| Birch Avenue 21C | 7.41 | 3.8 | 274.0 | 0.81 | 0.80 | Forest with heavy ground litter & meadow | 0.15 | 0.52 | 31.23 | 0.63 | 1.04 | 0.60 | 0.94 | 0.78 | 1.23 |
| Birch Avenue 22C | 7.93 | 2.8 | 282.1 | 0.88 | 0.88 | Forest with heavy ground litter & meadow | 0.13 | 0.62 | 37.49 | 0.66 | 1.09 | 0.63 | 1.00 | 0.82 | 1.30 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Return Period | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Bog Pond 1A | 0.01 | 17 | 47.0 | 2.38 | 2.65 | Nearly Bare Ground | 1.25 | 0.08 | 5.00 | 0.01 | 0.01 | 0.00 | 0.00 | 0.01 | 0.01 |
| Bog Pond 1B | 1.05 | 7.5 | 120.0 | 0.62 | 0.61 | Nearly Bare Ground | 0.83 | 0.08 | 5.00 | 0.19 | 0.31 | 0.18 | 0.28 | 0.23 | 0.36 |
| Bog Pond 2B | 0.12 | 16.1 | 50.0 | 0.31 | 0.33 | Nearly Bare Ground | 1.21 | 0.08 | 5.00 | 0.01 | 0.02 | 0.01 | 0.02 | 0.01 | 0.02 |
| Bog Pond 3B | 0.20 | 20 | 75.0 | 0.38 | 0.34 | short grass pasture and lawns | 0.96 | 0.08 | 5.00 | 0.02 | 0.03 | 0.02 | 0.03 | 0.03 | 0.04 |
| Bog Pond 1C | 0.20 | 7.5 | 76.8 | 0.67 | 0.66 | Nearly Bare Ground | 0.83 | 0.08 | 5.00 | 0.04 | 0.07 | 0.04 | 0.06 | 0.05 | 0.08 |
| Bog Pond 2C | 0.16 | 18.6 | 15.0 | 0.30 | 0.32 | Nearly Bare Ground | 1.31 | 0.08 | 5.00 | 0.01 | 0.03 | 0.01 | 0.02 | 0.02 | 0.03 |
| Bog Pond 3C | 0.16 | 5 | 12.2 | 0.36 | 0.36 | Nearly Bare Ground | 0.68 | 0.08 | 5.00 | 0.02 | 0.03 | 0.02 | 0.03 | 0.02 | 0.03 |
| Bog Pond 4C | 0.32 | 31.3 | 20.9 | 0.33 | 0.33 | Nearly Bare Ground | 1.69 | 0.08 | 5.00 | 0.03 | 0.05 | 0.03 | 0.05 | 0.04 | 0.06 |
| Bog Pond 5C | 0.40 | 11.1 | 63.2 | 0.33 | 0.33 | Nearly Bare Ground | 1.01 | 0.08 | 5.00 | 0.04 | 0.07 | 0.04 | 0.06 | 0.05 | 0.08 |
| Bog Pond 6C | 0.40 | 3.1 | 80.2 | 0.50 | 0.49 | Nearly Bare Ground | 0.53 | 0.08 | 5.00 | 0.06 | 0.10 | 0.06 | 0.09 | 0.07 | 0.11 |
| Bog Pond 7C | 0.16 | 7.7 | 71.4 | 0.36 | 0.36 | Nearly Bare Ground | 0.84 | 0.08 | 5.00 | 0.02 | 0.03 | 0.02 | 0.03 | 0.02 | 0.03 |
| Bog Pond 8C | 0.36 | 2.9 | 89.2 | 0.48 | 0.48 | Nearly Bare Ground | 0.52 | 0.08 | 5.00 | 0.05 | 0.08 | 0.05 | 0.08 | 0.06 | 0.10 |
| Bog Pond 9C | 0.20 | 1.3 | 49.0 | 0.33 | 0.31 | Nearly Bare Ground | 0.35 | 0.08 | 5.00 | 0.02 | 0.03 | 0.02 | 0.03 | 0.02 | 0.04 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report |  | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  | Return Period |  |  |  |  |  | 1993 |  | 2019 |  | Future Conditions |  |
|  |  |  |  |  |  |  |  |  |  | Return Period |  | Return Period |  | Return Period |  |
|  | hectre | % | meter | 5 year | 100 year |  | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Bog Pond 10C | 0.53 | 13.9 | 59.1 | 0.31 | 0.31 | Forest with heavy ground litter & meadow | 0.28 | 0.08 | 5.00 | 0.05 | 0.08 | 0.04 | 0.07 | 0.06 | 0.09 |
| Bog Pond 11C | 0.32 | 9.6 | 85.5 | 0.33 | 0.33 | short grass pasture and lawns | 0.67 | 0.08 | 5.00 | 0.03 | 0.05 | 0.03 | 0.05 | 0.04 | 0.06 |
| Bog Pond 12C | 0.04 | 7.3 | 18.4 | 0.24 | 0.24 | Forest with heavy ground litter & meadow | 0.20 | 0.08 | 5.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.01 |
| Bog Pond 13C | 0.97 | 4 | 131.9 | 0.39 | 0.39 | Nearly Bare Ground | 0.61 | 0.08 | 5.00 | 0.11 | 0.18 | 0.10 | 0.16 | 0.13 | 0.21 |
| Bog Pond 14C | 0.53 | 6.9 | 97.9 | 0.31 | 0.31 | Nearly Bare Ground | 0.80 | 0.08 | 5.00 | 0.05 | 0.08 | 0.04 | 0.07 | 0.06 | 0.09 |
| Bog Pond 1D | 0.32 | 2.1 | 64.6 | 0.48 | 0.46 | Nearly Bare Ground | 0.44 | 0.08 | 5.00 | 0.05 | 0.07 | 0.04 | 0.07 | 0.05 | 0.09 |
| Bog Pond 2D | 0.57 | 4.5 | 78.1 | 0.61 | 0.61 | Nearly Bare Ground | 0.64 | 0.08 | 5.00 | 0.10 | 0.17 | 0.10 | 0.15 | 0.12 | 0.20 |
| Bog Pond 3D | 0.61 | 3.5 | 168.8 | 0.59 | 0.58 | Nearly Bare Ground | 0.57 | 0.08 | 5.00 | 0.10 | 0.17 | 0.10 | 0.15 | 0.13 | 0.20 |
| Bog Pond 4D | 0.32 | 3.4 | 108.9 | 0.63 | 0.61 | Nearly Bare Ground | 0.56 | 0.08 | 5.00 | 0.06 | 0.10 | 0.06 | 0.09 | 0.07 | 0.11 |
| Bog Pond 5D | 0.24 | 3 | 73.5 | 0.48 | 0.48 | Nearly Bare Ground | 0.52 | 0.08 | 5.00 | 0.03 | 0.06 | 0.03 | 0.05 | 0.04 | 0.07 |
| Bog Pond 6D | 0.36 | 2.2 | 181.1 | 0.97 | 0.96 | Nearly Bare Ground | 0.45 | 0.11 | 6.72 | 0.09 | 0.14 | 0.08 | 0.13 | 0.11 | 0.17 |
| Bog Pond 7D | 0.04 | 1.7 | 16.2 | 0.48 | 0.48 | Nearly Bare Ground | 0.39 | 0.08 | 5.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Bog Pond 8D | 0.28 | 2.8 | 202.1 | 1.00 | 0.96 | Nearly Bare Ground | 0.51 | 0.11 | 6.65 | 0.07 | 0.11 | 0.07 | 0.10 | 0.09 | 0.13 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Return Period | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Bog Pond 9D | 2.19 | 2.9 | 250.9 | 0.38 | 0.38 | Nearly Bare Ground | 0.52 | 0.14 | 8.11 | 0.19 | 0.31 | 0.17 | 0.28 | 0.23 | 0.36 |
| Bog Pond 1E | 0.28 | 8.6 | 120.0 | 0.48 | 0.46 | Forest with heavy ground litter & meadow | 0.22 | 0.15 | 9.07 | 0.03 | 0.05 | 0.03 | 0.04 | 0.03 | 0.05 |
| Bog Pond 2E | 1.42 | 21.2 | 155.7 | 0.38 | 0.37 | Forest with heavy ground litter & meadow | 0.35 | 0.12 | 7.48 | 0.12 | 0.20 | 0.12 | 0.18 | 0.15 | 0.24 |
| Bog Pond 3E | 0.69 | 7 | 116.5 | 0.47 | 0.47 | Forest with heavy ground litter & meadow | 0.20 | 0.16 | 9.77 | 0.07 | 0.11 | 0.06 | 0.10 | 0.08 | 0.13 |
| Bog Pond 4E | 0.20 | 6.5 | 38.2 | 0.33 | 0.31 | Forest with heavy ground litter & meadow | 0.19 | 0.08 | 5.00 | 0.02 | 0.03 | 0.02 | 0.03 | 0.02 | 0.04 |
| Bog Pond 5E | 0.24 | 11.9 | 41.9 | 0.31 | 0.33 | Forest with heavy ground litter & meadow | 0.26 | 0.08 | 5.00 | 0.02 | 0.04 | 0.02 | 0.04 | 0.03 | 0.05 |
| Bog Pond 6E | 0.12 | 7.5 | 48.6 | 0.31 | 0.33 | Forest with heavy ground litter & meadow | 0.21 | 0.08 | 5.00 | 0.01 | 0.02 | 0.01 | 0.02 | 0.01 | 0.02 |
| Bog Pond 7E | 1.38 | 10.3 | 49.4 | 0.32 | 0.32 | Nearly Bare Ground | 0.97 | 0.08 | 5.00 | 0.13 | 0.22 | 0.12 | 0.19 | 0.16 | 0.25 |
| Bog Pond 1F | 0.45 | 2.8 | 78.9 | 0.63 | 0.61 | Nearly Bare Ground | 0.51 | 0.08 | 5.00 | 0.08 | 0.13 | 0.08 | 0.12 | 0.10 | 0.15 |
| Bog Pond 2F | 1.13 | 5 | 200.6 | 0.57 | 0.56 | Nearly Bare Ground | 0.68 | 0.08 | 5.00 | 0.19 | 0.31 | 0.18 | 0.28 | 0.23 | 0.36 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | Return Period | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Bog Pond 3F | 1.05 | 4.5 | 102.0 | 0.48 | 0.47 | Forest with heavy ground litter & meadow | 0.16 | 0.18 | 10.68 | 0.10 | 0.16 | 0.09 | 0.14 | 0.12 | 0.19 |
| Bog Pond 4F | 0.77 | 6.2 | 85.4 | 0.41 | 0.41 | Nearly Bare Ground | 0.75 | 0.08 | 5.00 | 0.09 | 0.15 | 0.09 | 0.14 | 0.11 | 0.18 |
| Bog Pond 5F | 0.69 | 6.7 | 78.5 | 0.42 | 0.40 | Nearly Bare Ground | 0.78 | 0.08 | 5.00 | 0.08 | 0.14 | 0.08 | 0.12 | 0.10 | 0.16 |
| Bog Pond 1G | 0.89 | 2.6 | 53.7 | 0.60 | 0.59 | Nearly Bare Ground | 0.49 | 0.08 | 5.00 | 0.16 | 0.26 | 0.15 | 0.23 | 0.19 | 0.30 |
| Bog Pond 1H | 0.77 | 4.8 | 134.9 | 0.59 | 0.58 | Nearly Bare Ground | 0.66 | 0.08 | 5.00 | 0.13 | 0.22 | 0.12 | 0.20 | 0.16 | 0.25 |
| Bog Pond 2H | 0.16 | 2.9 | 47.6 | 0.36 | 0.32 | Nearly Bare Ground | 0.52 | 0.08 | 5.00 | 0.02 | 0.03 | 0.02 | 0.02 | 0.02 | 0.03 |
| Bog Pond 3H | 0.89 | 7.3 | 98.7 | 0.33 | 0.32 | Nearly Bare Ground | 0.82 | 0.08 | 5.00 | 0.08 | 0.14 | 0.08 | 0.12 | 0.10 | 0.16 |
| Bog Pond 4H | 1.21 | 5.5 | 169.4 | 0.45 | 0.44 | Nearly Bare Ground | 0.71 | 0.08 | 5.00 | 0.16 | 0.26 | 0.15 | 0.23 | 0.19 | 0.30 |
| Bog Pond 5H | 0.53 | 9.9 | 85.3 | 0.33 | 0.33 | Nearly Bare Ground | 0.95 | 0.08 | 5.00 | 0.05 | 0.08 | 0.05 | 0.08 | 0.06 | 0.10 |
| Bog Pond 6H | 3.48 | 3.8 | 332.4 | 0.90 | 0.89 | Forest with heavy ground litter & meadow | 0.15 | 0.63 | 37.89 | 0.29 | 0.48 | 0.28 | 0.44 | 0.36 | 0.57 |
| Bog Pond 7H | 1.17 | 7.6 | 122.7 | 0.47 | 0.47 | Forest with heavy ground litter & meadow | 0.21 | 0.16 | 9.87 | 0.11 | 0.18 | 0.10 | 0.17 | 0.13 | 0.22 |
| Bog Pond 8H | 0.69 | 4.8 | 71.2 | 0.62 | 0.60 | Nearly Bare Ground | 0.66 | 0.08 | 5.00 | 0.12 | 0.20 | 0.12 | 0.18 | 0.15 | 0.23 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report Return Period | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) 1993 Return Period | | 2019 Return Period | | Future Conditions Return Period | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Bog Pond 9H | 3.12 | 3.6 | 300.7 | 0.62 | 0.61 | short grass pasture and lawns | 0.41 | 0.20 | 12.26 | 0.34 | 0.56 | 0.32 | 0.50 | 0.42 | 0.65 |
| Bog Pond 10H | 3.24 | 1.3 | 325.0 | 1.00 | 1.00 | Forest with heavy ground litter & meadow | 0.09 | 1.06 | 63.50 | 0.46 | 0.76 | 0.44 | 0.34 | 0.57 | 0.91 |
| Bog Pond 11H | 3.52 | 1.5 | 350.0 | 1.42 | 1.41 | Forest with heavy ground litter & meadow | 0.09 | 1.06 | 63.64 | 0.35 | 0.58 | 0.23 | 0.37 | 0.44 | 0.69 |
| Bog Pond 1I | 0.28 | 8.3 | 99.9 | 0.54 | 0.53 | Nearly Bare Ground | 0.87 | 0.08 | 5.00 | 0.05 | 0.07 | 0.04 | 0.07 | 0.05 | 0.09 |
| Bog Pond 2I | 0.28 | 5.8 | 78.2 | 0.31 | 0.31 | Nearly Bare Ground | 0.73 | 0.08 | 5.00 | 0.03 | 0.04 | 0.02 | 0.04 | 0.03 | 0.05 |
| Bog Pond 3I | 0.32 | 2.2 | 66.7 | 0.39 | 0.39 | Nearly Bare Ground | 0.45 | 0.08 | 5.00 | 0.04 | 0.06 | 0.03 | 0.05 | 0.04 | 0.07 |
| Bog Pond 4I | 0.61 | 4.6 | 134.3 | 0.40 | 0.39 | Nearly Bare Ground | 0.65 | 0.08 | 5.00 | 0.07 | 0.12 | 0.07 | 0.10 | 0.09 | 0.14 |
| Bog Pond 5I | 0.61 | 12.5 | 135.3 | 0.33 | 0.32 | Nearly Bare Ground | 1.07 | 0.08 | 5.00 | 0.06 | 0.10 | 0.06 | 0.09 | 0.07 | 0.11 |
| Bog Pond 6I | 0.65 | 7.1 | 97.2 | 0.33 | 0.32 | Nearly Bare Ground | 0.81 | 0.08 | 5.00 | 0.06 | 0.10 | 0.06 | 0.09 | 0.08 | 0.12 |
| Bog Pond 7I | 0.61 | 5.4 | 137.6 | 0.59 | 0.58 | Nearly Bare Ground | 0.70 | 0.08 | 5.00 | 0.10 | 0.17 | 0.10 | 0.15 | 0.13 | 0.20 |
| Bog Pond 8I | 0.36 | 8.8 | 74.1 | 0.50 | 0.49 | Nearly Bare Ground | 0.90 | 0.08 | 5.00 | 0.05 | 0.09 | 0.05 | 0.08 | 0.07 | 0.10 |
| Bog Pond 9I | 0.12 | 8.3 | 30.7 | 0.79 | 0.79 | Nearly Bare Ground | 0.87 | 0.08 | 5.00 | 0.03 | 0.05 | 0.03 | 0.04 | 0.03 | 0.05 |
| Bog Pond 10I | 0.65 | 4.4 | 91.4 | 0.46 | 0.46 | Nearly Bare Ground | 0.64 | 0.08 | 5.00 | 0.09 | 0.14 | 0.08 | 0.13 | 0.11 | 0.17 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Return Period | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Bog Pond 11I | 0.20 | 3.6 | 115.0 | 0.91 | 0.91 | Nearly Bare Ground | 0.57 | 0.08 | 5.00 | 0.05 | 0.09 | 0.05 | 0.08 | 0.07 | 0.10 |
| Bog Pond 12I | 3.12 | 2.4 | 300.7 | 0.52 | 0.51 | short grass pasture and lawns | 0.33 | 0.25 | 15.01 | 0.25 | 0.42 | 0.24 | 0.38 | 0.31 | 0.49 |
| Bog Pond 13I | 2.19 | 1.1 | 320.0 | 0.81 | 0.81 | short grass pasture and lawns | 0.23 | 0.39 | 23.59 | 0.22 | 0.36 | 0.21 | 0.33 | 0.27 | 0.42 |
| Bristol Avenue West 1A | 0.53 | 3.7 | 90.0 | 0.97 | 0.96 | Nearly Bare Ground | 0.58 | 0.08 | 5.00 | 0.15 | 0.25 | 0.14 | 0.22 | 0.18 | 0.29 |
| Bristol Avenue West 2A | 1.29 | 4.2 | 156.9 | 0.58 | 0.58 | Nearly Bare Ground | 0.62 | 0.08 | 5.00 | 0.22 | 0.37 | 0.21 | 0.33 | 0.27 | 0.42 |
| Bristol Avenue West 3A | 0.77 | 5 | 89.5 | 0.60 | 0.60 | Nearly Bare Ground | 0.68 | 0.08 | 5.00 | 0.14 | 0.22 | 0.13 | 0.20 | 0.16 | 0.26 |
| Bristol Avenue West 4A | 0.61 | 5.4 | 92.2 | 0.48 | 0.47 | short grass pasture and lawns | 0.50 | 0.08 | 5.00 | 0.08 | 0.14 | 0.08 | 0.12 | 0.10 | 0.16 |
| Bristol Avenue West 5A | 0.69 | 7.1 | 100.9 | 0.48 | 0.47 | short grass pasture and lawns | 0.57 | 0.08 | 5.00 | 0.10 | 0.16 | 0.09 | 0.14 | 0.12 | 0.18 |
| Bristol Avenue West 6A | 0.93 | 8.3 | 130.2 | 0.46 | 0.45 | short grass pasture and lawns | 0.62 | 0.08 | 5.00 | 0.12 | 0.21 | 0.12 | 0.18 | 0.15 | 0.24 |
| Bristol Avenue West 7A | 1.17 | 4.9 | 175.4 | 0.54 | 0.53 | Nearly Bare Ground | 0.67 | 0.08 | 5.00 | 0.19 | 0.31 | 0.17 | 0.27 | 0.23 | 0.36 |
| Bristol Avenue West 8A | 1.90 | 4.4 | 226.1 | 0.56 | 0.56 | Nearly Bare Ground | 0.64 | 0.10 | 5.93 | 0.28 | 0.47 | 0.26 | 0.42 | 0.34 | 0.55 |
| Bristol Avenue West 9A | 0.57 | 6 | 101.7 | 0.31 | 0.31 | Nearly Bare Ground | 0.74 | 0.08 | 5.00 | 0.05 | 0.08 | 0.05 | 0.08 | 0.06 | 0.10 |
| Bristol Avenue West 10A | 1.13 | 6.4 | 190.4 | 0.87 | 0.88 | Forest with heavy ground litter & meadow | 0.19 | 0.28 | 16.71 | 0.15 | 0.25 | 0.14 | 0.22 | 0.18 | 0.29 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | Return Period | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Bristol Avenue West 11A | 0.77 | 4.2 | 175.2 | 0.30 | 0.30 | Nearly Bare Ground | 0.62 | 0.08 | 5.00 | 0.07 | 0.11 | 0.06 | 0.10 | 0.08 | 0.13 |
| Bristol Avenue West 12A | 0.32 | 9.5 | 34.6 | 0.33 | 0.33 | Nearly Bare Ground | 0.93 | 0.08 | 5.00 | 0.03 | 0.05 | 0.03 | 0.05 | 0.04 | 0.06 |
| Bristol Avenue West 13A | 1.94 | 7.5 | 173.6 | 0.45 | 0.45 | Nearly Bare Ground | 0.83 | 0.08 | 5.00 | 0.26 | 0.43 | 0.24 | 0.38 | 0.31 | 0.50 |
| Bristol Avenue West 14A | 0.16 | 8.8 | 175.3 | 0.36 | 0.32 | Nearly Bare Ground | 0.90 | 0.08 | 5.00 | 0.02 | 0.03 | 0.02 | 0.02 | 0.02 | 0.03 |
| Bristol Avenue West 15A | 0.40 | 8.7 | 82.2 | 0.37 | 0.39 | Forest with heavy ground litter & meadow | 0.22 | 0.10 | 6.18 | 0.04 | 0.07 | 0.04 | 0.06 | 0.05 | 0.08 |
| Bristol Avenue West 16A | 3.28 | 2.2 | 183.2 | 1.00 | 1.00 | Forest with heavy ground litter & meadow | 0.11 | 0.46 | 27.49 | 0.53 | 0.88 | 0.35 | 0.55 | 0.66 | 1.04 |
| Bristol Avenue West 17A | 1.70 | 2.4 | 110.8 | 0.61 | 0.60 | Forest with heavy ground litter & meadow | 0.12 | 0.27 | 15.90 | 0.16 | 0.26 | 0.15 | 0.24 | 0.19 | 0.31 |
| Bristol Avenue West 18A | 2.83 | 2.4 | 177.7 | 1.00 | 1.00 | Forest with heavy ground litter & meadow | 0.12 | 0.43 | 25.51 | 0.46 | 0.77 | 0.31 | 0.50 | 0.57 | 0.91 |
| Bristol Avenue West 19A | 1.94 | 2.8 | 34.2 | 0.33 | 0.33 | Forest with heavy ground litter & meadow | 0.13 | 0.08 | 5.00 | 0.19 | 0.31 | 0.18 | 0.28 | 0.23 | 0.36 |
| Bristol Avenue West 20A | 10.12 | 6 | 359.9 | 0.81 | 0.80 | Forest with heavy ground litter & meadow | 0.18 | 0.54 | 32.61 | 0.83 | 1.38 | 0.79 | 1.26 | 1.03 | 1.63 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report (Return Period) | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) 1993 (Return Period) | | Flow (m3/s) 2019 (Return Period) | | Flow (m3/s) Future Conditions (Return Period) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Bristol Avenue West 1B | 0.53 | 15.3 | 13.8 | 0.66 | 0.65 | Forest with heavy ground litter & meadow | 0.29 | 0.08 | 5.00 | 0.10 | 0.17 | 0.10 | 0.15 | 0.12 | 0.19 |
| Bristol Avenue West 2B | 0.12 | 9.4 | 104.8 | 0.64 | 0.64 | Nearly Bare Ground | 0.93 | 0.08 | 5.00 | 0.02 | 0.04 | 0.02 | 0.03 | 0.03 | 0.04 |
| Bristol Avenue West 3B | 7.08 | 1.3 | 359.9 | 0.98 | 0.97 | Nearly Bare Ground | 0.35 | 0.29 | 17.37 | 1.01 | 1.67 | 0.96 | 1.51 | 1.24 | 1.96 |
| Bristol Avenue West 4B | 0.57 | 7.9 | 57.1 | 0.73 | 0.72 | Nearly Bare Ground | 0.85 | 0.08 | 5.00 | 0.12 | 0.20 | 0.11 | 0.18 | 0.15 | 0.23 |
| Bristol Avenue West 5B | 1.13 | 14.3 | 114.7 | 0.32 | 0.32 | Nearly Bare Ground | 1.14 | 0.08 | 5.00 | 0.10 | 0.18 | 0.10 | 0.16 | 0.13 | 0.20 |
| Bristol Avenue West 6B | 0.40 | 12.5 | 120.3 | 0.71 | 0.70 | Nearly Bare Ground | 1.07 | 0.08 | 5.00 | 0.08 | 0.14 | 0.08 | 0.12 | 0.10 | 0.16 |
| Bristol Avenue West 7B | 4.53 | 15 | 284.7 | 0.58 | 0.58 | Nearly Bare Ground | 1.17 | 0.08 | 5.00 | 0.77 | 1.28 | 0.72 | 1.14 | 0.94 | 1.48 |
| Bristol Avenue East 1A | 0.32 | 8.8 | 40.1 | 0.48 | 0.48 | Nearly Bare Ground | 0.90 | 0.08 | 5.00 | 0.05 | 0.08 | 0.04 | 0.07 | 0.05 | 0.09 |
| Bristol Avenue East 2A | 0.57 | 1.7 | 50.4 | 0.46 | 0.45 | Nearly Bare Ground | 0.39 | 0.08 | 5.00 | 0.08 | 0.12 | 0.07 | 0.11 | 0.09 | 0.14 |
| Bristol Avenue East 3A | 1.54 | 4 | 136.9 | 0.31 | 0.31 | Nearly Bare Ground | 0.61 | 0.08 | 5.00 | 0.14 | 0.24 | 0.13 | 0.21 | 0.17 | 0.27 |
| Bristol Avenue East 4A | 1.34 | 5.4 | 208.4 | 0.30 | 0.30 | Nearly Bare Ground | 0.70 | 0.08 | 5.00 | 0.12 | 0.20 | 0.11 | 0.17 | 0.14 | 0.23 |
| Bristol Avenue East 1B | 3.97 | 1.8 | 254.9 | 0.86 | 0.86 | Forest with heavy ground litter & meadow | 0.10 | 0.70 | 42.30 | 0.30 | 0.50 | 0.29 | 0.46 | 0.37 | 0.59 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Return Period | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Bristol Avenue East 2B | 0.65 | 8.3 | 70.0 | 0.34 | 0.34 | Forest with heavy ground litter & meadow | 0.22 | 0.09 | 5.39 | 0.06 | 0.10 | 0.06 | 0.09 | 0.08 | 0.12 |
| Bristol Avenue East 1C | 9.06 | 1.8 | 599.8 | 0.47 | 0.47 | Nearly Bare Ground | 0.41 | 0.41 | 24.61 | 0.51 | 0.85 | 0.48 | 0.77 | 0.63 | 1.00 |
| Bristol Avenue East 2C | 0.40 | 6.8 | 109.6 | 0.33 | 0.34 | Nearly Bare Ground | 0.79 | 0.08 | 5.00 | 0.04 | 0.07 | 0.04 | 0.06 | 0.05 | 0.08 |
| Bristol Avenue East 3C | 0.81 | 6.2 | 127.6 | 0.45 | 0.45 | Nearly Bare Ground | 0.75 | 0.08 | 5.00 | 0.11 | 0.18 | 0.10 | 0.16 | 0.13 | 0.21 |
| Bristol Avenue East 4C | 0.81 | 7.3 | 132.5 | 0.45 | 0.45 | Nearly Bare Ground | 0.82 | 0.08 | 5.00 | 0.11 | 0.18 | 0.10 | 0.16 | 0.13 | 0.21 |
| Bristol Avenue East 5C | 0.08 | 0.1 | 22.5 | 0.36 | 0.36 | Nearly Bare Ground | 0.10 | 0.08 | 5.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 |
| Bristol Avenue East 6C | 1.94 | 4.2 | 179.6 | 0.44 | 0.43 | Nearly Bare Ground | 0.62 | 0.08 | 5.00 | 0.25 | 0.41 | 0.23 | 0.37 | 0.30 | 0.48 |
| Bristol Avenue East 7C | 1.21 | 1.7 | 125.0 | 0.55 | 0.54 | Nearly Bare Ground | 0.39 | 0.09 | 5.28 | 0.19 | 0.31 | 0.18 | 0.28 | 0.23 | 0.36 |
| Bristol Avenue East 8C | 3.97 | 4.2 | 84.9 | 0.68 | 0.68 | Nearly Bare Ground | 0.62 | 0.08 | 5.00 | 0.80 | 1.31 | 0.74 | 1.18 | 0.96 | 1.53 |
| Bristol Avenue East 9C | 2.35 | 5.9 | 301.7 | 0.65 | 0.65 | Nearly Bare Ground | 0.74 | 0.11 | 6.84 | 0.38 | 0.62 | 0.35 | 0.56 | 0.46 | 0.73 |
| Bristol Avenue East 10C | 0.89 | 6.9 | 195.0 | 0.64 | 0.62 | Forest with heavy ground litter & meadow | 0.20 | 0.27 | 16.47 | 0.08 | 0.14 | 0.08 | 0.13 | 0.10 | 0.16 |
| Bristol Avenue East 11C | 0.40 | 8.7 | 76.9 | 0.36 | 0.36 | Forest with heavy ground litter & meadow | 0.22 | 0.10 | 5.78 | 0.04 | 0.07 | 0.04 | 0.06 | 0.05 | 0.08 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | Return Period | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Bristol Avenue East 12C | 1.25 | 8.7 | 129.5 | 0.55 | 0.55 | Nearly Bare Ground | 0.89 | 0.08 | 5.00 | 0.20 | 0.34 | 0.19 | 0.30 | 0.25 | 0.39 |
| Bristol Avenue East 13C | 0.73 | 4.3 | 170.0 | 0.63 | 0.63 | Forest with heavy ground litter & meadow | 0.16 | 0.30 | 18.21 | 0.07 | 0.11 | 0.06 | 0.10 | 0.08 | 0.13 |
| Bristol Avenue East 14C | 0.28 | 1.8 | 109.0 | 0.34 | 0.33 | Nearly Bare Ground | 0.41 | 0.08 | 5.00 | 0.03 | 0.05 | 0.03 | 0.04 | 0.03 | 0.05 |
| Bristol Avenue East 15C | 0.61 | 3.9 | 134.8 | 0.64 | 0.63 | Nearly Bare Ground | 0.60 | 0.08 | 5.00 | 0.11 | 0.19 | 0.11 | 0.17 | 0.14 | 0.22 |
| Bristol Avenue East 16C | 1.05 | 4 | 100.0 | 0.63 | 0.62 | Nearly Bare Ground | 0.61 | 0.08 | 5.00 | 0.20 | 0.32 | 0.18 | 0.29 | 0.24 | 0.37 |
| Bristol Avenue East 17C | 9.06 | 4.8 | 269.2 | 0.36 | 0.35 | Nearly Bare Ground | 0.66 | 0.11 | 6.76 | 0.80 | 1.32 | 0.75 | 1.18 | 0.97 | 1.54 |
| Bristol Avenue East 18C | 4.13 | 1.7 | 284.3 | 0.43 | 0.43 | Nearly Bare Ground | 0.39 | 0.20 | 12.00 | 0.32 | 0.53 | 0.30 | 0.48 | 0.39 | 0.62 |
| Bristol Avenue East 19C | 5.99 | 2.4 | 547.6 | 0.52 | 0.51 | Nearly Bare Ground | 0.47 | 0.32 | 19.46 | 0.42 | 0.70 | 0.40 | 0.63 | 0.52 | 0.82 |
| Bristol Avenue East 20C | 7.77 | 3.3 | 584.6 | 0.51 | 0.51 | Nearly Bare Ground | 0.55 | 0.30 | 17.72 | 0.57 | 0.95 | 0.54 | 0.86 | 0.70 | 1.11 |
| Bristol Avenue East 21C | 3.44 | 3.6 | 299.6 | 0.86 | 0.85 | Forest with heavy ground litter & meadow | 0.14 | 0.58 | 35.09 | 0.29 | 0.48 | 0.27 | 0.43 | 0.36 | 0.56 |
| Bristol Avenue East 22C | 1.34 | 1.7 | 130.2 | 0.69 | 0.67 | Forest with heavy ground litter & meadow | 0.10 | 0.37 | 22.23 | 0.12 | 0.19 | 0.11 | 0.17 | 0.14 | 0.22 |
| Bristol Avenue East 23C | 1.17 | 5.5 | 144.7 | 0.55 | 0.55 | Forest with heavy ground litter & meadow | 0.18 | 0.23 | 13.69 | 0.11 | 0.18 | 0.10 | 0.16 | 0.13 | 0.21 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Return Period | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Bristol Avenue East 24C | 19.02 | 3.7 | 997.6 | 1.00 | 1.00 | Forest with heavy ground litter & meadow | 0.14 | 1.92 | 115.25 | 1.80 | 2.96 | 0.91 | 2.74 | 2.24 | 3.56 |
| Bristol Avenue East 25C | 5.34 | 5.3 | 352.6 | 0.85 | 0.85 | Forest with heavy ground litter & meadow | 0.17 | 0.57 | 34.01 | 0.46 | 0.75 | 0.43 | 0.69 | 0.56 | 0.89 |
| Bristol Avenue East 26C | 4.69 | 3.7 | 262.2 | 0.80 | 0.79 | Forest with heavy ground litter & meadow | 0.14 | 0.50 | 30.29 | 0.40 | 0.66 | 0.38 | 0.60 | 0.49 | 0.78 |
| Bristol Avenue East 27C | 0.93 | 7.2 | 136.3 | 0.49 | 0.49 | Forest with heavy ground litter & meadow | 0.20 | 0.19 | 11.27 | 0.08 | 0.14 | 0.08 | 0.13 | 0.10 | 0.17 |
| Bristol Avenue East 28C | 5.99 | 3 | 251.8 | 0.83 | 0.82 | Forest with heavy ground litter & meadow | 0.13 | 0.54 | 32.32 | 0.51 | 0.84 | 0.48 | 0.77 | 0.63 | 1.00 |
| Bristol Avenue East 29C | 5.22 | 3.9 | 284.1 | 0.81 | 0.81 | Forest with heavy ground litter & meadow | 0.15 | 0.53 | 31.97 | 0.44 | 0.72 | 0.42 | 0.66 | 0.54 | 0.86 |
| Bristol Avenue East 30C | 59.00 | 5.6 | 1387.1 | 1.00 | 1.00 | Forest with heavy ground litter & meadow | 0.18 | 2.17 | 130.13 | 3.40 | 5.63 | 2.64 | 4.21 | 4.25 | 6.77 |
| Cobbs Ridge 1A | 0.40 | 20 | 52.7 | 0.62 | 0.60 | Nearly Bare Ground | 1.35 | 0.08 | 5.00 | 0.07 | 0.12 | 0.07 | 0.11 | 0.09 | 0.14 |
| Cobbs Ridge 2A | 0.97 | 14.6 | 86.4 | 0.61 | 0.60 | Nearly Bare Ground | 1.16 | 0.08 | 5.00 | 0.17 | 0.29 | 0.16 | 0.26 | 0.21 | 0.33 |
| Cobbs Ridge 3A | 1.58 | 11 | 96.4 | 0.61 | 0.61 | Nearly Bare Ground | 1.00 | 0.08 | 5.00 | 0.28 | 0.47 | 0.26 | 0.42 | 0.34 | 0.54 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report Return Period | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) 1993 Return Period | | Flow (m3/s) 2019 Return Period | | Flow (m3/s) Future Conditions Return Period | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Cobbs Ridge 4A | 0.81 | 15 | 28.0 | 0.62 | 0.61 | Nearly Bare Ground | 1.17 | 0.08 | 5.00 | 0.15 | 0.24 | 0.14 | 0.22 | 0.18 | 0.28 |
| Cobbs Ridge 5A | 0.73 | 12.7 | 52.1 | 0.21 | 0.60 | Nearly Bare Ground | 1.08 | 0.08 | 5.00 | 0.05 | 0.21 | 0.04 | 0.19 | 0.05 | 0.25 |
| Cobbs Ridge 6A | 0.57 | 8.3 | 52.5 | 0.63 | 0.62 | Nearly Bare Ground | 0.87 | 0.08 | 5.00 | 0.10 | 0.17 | 0.10 | 0.15 | 0.13 | 0.20 |
| Cobbs Ridge 7A | 0.53 | 6.3 | 160.4 | 0.61 | 0.58 | Nearly Bare Ground | 0.76 | 0.08 | 5.00 | 0.09 | 0.15 | 0.09 | 0.13 | 0.11 | 0.17 |
| Cobbs Ridge 8A | 0.77 | 5.7 | 168.6 | 0.58 | 0.57 | Nearly Bare Ground | 0.72 | 0.08 | 5.00 | 0.13 | 0.22 | 0.12 | 0.19 | 0.16 | 0.25 |
| Cobbs Ridge 9A | 1.21 | 3.5 | 83.7 | 0.86 | 0.85 | Nearly Bare Ground | 0.57 | 0.08 | 5.00 | 0.31 | 0.50 | 0.29 | 0.45 | 0.37 | 0.59 |
| Cobbs Ridge 10A | 1.05 | 4.1 | 81.2 | 0.87 | 0.86 | Nearly Bare Ground | 0.61 | 0.08 | 5.00 | 0.27 | 0.44 | 0.25 | 0.40 | 0.33 | 0.51 |
| Cobbs Ridge 11A | 1.09 | 3.5 | 223.8 | 0.95 | 0.93 | Nearly Bare Ground | 0.57 | 0.11 | 6.58 | 0.26 | 0.43 | 0.24 | 0.38 | 0.32 | 0.50 |
| Cobbs Ridge 12A | 0.53 | 2.6 | 116.6 | 0.86 | 0.86 | Nearly Bare Ground | 0.49 | 0.08 | 5.00 | 0.13 | 0.22 | 0.12 | 0.20 | 0.16 | 0.26 |
| Cobbs Ridge 13A | 0.89 | 3.4 | 194.3 | 0.90 | 0.88 | Nearly Bare Ground | 0.56 | 0.10 | 5.80 | 0.22 | 0.35 | 0.20 | 0.32 | 0.26 | 0.41 |
| Cobbs Ridge 14A | 1.05 | 3.9 | 147.2 | 0.87 | 0.86 | Nearly Bare Ground | 0.60 | 0.08 | 5.00 | 0.27 | 0.44 | 0.25 | 0.40 | 0.33 | 0.51 |
| Cobbs Ridge 15A | 1.50 | 4.9 | 193.2 | 0.85 | 0.83 | Nearly Bare Ground | 0.67 | 0.08 | 5.00 | 0.37 | 0.61 | 0.35 | 0.55 | 0.45 | 0.71 |
| Cobbs Ridge 1B | 1.38 | 3.2 | 171.3 | 0.87 | 0.86 | Nearly Bare Ground | 0.54 | 0.09 | 5.27 | 0.34 | 0.56 | 0.32 | 0.50 | 0.41 | 0.65 |
| Cobbs Ridge 2B | 0.89 | 4.1 | 180.7 | 0.83 | 0.83 | Nearly Bare Ground | 0.61 | 0.08 | 5.00 | 0.22 | 0.36 | 0.20 | 0.32 | 0.26 | 0.42 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Return Period | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Cobbs Ridge 3B | 1.42 | 6 | 170.3 | 0.77 | 0.76 | Nearly Bare Ground | 0.74 | 0.08 | 5.00 | 0.32 | 0.53 | 0.30 | 0.47 | 0.39 | 0.61 |
| Cobbs Ridge 4B | 0.36 | 1.1 | 104.5 | 0.84 | 0.82 | Nearly Bare Ground | 0.32 | 0.09 | 5.48 | 0.08 | 0.14 | 0.08 | 0.12 | 0.10 | 0.16 |
| Cobbs Ridge 5B | 0.73 | 3.5 | 109.2 | 0.46 | 0.46 | Nearly Bare Ground | 0.57 | 0.08 | 5.00 | 0.10 | 0.16 | 0.09 | 0.15 | 0.12 | 0.19 |
| Cobbs Ridge 6B | 0.08 | 5.2 | 34.7 | 0.71 | 0.79 | Nearly Bare Ground | 0.69 | 0.08 | 5.00 | 0.02 | 0.03 | 0.02 | 0.03 | 0.02 | 0.04 |
| Cobbs Ridge 7B | 0.24 | 8 | 108.2 | 0.87 | 0.87 | Nearly Bare Ground | 0.86 | 0.08 | 5.00 | 0.06 | 0.10 | 0.06 | 0.09 | 0.08 | 0.12 |
| Cobbs Ridge 8B | 0.73 | 9.6 | 137.2 | 0.75 | 0.74 | Nearly Bare Ground | 0.94 | 0.08 | 5.00 | 0.16 | 0.26 | 0.15 | 0.24 | 0.20 | 0.31 |
| Cobbs Ridge 1C | 0.65 | 2.8 | 105.8 | 0.58 | 0.57 | Nearly Bare Ground | 0.51 | 0.08 | 5.00 | 0.11 | 0.18 | 0.10 | 0.16 | 0.13 | 0.21 |
| Cobbs Ridge 2C | 0.16 | 6.7 | 52.2 | 0.66 | 0.68 | Nearly Bare Ground | 0.78 | 0.08 | 5.00 | 0.03 | 0.05 | 0.03 | 0.05 | 0.04 | 0.06 |
| Cobbs Ridge 3C | 0.36 | 2.1 | 38.2 | 0.82 | 0.81 | Nearly Bare Ground | 0.44 | 0.08 | 5.00 | 0.09 | 0.14 | 0.08 | 0.13 | 0.11 | 0.17 |
| Cobbs Ridge 4C | 0.65 | 4.2 | 136.4 | 0.66 | 0.64 | Nearly Bare Ground | 0.62 | 0.08 | 5.00 | 0.12 | 0.20 | 0.12 | 0.18 | 0.15 | 0.24 |
| Cobbs Ridge 5C | 0.24 | 3.8 | 92.0 | 0.87 | 0.83 | Nearly Bare Ground | 0.59 | 0.08 | 5.00 | 0.06 | 0.10 | 0.06 | 0.09 | 0.08 | 0.12 |
| Cobbs Ridge 6C | 0.45 | 2.2 | 107.0 | 0.63 | 0.62 | Nearly Bare Ground | 0.45 | 0.08 | 5.00 | 0.08 | 0.14 | 0.08 | 0.12 | 0.10 | 0.16 |
| Cobbs Ridge 7C | 0.32 | 6.5 | 88.2 | 0.33 | 0.34 | Nearly Bare Ground | 0.77 | 0.08 | 5.00 | 0.03 | 0.05 | 0.03 | 0.05 | 0.04 | 0.06 |
| Cobbs Ridge 8C | 0.65 | 4.6 | 78.2 | 0.48 | 0.47 | Nearly Bare Ground | 0.65 | 0.08 | 5.00 | 0.09 | 0.15 | 0.08 | 0.13 | 0.11 | 0.17 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Return Period | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Cobbs Ridge 9C | 0.36 | 4.3 | 67.2 | 0.45 | 0.46 | Nearly Bare Ground | 0.63 | 0.08 | 5.00 | 0.05 | 0.08 | 0.04 | 0.07 | 0.06 | 0.10 |
| Cobbs Ridge 10C | 0.08 | 3.6 | 32.6 | 0.36 | 0.36 | Nearly Bare Ground | 0.57 | 0.08 | 5.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 |
| Cobbs Ridge 11C | 0.81 | 5 | 97.4 | 0.61 | 0.60 | Nearly Bare Ground | 0.68 | 0.08 | 5.00 | 0.14 | 0.24 | 0.13 | 0.21 | 0.17 | 0.28 |
| Cobbs Ridge 12C | 0.02 | 2.9 | 83.5 | 0.60 | 0.60 | Nearly Bare Ground | 0.52 | 0.08 | 5.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.01 |
| Cobbs Ridge 13C | 0.12 | 3.6 | 50.2 | 0.64 | 0.67 | Nearly Bare Ground | 0.57 | 0.08 | 5.00 | 0.02 | 0.04 | 0.02 | 0.04 | 0.03 | 0.05 |
| Cobbs Ridge 14C | 0.16 | 5 | 65.7 | 0.54 | 0.54 | Nearly Bare Ground | 0.68 | 0.08 | 5.00 | 0.03 | 0.04 | 0.02 | 0.04 | 0.03 | 0.05 |
| Cobbs Ridge 15C | 0.20 | 1.2 | 56.9 | 0.52 | 0.54 | Nearly Bare Ground | 0.33 | 0.08 | 5.00 | 0.03 | 0.05 | 0.03 | 0.05 | 0.04 | 0.06 |
| Cobbs Ridge 16C | 0.20 | 3.5 | 68.3 | 0.62 | 0.62 | Nearly Bare Ground | 0.57 | 0.08 | 5.00 | 0.04 | 0.06 | 0.03 | 0.05 | 0.04 | 0.07 |
| Cobbs Ridge 17C | 0.61 | 1.9 | 79.3 | 0.46 | 0.45 | Nearly Bare Ground | 0.42 | 0.08 | 5.00 | 0.08 | 0.13 | 0.08 | 0.12 | 0.10 | 0.15 |
| Cobbs Ridge 18C | 0.24 | 2.9 | 91.7 | 0.95 | 0.95 | Nearly Bare Ground | 0.52 | 0.08 | 5.00 | 0.07 | 0.11 | 0.06 | 0.10 | 0.08 | 0.13 |
| Cobbs Ridge 19C | 0.32 | 1 | 62.6 | 0.48 | 0.45 | Nearly Bare Ground | 0.30 | 0.08 | 5.00 | 0.05 | 0.07 | 0.04 | 0.06 | 0.05 | 0.08 |
| Cobbs Ridge 20C | 0.45 | 9.7 | 131.8 | 0.46 | 0.44 | Nearly Bare Ground | 0.94 | 0.08 | 5.00 | 0.06 | 0.10 | 0.06 | 0.09 | 0.07 | 0.11 |
| Cobbs Ridge 21C | 0.04 | 10 | 41.1 | 0.71 | 0.86 | Nearly Bare Ground | 0.96 | 0.08 | 5.00 | 0.01 | 0.02 | 0.01 | 0.02 | 0.01 | 0.02 |
| Cobbs Ridge 22C | 0.04 | 12.5 | 23.0 | 0.95 | 0.86 | Nearly Bare Ground | 1.07 | 0.08 | 5.00 | 0.01 | 0.02 | 0.01 | 0.02 | 0.01 | 0.02 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Return Period | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Cobbs Ridge 1D | 0.08 | 12.5 | 17.9 | 0.71 | 0.71 | Nearly Bare Ground | 1.07 | 0.08 | 5.00 | 0.02 | 0.03 | 0.02 | 0.03 | 0.02 | 0.03 |
| Cobbs Ridge 2D | 0.77 | 4.2 | 173.6 | 0.75 | 0.74 | Nearly Bare Ground | 0.62 | 0.08 | 5.00 | 0.17 | 0.28 | 0.16 | 0.25 | 0.21 | 0.32 |
| Cobbs Ridge 3D | 0.12 | 8.1 | 56.7 | 0.64 | 0.67 | Nearly Bare Ground | 0.86 | 0.08 | 5.00 | 0.02 | 0.04 | 0.02 | 0.04 | 0.03 | 0.05 |
| Cobbs Ridge 4D | 1.17 | 4.4 | 188.1 | 0.66 | 0.65 | Nearly Bare Ground | 0.64 | 0.08 | 5.00 | 0.23 | 0.37 | 0.21 | 0.33 | 0.27 | 0.43 |
| Cobbs Ridge 1E | 0.61 | 6.1 | 66.3 | 0.79 | 0.79 | Nearly Bare Ground | 0.75 | 0.08 | 5.00 | 0.14 | 0.24 | 0.13 | 0.21 | 0.17 | 0.27 |
| Cobbs Ridge 2E | 0.85 | 3.5 | 198.6 | 0.58 | 0.56 | Nearly Bare Ground | 0.57 | 0.10 | 5.84 | 0.13 | 0.22 | 0.12 | 0.19 | 0.16 | 0.25 |
| Cobbs Ridge 3E | 0.20 | 5.9 | 48.8 | 0.86 | 0.86 | Nearly Bare Ground | 0.74 | 0.08 | 5.00 | 0.05 | 0.08 | 0.05 | 0.08 | 0.06 | 0.10 |
| Cobbs Ridge 4E | 0.57 | 1.5 | 99.6 | 0.66 | 0.65 | Nearly Bare Ground | 0.37 | 0.08 | 5.00 | 0.11 | 0.18 | 0.10 | 0.16 | 0.13 | 0.21 |
| Cobbs Ridge 5E | 0.49 | 3.2 | 125.5 | 0.74 | 0.73 | Nearly Bare Ground | 0.54 | 0.08 | 5.00 | 0.10 | 0.17 | 0.10 | 0.15 | 0.13 | 0.20 |
| Cobbs Ridge 6E | 0.45 | 3.1 | 122.2 | 0.43 | 0.43 | Nearly Bare Ground | 0.53 | 0.08 | 5.00 | 0.06 | 0.09 | 0.05 | 0.08 | 0.07 | 0.11 |
| Cobbs Ridge 7E | 0.77 | 5.5 | 171.0 | 0.69 | 0.68 | Nearly Bare Ground | 0.71 | 0.08 | 5.00 | 0.16 | 0.25 | 0.15 | 0.23 | 0.19 | 0.30 |
| Cobbs Ridge 8E | 0.49 | 3.7 | 97.9 | 0.46 | 0.45 | Nearly Bare Ground | 0.58 | 0.08 | 5.00 | 0.07 | 0.11 | 0.06 | 0.10 | 0.08 | 0.12 |
| Cobbs Ridge 9E | 0.36 | 2.7 | 84.7 | 0.45 | 0.45 | Nearly Bare Ground | 0.50 | 0.08 | 5.00 | 0.05 | 0.08 | 0.04 | 0.07 | 0.06 | 0.09 |
| Cobbs Ridge 10E | 0.73 | 2.9 | 118.6 | 0.46 | 0.45 | Nearly Bare Ground | 0.52 | 0.08 | 5.00 | 0.10 | 0.16 | 0.09 | 0.14 | 0.12 | 0.19 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Return Period | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Cobbs Ridge 11E | 0.73 | 3.7 | 130.5 | 0.45 | 0.45 | Nearly Bare Ground | 0.58 | 0.08 | 5.00 | 0.10 | 0.16 | 0.09 | 0.14 | 0.12 | 0.18 |
| Cobbs Ridge 12E | 0.20 | 4.4 | 57.1 | 0.33 | 0.33 | Nearly Bare Ground | 0.64 | 0.08 | 5.00 | 0.02 | 0.03 | 0.02 | 0.03 | 0.02 | 0.04 |
| Cobbs Ridge 13E | 0.69 | 3.4 | 136.5 | 0.31 | 0.31 | Nearly Bare Ground | 0.56 | 0.08 | 5.00 | 0.06 | 0.10 | 0.06 | 0.09 | 0.08 | 0.12 |
| Cobbs Ridge 14E | 0.53 | 2.8 | 102.3 | 0.57 | 0.56 | Nearly Bare Ground | 0.51 | 0.08 | 5.00 | 0.09 | 0.14 | 0.08 | 0.13 | 0.11 | 0.17 |
| Cobbs Ridge 15E | 0.24 | 3.3 | 130.1 | 0.71 | 0.69 | Nearly Bare Ground | 0.55 | 0.08 | 5.00 | 0.05 | 0.08 | 0.05 | 0.07 | 0.06 | 0.10 |
| Cobbs Ridge 16E | 0.08 | 3.3 | 35.9 | 0.71 | 0.71 | Nearly Bare Ground | 0.55 | 0.08 | 5.00 | 0.02 | 0.03 | 0.02 | 0.03 | 0.02 | 0.03 |
| Cobbs Ridge 17E | 0.40 | 3.4 | 78.1 | 0.57 | 0.56 | Nearly Bare Ground | 0.56 | 0.08 | 5.00 | 0.07 | 0.11 | 0.06 | 0.10 | 0.08 | 0.13 |
| Cobbs Ridge 18E | 0.65 | 3.6 | 99.6 | 0.91 | 0.89 | Nearly Bare Ground | 0.57 | 0.08 | 5.00 | 0.17 | 0.28 | 0.16 | 0.25 | 0.21 | 0.33 |
| Cobbs Ridge 19E | 0.12 | 2.9 | 65.5 | 0.95 | 0.95 | Nearly Bare Ground | 0.52 | 0.08 | 5.00 | 0.03 | 0.06 | 0.03 | 0.05 | 0.04 | 0.07 |
| Cobbs Ridge 20E | 0.40 | 3.8 | 86.2 | 0.29 | 0.27 | Nearly Bare Ground | 0.59 | 0.08 | 5.00 | 0.03 | 0.05 | 0.03 | 0.05 | 0.04 | 0.06 |
| Cobbs Ridge 21E | 0.16 | 3.6 | 57.4 | 0.24 | 0.24 | Nearly Bare Ground | 0.57 | 0.08 | 5.00 | 0.01 | 0.02 | 0.01 | 0.02 | 0.01 | 0.02 |
| Cobbs Ridge 22E | 0.24 | 3.4 | 78.6 | 0.31 | 0.33 | Nearly Bare Ground | 0.56 | 0.08 | 5.00 | 0.02 | 0.04 | 0.02 | 0.04 | 0.03 | 0.05 |
| Cobbs Ridge 23E | 0.45 | 0.6 | 148.1 | 0.59 | 0.59 | Nearly Bare Ground | 0.23 | 0.18 | 10.52 | 0.05 | 0.08 | 0.05 | 0.08 | 0.06 | 0.10 |
| Cobbs Ridge 24E | 0.28 | 2.9 | 98.1 | 0.58 | 0.59 | Nearly Bare Ground | 0.52 | 0.08 | 5.00 | 0.05 | 0.08 | 0.04 | 0.07 | 0.06 | 0.10 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | Return Period | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Cobbs Ridge 25E | 0.04 | 1.3 | 18.5 | 0.48 | 0.48 | Nearly Bare Ground | 0.35 | 0.08 | 5.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Cobbs Ridge 26E | 0.40 | 3.1 | 117.4 | 0.45 | 0.44 | Nearly Bare Ground | 0.53 | 0.08 | 5.00 | 0.05 | 0.09 | 0.05 | 0.08 | 0.07 | 0.10 |
| Cobbs Ridge 27E | 0.20 | 1.5 | 43.9 | 0.71 | 0.69 | Nearly Bare Ground | 0.37 | 0.08 | 5.00 | 0.04 | 0.07 | 0.04 | 0.06 | 0.05 | 0.08 |
| Cobbs Ridge 28E | 0.36 | 0.9 | 8.3 | 0.61 | 0.59 | Nearly Bare Ground | 0.29 | 0.08 | 5.00 | 0.07 | 0.10 | 0.06 | 0.09 | 0.08 | 0.12 |
| Cobbs Ridge 29E | 0.12 | 1.2 | 37.6 | 0.64 | 0.64 | Nearly Bare Ground | 0.33 | 0.08 | 5.00 | 0.02 | 0.04 | 0.02 | 0.03 | 0.03 | 0.04 |
| Cobbs Ridge 30E | 0.65 | 1.8 | 145.8 | 0.35 | 0.34 | Nearly Bare Ground | 0.41 | 0.10 | 5.98 | 0.06 | 0.10 | 0.06 | 0.09 | 0.07 | 0.11 |
| Cobbs Ridge 31E | 0.28 | 1.4 | 71.7 | 0.31 | 0.31 | Nearly Bare Ground | 0.36 | 0.08 | 5.00 | 0.03 | 0.04 | 0.02 | 0.04 | 0.03 | 0.05 |
| Cobbs Ridge 32E | 0.20 | 5 | 71.3 | 0.33 | 0.31 | Nearly Bare Ground | 0.68 | 0.08 | 5.00 | 0.02 | 0.03 | 0.02 | 0.03 | 0.02 | 0.04 |
| Cobbs Ridge 33E | 0.32 | 4 | 117.7 | 0.33 | 0.33 | Nearly Bare Ground | 0.61 | 0.08 | 5.00 | 0.03 | 0.05 | 0.03 | 0.05 | 0.04 | 0.06 |
| Cobbs Ridge 34E | 0.24 | 1.5 | 106.8 | 0.31 | 0.33 | Nearly Bare Ground | 0.37 | 0.08 | 5.00 | 0.02 | 0.04 | 0.02 | 0.04 | 0.03 | 0.05 |
| Cobbs Ridge 35E | 0.28 | 0.4 | 92.9 | 0.39 | 0.37 | Nearly Bare Ground | 0.19 | 0.13 | 8.08 | 0.02 | 0.04 | 0.02 | 0.04 | 0.03 | 0.05 |
| Cobbs Ridge 36E | 0.04 | 0.3 | 35.1 | 0.48 | 0.48 | Nearly Bare Ground | 0.17 | 0.08 | 5.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Cobbs Ridge 37E | 0.28 | 1 | 61.2 | 0.41 | 0.39 | Nearly Bare Ground | 0.30 | 0.08 | 5.00 | 0.03 | 0.05 | 0.03 | 0.05 | 0.04 | 0.06 |
| Cobbs Ridge 38E | 0.12 | 1.8 | 40.0 | 0.48 | 0.48 | Nearly Bare Ground | 0.41 | 0.08 | 5.00 | 0.02 | 0.03 | 0.02 | 0.03 | 0.02 | 0.03 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Return Period | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Cobbs Ridge 39E | 0.53 | 3.4 | 160.6 | 0.46 | 0.45 | Nearly Bare Ground | 0.56 | 0.08 | 5.00 | 0.07 | 0.12 | 0.07 | 0.10 | 0.09 | 0.14 |
| Cobbs Ridge 40E | 1.01 | 2.3 | 117.8 | 0.58 | 0.58 | Nearly Bare Ground | 0.46 | 0.08 | 5.00 | 0.17 | 0.29 | 0.16 | 0.26 | 0.21 | 0.33 |
| Cobbs Ridge 41E | 0.45 | 1.7 | 100.0 | 0.30 | 0.31 | Nearly Bare Ground | 0.39 | 0.08 | 5.00 | 0.04 | 0.07 | 0.04 | 0.06 | 0.05 | 0.08 |
| Cobbs Ridge 42E | 0.12 | 3.6 | 113.1 | 1.03 | 1.00 | Nearly Bare Ground | 0.57 | 0.08 | 5.00 | 0.04 | 0.06 | 0.03 | 0.05 | 0.04 | 0.07 |
| Cobbs Ridge 43E | 0.40 | 3 | 104.0 | 0.31 | 0.31 | Nearly Bare Ground | 0.52 | 0.08 | 5.00 | 0.04 | 0.06 | 0.03 | 0.05 | 0.04 | 0.07 |
| Cobbs Ridge 44E | 0.20 | 3.5 | 125.9 | 0.62 | 0.60 | Nearly Bare Ground | 0.57 | 0.08 | 5.00 | 0.04 | 0.06 | 0.03 | 0.05 | 0.04 | 0.07 |
| Cobbs Ridge 45E | 0.08 | 1.9 | 42.3 | 0.24 | 0.26 | Nearly Bare Ground | 0.42 | 0.08 | 5.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Cobbs Ridge 46E | 0.16 | 2.1 | 53.0 | 0.36 | 0.36 | Nearly Bare Ground | 0.44 | 0.08 | 5.00 | 0.02 | 0.03 | 0.02 | 0.03 | 0.02 | 0.03 |
| Cobbs Ridge 47E | 0.28 | 3.6 | 22.9 | 0.44 | 0.44 | Nearly Bare Ground | 0.57 | 0.08 | 5.00 | 0.04 | 0.06 | 0.03 | 0.05 | 0.04 | 0.07 |
| Cobbs Ridge 1F | 0.49 | 10.5 | 60.3 | 0.34 | 0.33 | Nearly Bare Ground | 0.98 | 0.08 | 5.00 | 0.05 | 0.08 | 0.04 | 0.07 | 0.06 | 0.09 |
| Cobbs Ridge 2F | 0.32 | 8.7 | 70.4 | 0.45 | 0.43 | Nearly Bare Ground | 0.89 | 0.08 | 5.00 | 0.04 | 0.07 | 0.04 | 0.06 | 0.05 | 0.08 |
| Cobbs Ridge 3F | 0.12 | 8.9 | 58.1 | 0.31 | 0.33 | Nearly Bare Ground | 0.90 | 0.08 | 5.00 | 0.01 | 0.02 | 0.01 | 0.02 | 0.01 | 0.02 |
| Cobbs Ridge 4F | 0.28 | 5 | 73.5 | 0.31 | 0.31 | Nearly Bare Ground | 0.68 | 0.08 | 5.00 | 0.03 | 0.04 | 0.02 | 0.04 | 0.03 | 0.05 |
| Cobbs Ridge 5F | 0.24 | 6 | 70.2 | 0.36 | 0.33 | Nearly Bare Ground | 0.74 | 0.08 | 5.00 | 0.03 | 0.04 | 0.02 | 0.04 | 0.03 | 0.05 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Return Period | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Cobbs Ridge 6F | 0.24 | 2.6 | 71.2 | 0.31 | 0.33 | Nearly Bare Ground | 0.49 | 0.08 | 5.00 | 0.02 | 0.04 | 0.02 | 0.04 | 0.03 | 0.05 |
| Cobbs Ridge 7F | 0.45 | 5.7 | 102.5 | 0.48 | 0.47 | Nearly Bare Ground | 0.72 | 0.08 | 5.00 | 0.06 | 0.10 | 0.06 | 0.09 | 0.08 | 0.12 |
| Cobbs Ridge 8F | 0.32 | 12.5 | 39.1 | 0.33 | 0.30 | Nearly Bare Ground | 1.07 | 0.08 | 5.00 | 0.03 | 0.05 | 0.03 | 0.04 | 0.04 | 0.06 |
| Cobbs Ridge 9F | 0.36 | 11 | 98.8 | 0.34 | 0.33 | Nearly Bare Ground | 1.00 | 0.08 | 5.00 | 0.04 | 0.06 | 0.03 | 0.05 | 0.04 | 0.07 |
| Cobbs Ridge 10F | 0.69 | 7.8 | 8.9 | 0.34 | 0.34 | Nearly Bare Ground | 0.85 | 0.08 | 5.00 | 0.07 | 0.11 | 0.06 | 0.10 | 0.08 | 0.13 |
| Cobbs Ridge 11F | 0.65 | 4.6 | 147.8 | 0.33 | 0.31 | Nearly Bare Ground | 0.65 | 0.08 | 5.00 | 0.06 | 0.10 | 0.06 | 0.09 | 0.08 | 0.12 |
| Cobbs Ridge 1G | 0.16 | 5.5 | 58.2 | 0.77 | 0.77 | short grass pasture and lawns | 0.51 | 0.08 | 5.00 | 0.04 | 0.06 | 0.03 | 0.05 | 0.04 | 0.07 |
| Cobbs Ridge 2G | 0.73 | 10.1 | 104.0 | 0.45 | 0.45 | short grass pasture and lawns | 0.68 | 0.08 | 5.00 | 0.10 | 0.16 | 0.09 | 0.14 | 0.12 | 0.18 |
| Cobbs Ridge 3G | 0.24 | 10 | 88.3 | 0.48 | 0.45 | short grass pasture and lawns | 0.68 | 0.08 | 5.00 | 0.03 | 0.05 | 0.03 | 0.05 | 0.04 | 0.06 |
| Cobbs Ridge 4G | 0.69 | 8.9 | 119.4 | 0.31 | 0.31 | short grass pasture and lawns | 0.64 | 0.08 | 5.00 | 0.06 | 0.10 | 0.06 | 0.09 | 0.08 | 0.12 |
| Cobbs Ridge 5G | 0.20 | 13.3 | 49.0 | 0.24 | 0.26 | short grass pasture and lawns | 0.79 | 0.08 | 5.00 | 0.01 | 0.03 | 0.01 | 0.02 | 0.02 | 0.03 |
| Cobbs Ridge 6G | 0.20 | 13.4 | 62.7 | 0.38 | 0.34 | short grass pasture and lawns | 0.79 | 0.08 | 5.00 | 0.02 | 0.03 | 0.02 | 0.03 | 0.03 | 0.04 |
| Cobbs Ridge 7G | 0.24 | 14.7 | 60.0 | 0.36 | 0.36 | short grass pasture and lawns | 0.83 | 0.08 | 5.00 | 0.03 | 0.04 | 0.02 | 0.04 | 0.03 | 0.05 |
| Cobbs Ridge 8G | 0.65 | 9.4 | 79.1 | 0.48 | 0.46 | short grass pasture and lawns | 0.66 | 0.08 | 5.00 | 0.09 | 0.15 | 0.08 | 0.13 | 0.11 | 0.17 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | Return Period | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Cobbs Ridge 9G | 1.94 | 4.8 | 255.1 | 0.45 | 0.45 | short grass pasture and lawns | 0.47 | 0.15 | 9.00 | 0.18 | 0.30 | 0.17 | 0.27 | 0.22 | 0.36 |
| Cobbs Ridge 10G | 1.74 | 7 | 206.7 | 0.45 | 0.44 | Nearly Bare Ground | 0.80 | 0.08 | 5.00 | 0.23 | 0.38 | 0.21 | 0.34 | 0.28 | 0.44 |
| Cobbs Ridge 1H | 0.57 | 2.3 | 114.0 | 0.46 | 0.45 | Nearly Bare Ground | 0.46 | 0.08 | 5.00 | 0.08 | 0.12 | 0.07 | 0.11 | 0.09 | 0.14 |
| Cobbs Ridge 2H | 0.57 | 8.5 | 105.7 | 0.32 | 0.32 | Nearly Bare Ground | 0.88 | 0.08 | 5.00 | 0.05 | 0.09 | 0.05 | 0.08 | 0.07 | 0.10 |
| Cobbs Ridge 3H | 0.36 | 7.5 | 107.8 | 0.31 | 0.31 | Nearly Bare Ground | 0.83 | 0.08 | 5.00 | 0.03 | 0.06 | 0.03 | 0.05 | 0.04 | 0.06 |
| Cobbs Ridge 4H | 0.65 | 9.4 | 101.8 | 0.46 | 0.46 | Nearly Bare Ground | 0.93 | 0.08 | 5.00 | 0.09 | 0.14 | 0.08 | 0.13 | 0.11 | 0.17 |
| Cobbs Ridge 5H | 0.45 | 9 | 125.2 | 0.48 | 0.47 | Nearly Bare Ground | 0.91 | 0.08 | 5.00 | 0.06 | 0.10 | 0.06 | 0.09 | 0.08 | 0.12 |
| Cobbs Ridge 6H | 1.38 | 9 | 190.0 | 0.46 | 0.45 | Nearly Bare Ground | 0.91 | 0.08 | 5.00 | 0.18 | 0.30 | 0.17 | 0.27 | 0.22 | 0.35 |
| Cobbs Ridge 7H | 0.16 | 4.3 | 55.8 | 0.30 | 0.30 | Nearly Bare Ground | 0.63 | 0.08 | 5.00 | 0.01 | 0.02 | 0.01 | 0.02 | 0.02 | 0.03 |
| Cobbs Ridge 8H | 0.12 | 4.3 | 42.2 | 0.24 | 0.29 | Nearly Bare Ground | 0.63 | 0.08 | 5.00 | 0.01 | 0.02 | 0.01 | 0.02 | 0.01 | 0.02 |
| Cobbs Ridge 9H | 1.09 | 3.2 | 233.5 | 0.37 | 0.36 | Nearly Bare Ground | 0.54 | 0.12 | 7.19 | 0.10 | 0.16 | 0.09 | 0.14 | 0.12 | 0.18 |
| Cobbs Ridge 10H | 0.65 | 2.4 | 85.4 | 0.60 | 0.58 | Nearly Bare Ground | 0.47 | 0.08 | 5.00 | 0.11 | 0.18 | 0.11 | 0.16 | 0.14 | 0.21 |
| Cobbs Ridge 11H | 0.28 | 6.2 | 46.9 | 0.34 | 0.33 | Nearly Bare Ground | 0.75 | 0.08 | 5.00 | 0.03 | 0.05 | 0.03 | 0.04 | 0.03 | 0.05 |
| Cobbs Ridge 12H | 0.81 | 12.2 | 157.0 | 0.45 | 0.45 | Nearly Bare Ground | 1.06 | 0.08 | 5.00 | 0.11 | 0.18 | 0.10 | 0.16 | 0.13 | 0.21 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | Return Period | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Cobbs Ridge 13H | 0.36 | 5 | 162.2 | 0.71 | 0.70 | Nearly Bare Ground | 0.68 | 0.08 | 5.00 | 0.08 | 0.12 | 0.07 | 0.11 | 0.09 | 0.15 |
| Cobbs Ridge 14H | 0.45 | 4.3 | 79.3 | 0.48 | 0.47 | Nearly Bare Ground | 0.63 | 0.08 | 5.00 | 0.06 | 0.10 | 0.06 | 0.09 | 0.08 | 0.12 |
| Cobbs Ridge 15H | 0.45 | 5.2 | 146.1 | 0.61 | 0.60 | Nearly Bare Ground | 0.69 | 0.08 | 5.00 | 0.08 | 0.13 | 0.07 | 0.12 | 0.10 | 0.15 |
| Cobbs Ridge 16H | 0.36 | 9.5 | 15.5 | 0.61 | 0.60 | Nearly Bare Ground | 0.93 | 0.08 | 5.00 | 0.07 | 0.11 | 0.06 | 0.10 | 0.08 | 0.12 |
| Cobbs Ridge 17H | 0.24 | 5 | 88.9 | 0.36 | 0.33 | Nearly Bare Ground | 0.68 | 0.08 | 5.00 | 0.03 | 0.04 | 0.02 | 0.04 | 0.03 | 0.05 |
| Cobbs Ridge 18H | 0.16 | 12.5 | 54.9 | 0.66 | 0.66 | Nearly Bare Ground | 1.07 | 0.08 | 5.00 | 0.03 | 0.05 | 0.03 | 0.05 | 0.04 | 0.06 |
| Cobbs Ridge 19H | 1.42 | 5.4 | 341.1 | 0.52 | 0.51 | Nearly Bare Ground | 0.70 | 0.13 | 8.08 | 0.16 | 0.27 | 0.15 | 0.24 | 0.20 | 0.32 |
| Cobbs Ridge 1I | 0.49 | 3 | 165.7 | 0.67 | 0.67 | Forest with heavy ground litter & meadow | 0.13 | 0.35 | 21.26 | 0.04 | 0.07 | 0.04 | 0.06 | 0.05 | 0.08 |
| Cobbs Ridge 2I | 0.20 | 5.4 | 65.4 | 0.32 | 0.35 | Forest with heavy ground litter & meadow | 0.17 | 0.10 | 6.25 | 0.02 | 0.03 | 0.02 | 0.03 | 0.02 | 0.04 |
| Cobbs Ridge 3I | 0.28 | 2.5 | 69.2 | 0.45 | 0.45 | Forest with heavy ground litter & meadow | 0.12 | 0.16 | 9.73 | 0.03 | 0.04 | 0.02 | 0.04 | 0.03 | 0.05 |
| Cobbs Ridge 4I | 0.65 | 3 | 96.7 | 0.62 | 0.62 | Forest with heavy ground litter & meadow | 0.13 | 0.21 | 12.41 | 0.07 | 0.12 | 0.07 | 0.11 | 0.09 | 0.14 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Return Period | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Cobbs Ridge 1J | 0.12 | 6.4 | 42.4 | 0.31 | 0.33 | Forest with heavy ground litter & meadow | 0.19 | 0.08 | 5.00 | 0.01 | 0.02 | 0.01 | 0.02 | 0.01 | 0.02 |
| Cobbs Ridge 2J | 0.20 | 2.3 | 50.0 | 0.41 | 0.41 | Forest with heavy ground litter & meadow | 0.11 | 0.12 | 7.33 | 0.02 | 0.03 | 0.02 | 0.03 | 0.02 | 0.04 |
| Cobbs Ridge 3J | 0.32 | 2.2 | 51.4 | 0.42 | 0.41 | Forest with heavy ground litter & meadow | 0.11 | 0.13 | 7.71 | 0.03 | 0.05 | 0.03 | 0.05 | 0.04 | 0.06 |
| Cobbs Ridge 4J | 0.81 | 7.7 | 82.1 | 0.38 | 0.38 | Forest with heavy ground litter & meadow | 0.21 | 0.11 | 6.56 | 0.08 | 0.13 | 0.07 | 0.11 | 0.09 | 0.15 |
| Cobbs Ridge 5J | 0.12 | 6.1 | 34.5 | 0.31 | 0.29 | Forest with heavy ground litter & meadow | 0.19 | 0.08 | 5.00 | 0.01 | 0.02 | 0.01 | 0.02 | 0.01 | 0.02 |
| Cobbs Ridge 6J | 10.68 | 4.5 | 401.0 | 0.73 | 0.72 | Forest with heavy ground litter & meadow | 0.16 | 0.70 | 41.99 | 0.69 | 1.14 | 0.66 | 1.04 | 0.85 | 1.35 |
| Hospital Area 1A | 0.20 | 13 | 80.0 | 0.33 | 0.31 | Forest with heavy ground litter & meadow | 0.27 | 0.08 | 5.00 | 0.02 | 0.03 | 0.02 | 0.03 | 0.02 | 0.04 |
| Hospital Area 2A | 0.08 | 2.5 | 65.0 | 0.47 | 0.47 | Forest with heavy ground litter & meadow | 0.12 | 0.15 | 9.14 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 |
| Hospital Area 3A | 0.69 | 15 | 78.0 | 0.32 | 0.32 | Nearly Bare Ground | 1.17 | 0.08 | 5.00 | 0.07 | 0.11 | 0.06 | 0.10 | 0.08 | 0.12 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Return Period | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Hospital Area 4A | 0.24 | 7.1 | 41.1 | 0.36 | 0.36 | Forest with heavy ground litter & meadow | 0.20 | 0.08 | 5.00 | 0.03 | 0.04 | 0.02 | 0.04 | 0.03 | 0.05 |
| Hospital Area 5A | 0.24 | 7.5 | 88.4 | 0.68 | 0.67 | Nearly Bare Ground | 0.83 | 0.08 | 5.00 | 0.05 | 0.08 | 0.04 | 0.07 | 0.06 | 0.09 |
| Hospital Area 6A | 0.57 | 6.7 | 180.2 | 0.43 | 0.43 | Nearly Bare Ground | 0.78 | 0.08 | 5.00 | 0.07 | 0.12 | 0.07 | 0.11 | 0.09 | 0.14 |
| Hospital Area 7A | 0.61 | 2.5 | 129.3 | 0.33 | 0.32 | Nearly Bare Ground | 0.48 | 0.08 | 5.00 | 0.06 | 0.10 | 0.06 | 0.09 | 0.07 | 0.11 |
| Hospital Area 8A | 0.57 | 3 | 123.7 | 0.61 | 0.59 | Nearly Bare Ground | 0.52 | 0.08 | 5.00 | 0.10 | 0.16 | 0.10 | 0.15 | 0.12 | 0.19 |
| Hospital Area 9A | 0.32 | 4.4 | 65.3 | 0.66 | 0.65 | Nearly Bare Ground | 0.64 | 0.08 | 5.00 | 0.06 | 0.10 | 0.06 | 0.09 | 0.08 | 0.12 |
| Hospital Area 10A | 1.94 | 2.5 | 360.2 | 0.86 | 0.85 | Nearly Bare Ground | 0.48 | 0.21 | 12.54 | 0.29 | 0.48 | 0.27 | 0.43 | 0.36 | 0.56 |
| Hospital Area 1B | 0.53 | 6.2 | 120.0 | 0.33 | 0.33 | Nearly Bare Ground | 0.75 | 0.08 | 5.00 | 0.05 | 0.08 | 0.05 | 0.08 | 0.06 | 0.10 |
| Hospital Area 2B | 0.28 | 12.5 | 20.0 | 0.34 | 0.33 | Nearly Bare Ground | 1.07 | 0.08 | 5.00 | 0.03 | 0.05 | 0.03 | 0.04 | 0.03 | 0.05 |
| Hospital Area 3B | 0.45 | 7.2 | 146.5 | 0.33 | 0.33 | Nearly Bare Ground | 0.81 | 0.08 | 5.00 | 0.04 | 0.07 | 0.04 | 0.06 | 0.05 | 0.08 |
| Hospital Area 4B | 0.08 | 14 | 40.0 | 0.60 | 0.64 | Nearly Bare Ground | 1.13 | 0.08 | 5.00 | 0.01 | 0.03 | 0.01 | 0.02 | 0.02 | 0.03 |
| Hospital Area 1C | 0.04 | 12.5 | 37.5 | 0.48 | 0.48 | Nearly Bare Ground | 1.07 | 0.08 | 5.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Hospital Area 2C | 0.53 | 5 | 130.8 | 0.61 | 0.59 | Nearly Bare Ground | 0.68 | 0.08 | 5.00 | 0.09 | 0.15 | 0.09 | 0.14 | 0.11 | 0.18 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Return Period | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Hospital Area 3C | 0.08 | 6.2 | 77.3 | 0.95 | 0.95 | Nearly Bare Ground | 0.75 | 0.08 | 5.00 | 0.02 | 0.04 | 0.02 | 0.03 | 0.03 | 0.04 |
| Hospital Area 1D | 0.24 | 17.3 | 41.0 | 0.31 | 0.33 | Nearly Bare Ground | 1.26 | 0.08 | 5.00 | 0.02 | 0.04 | 0.02 | 0.04 | 0.03 | 0.05 |
| Hospital Area 2D | 0.04 | 5.5 | 60.5 | 0.48 | 0.48 | Nearly Bare Ground | 0.71 | 0.08 | 5.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Hospital Area 3D | 0.16 | 6.3 | 59.6 | 0.30 | 0.32 | Nearly Bare Ground | 0.76 | 0.08 | 5.00 | 0.01 | 0.03 | 0.01 | 0.02 | 0.02 | 0.03 |
| Hospital Area 4D | 0.32 | 6.2 | 87.1 | 0.60 | 0.60 | Nearly Bare Ground | 0.75 | 0.08 | 5.00 | 0.06 | 0.10 | 0.05 | 0.09 | 0.07 | 0.11 |
| Hospital Area 5D | 0.65 | 5.5 | 215.6 | 0.30 | 0.30 | Nearly Bare Ground | 0.71 | 0.08 | 5.06 | 0.06 | 0.09 | 0.05 | 0.08 | 0.07 | 0.11 |
| Hospital Area 6D | 1.01 | 4.6 | 113.1 | 0.31 | 0.31 | Nearly Bare Ground | 0.65 | 0.08 | 5.00 | 0.09 | 0.16 | 0.09 | 0.14 | 0.11 | 0.18 |
| Hospital Area 7D | 2.83 | 5.6 | 353.8 | 0.39 | 0.38 | Nearly Bare Ground | 0.72 | 0.14 | 8.23 | 0.24 | 0.40 | 0.23 | 0.36 | 0.30 | 0.47 |
| Hospital Area 8D | 2.39 | 4.2 | 262.0 | 0.67 | 0.66 | Nearly Bare Ground | 0.62 | 0.12 | 7.04 | 0.39 | 0.64 | 0.36 | 0.57 | 0.47 | 0.74 |
| Hospital Area 9D | 1.38 | 5 | 149.3 | 0.45 | 0.44 | Nearly Bare Ground | 0.68 | 0.08 | 5.00 | 0.18 | 0.29 | 0.17 | 0.26 | 0.22 | 0.34 |
| Hospital Area 10D | 0.85 | 3.3 | 201.7 | 0.47 | 0.47 | Nearly Bare Ground | 0.55 | 0.10 | 6.11 | 0.10 | 0.17 | 0.10 | 0.16 | 0.13 | 0.20 |
| Hospital Area 1E | 0.28 | 10.2 | 16.8 | 0.37 | 0.35 | Nearly Bare Ground | 0.97 | 0.08 | 5.00 | 0.03 | 0.05 | 0.03 | 0.04 | 0.04 | 0.06 |
| Hospital Area 2E | 0.36 | 5 | 59.8 | 0.67 | 0.65 | Forest with heavy ground litter & meadow | 0.17 | 0.10 | 5.94 | 0.07 | 0.10 | 0.06 | 0.09 | 0.08 | 0.12 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Return Period | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Hospital Area 3E | 3.60 | 6.2 | 353.8 | 0.84 | 0.83 | Forest with heavy ground litter & meadow | 0.19 | 0.53 | 31.54 | 0.31 | 0.52 | 0.30 | 0.47 | 0.39 | 0.61 |
| Hospital Area 4E | 2.99 | 5.9 | 557.8 | 0.46 | 0.45 | Nearly Bare Ground | 0.74 | 0.21 | 12.64 | 0.24 | 0.39 | 0.22 | 0.36 | 0.29 | 0.46 |
| Meadow Pond 1A | 0.89 | 2.8 | 140.2 | 0.59 | 0.58 | Nearly Bare Ground | 0.51 | 0.08 | 5.00 | 0.15 | 0.25 | 0.14 | 0.23 | 0.19 | 0.29 |
| Meadow Pond 2A | 0.81 | 4 | 180.1 | 0.66 | 0.65 | Nearly Bare Ground | 0.61 | 0.08 | 5.00 | 0.16 | 0.26 | 0.15 | 0.23 | 0.19 | 0.30 |
| Meadow Pond 3A | 0.24 | 2.6 | 110.3 | 0.87 | 0.87 | Nearly Bare Ground | 0.49 | 0.08 | 5.00 | 0.06 | 0.10 | 0.06 | 0.09 | 0.08 | 0.12 |
| Meadow Pond 4A | 0.45 | 3.1 | 98.2 | 0.63 | 0.61 | Nearly Bare Ground | 0.53 | 0.08 | 5.00 | 0.08 | 0.13 | 0.08 | 0.12 | 0.10 | 0.15 |
| Meadow Pond 5A | 0.40 | 4.8 | 61.3 | 0.64 | 0.63 | Nearly Bare Ground | 0.66 | 0.08 | 5.00 | 0.08 | 0.12 | 0.07 | 0.11 | 0.09 | 0.14 |
| Meadow Pond 6A | 0.24 | 5.6 | 153.3 | 0.44 | 0.44 | Nearly Bare Ground | 0.72 | 0.08 | 5.00 | 0.03 | 0.05 | 0.03 | 0.05 | 0.04 | 0.06 |
| Meadow Pond 7A | 0.45 | 5 | 219.2 | 0.45 | 0.46 | Nearly Bare Ground | 0.68 | 0.09 | 5.40 | 0.06 | 0.10 | 0.05 | 0.09 | 0.07 | 0.11 |
| Meadow Pond 8A | 0.24 | 7.5 | 100.3 | 0.48 | 0.48 | Nearly Bare Ground | 0.83 | 0.08 | 5.00 | 0.03 | 0.06 | 0.03 | 0.05 | 0.04 | 0.07 |
| Meadow Pond 9A | 1.54 | 5.3 | 180.7 | 0.31 | 0.30 | Nearly Bare Ground | 0.70 | 0.08 | 5.00 | 0.14 | 0.23 | 0.13 | 0.21 | 0.17 | 0.27 |
| Meadow Pond 10A | 2.27 | 4.3 | 298.3 | 0.55 | 0.54 | Nearly Bare Ground | 0.63 | 0.13 | 7.92 | 0.28 | 0.46 | 0.26 | 0.41 | 0.34 | 0.54 |
| Meadow Pond 1B | 0.16 | 7 | 25.0 | 0.71 | 0.71 | Nearly Bare Ground | 0.80 | 0.08 | 5.00 | 0.03 | 0.06 | 0.03 | 0.05 | 0.04 | 0.07 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Return Period | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Meadow Pond 2B | 0.16 | 10 | 34.5 | 0.71 | 0.71 | Nearly Bare Ground | 0.96 | 0.08 | 5.00 | 0.03 | 0.06 | 0.03 | 0.05 | 0.04 | 0.07 |
| Meadow Pond 3B | 0.28 | 15 | 70.0 | 0.68 | 0.69 | Nearly Bare Ground | 1.17 | 0.08 | 5.00 | 0.06 | 0.10 | 0.05 | 0.09 | 0.07 | 0.11 |
| Meadow Pond 4B | 0.49 | 9 | 86.0 | 0.62 | 0.62 | Nearly Bare Ground | 0.91 | 0.08 | 5.00 | 0.09 | 0.15 | 0.08 | 0.13 | 0.11 | 0.17 |
| Meadow Pond 5B | 0.89 | 3.7 | 92.4 | 0.68 | 0.67 | Nearly Bare Ground | 0.58 | 0.08 | 5.00 | 0.18 | 0.29 | 0.17 | 0.26 | 0.22 | 0.34 |
| Meadow Pond 6B | 0.93 | 4.9 | 137.4 | 0.86 | 0.85 | Nearly Bare Ground | 0.67 | 0.08 | 5.00 | 0.24 | 0.39 | 0.22 | 0.34 | 0.28 | 0.45 |
| Meadow Pond 7B | 0.45 | 5 | 219.2 | 0.45 | 0.46 | Nearly Bare Ground | 0.68 | 0.09 | 5.40 | 0.06 | 0.10 | 0.05 | 0.09 | 0.07 | 0.11 |
| Meadow Pond 8B | 0.24 | 7.5 | 100.3 | 0.48 | 0.48 | Nearly Bare Ground | 0.83 | 0.08 | 5.00 | 0.03 | 0.06 | 0.03 | 0.05 | 0.04 | 0.07 |
| Meadow Pond 9B | 1.54 | 5.3 | 180.7 | 0.31 | 0.30 | Nearly Bare Ground | 0.70 | 0.08 | 5.00 | 0.14 | 0.23 | 0.13 | 0.21 | 0.17 | 0.27 |
| Meadow Pond 1C | 0.89 | 4.3 | 146.3 | 1.00 | 1.00 | Forest with heavy ground litter & meadow | 0.16 | 0.26 | 15.67 | 0.19 | 0.31 | 0.18 | 0.21 | 0.23 | 0.37 |
| Meadow Pond 2C | 0.57 | 6.5 | 64.1 | 0.62 | 0.61 | Forest with heavy ground litter & meadow | 0.19 | 0.09 | 5.58 | 0.10 | 0.16 | 0.09 | 0.14 | 0.12 | 0.18 |
| Meadow Pond 3C | 0.32 | 5.8 | 40.1 | 0.63 | 0.61 | Forest with heavy ground litter & meadow | 0.18 | 0.08 | 5.00 | 0.06 | 0.10 | 0.06 | 0.09 | 0.07 | 0.11 |
| Meadow Pond 4C | 1.42 | 2.3 | 122.0 | 0.91 | 0.91 | Forest with heavy ground litter & meadow | 0.11 | 0.30 | 17.89 | 0.18 | 0.31 | 0.17 | 0.28 | 0.23 | 0.36 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Return Period | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Meadow Pond 5C | 0.36 | 7.3 | 187.9 | 1.00 | 1.00 | Forest with heavy ground litter & meadow | 0.20 | 0.26 | 15.43 | 0.07 | 0.10 | 0.05 | 0.08 | 0.08 | 0.12 |
| Meadow Pond 6C | 0.57 | 6 | 123.4 | 0.94 | 0.92 | Forest with heavy ground litter & meadow | 0.18 | 0.19 | 11.18 | 0.10 | 0.16 | 0.09 | 0.15 | 0.12 | 0.19 |
| Meadow Pond 7C | 0.32 | 5.9 | 118.4 | 0.97 | 0.94 | Forest with heavy ground litter & meadow | 0.18 | 0.18 | 10.82 | 0.06 | 0.10 | 0.06 | 0.09 | 0.07 | 0.11 |
| Meadow Pond 8C | 1.90 | 7.1 | 351.8 | 1.00 | 1.00 | Forest with heavy ground litter & meadow | 0.20 | 0.49 | 29.29 | 0.23 | 0.38 | 0.19 | 0.31 | 0.29 | 0.45 |
| Meadow Pond 9C | 0.08 | 3.1 | 47.1 | 0.66 | 0.66 | Forest with heavy ground litter & meadow | 0.13 | 0.10 | 5.95 | 0.01 | 0.02 | 0.01 | 0.02 | 0.02 | 0.03 |
| Meadow Pond 10C | 0.32 | 4.4 | 32.3 | 0.36 | 0.34 | Forest with heavy ground litter & meadow | 0.16 | 0.08 | 5.00 | 0.03 | 0.05 | 0.03 | 0.05 | 0.04 | 0.06 |
| Meadow Pond 11C | 0.49 | 6.7 | 185.1 | 0.61 | 0.61 | Forest with heavy ground litter & meadow | 0.19 | 0.26 | 15.87 | 0.05 | 0.08 | 0.04 | 0.07 | 0.06 | 0.09 |
| Meadow Pond 12C | 0.49 | 6.9 | 160.9 | 0.80 | 0.80 | Forest with heavy ground litter & meadow | 0.20 | 0.23 | 13.59 | 0.07 | 0.11 | 0.06 | 0.10 | 0.08 | 0.13 |
| Meadow Pond 13C | 0.28 | 7.5 | 88.3 | 0.58 | 0.58 | Forest with heavy ground litter & meadow | 0.21 | 0.12 | 7.15 | 0.04 | 0.07 | 0.04 | 0.06 | 0.05 | 0.08 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Return Period | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Meadow Pond 14C | 0.89 | 7.6 | 262.4 | 1.00 | 1.00 | Forest with heavy ground litter & meadow | 0.21 | 0.35 | 21.12 | 0.15 | 0.24 | 0.14 | 0.17 | 0.18 | 0.28 |
| Meadow Pond 15C | 0.61 | 7 | 115.8 | 0.69 | 0.68 | Forest with heavy ground litter & meadow | 0.20 | 0.16 | 9.71 | 0.08 | 0.14 | 0.08 | 0.13 | 0.10 | 0.16 |
| Meadow Pond 16C | 0.32 | 8.5 | 57.5 | 0.36 | 0.34 | Forest with heavy ground litter & meadow | 0.22 | 0.08 | 5.00 | 0.03 | 0.05 | 0.03 | 0.05 | 0.04 | 0.06 |
| Meadow Pond 17C | 22.99 | 6.5 | 879.7 | 1.00 | 1.00 | Forest with heavy ground litter & meadow | 0.19 | 1.28 | 76.57 | 1.63 | 2.68 | 1.56 | 2.20 | 2.03 | 3.21 |
| Meadow Pond 18C | 0.16 | 10.8 | 65.9 | 0.36 | 0.36 | Forest with heavy ground litter & meadow | 0.25 | 0.08 | 5.00 | 0.02 | 0.03 | 0.02 | 0.03 | 0.02 | 0.03 |
| Meadow Pond 19C | 1.05 | 7.1 | 51.0 | 0.33 | 0.33 | Forest with heavy ground litter & meadow | 0.20 | 0.08 | 5.00 | 0.10 | 0.17 | 0.10 | 0.15 | 0.12 | 0.20 |
| Meadow Pond 20C | 0.20 | 5.5 | 113.0 | 0.51 | 0.51 | Forest with heavy ground litter & meadow | 0.18 | 0.18 | 10.69 | 0.02 | 0.03 | 0.02 | 0.03 | 0.02 | 0.04 |
| Meadow Pond 21C | 0.16 | 8.1 | 67.6 | 0.30 | 0.30 | Forest with heavy ground litter & meadow | 0.21 | 0.09 | 5.27 | 0.01 | 0.02 | 0.01 | 0.02 | 0.02 | 0.03 |
| Meadow Pond 22C | 1.34 | 8 | 186.0 | 0.57 | 0.56 | Forest with heavy ground litter & meadow | 0.21 | 0.24 | 14.58 | 0.12 | 0.20 | 0.11 | 0.18 | 0.15 | 0.24 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Return Period | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Meadow Pond 23C | 0.49 | 5.5 | 114.6 | 0.49 | 0.49 | Forest with heavy ground litter & meadow | 0.18 | 0.18 | 10.85 | 0.05 | 0.08 | 0.04 | 0.07 | 0.06 | 0.09 |
| Meadow Pond 24C | 0.69 | 4 | 82.1 | 0.45 | 0.45 | Forest with heavy ground litter & meadow | 0.15 | 0.15 | 9.12 | 0.07 | 0.11 | 0.06 | 0.10 | 0.08 | 0.13 |
| Meadow Pond 25C | 0.45 | 5.9 | 102.2 | 0.46 | 0.44 | Forest with heavy ground litter & meadow | 0.18 | 0.16 | 9.34 | 0.04 | 0.07 | 0.04 | 0.06 | 0.05 | 0.08 |
| Meadow Pond 26C | 1.05 | 4.3 | 180.7 | 0.67 | 0.66 | Forest with heavy ground litter & meadow | 0.16 | 0.32 | 19.35 | 0.10 | 0.16 | 0.09 | 0.14 | 0.12 | 0.19 |
| Meadow Pond 27C | 1.46 | 4.8 | 145.1 | 0.58 | 0.58 | Forest with heavy ground litter & meadow | 0.16 | 0.25 | 14.70 | 0.14 | 0.22 | 0.13 | 0.20 | 0.17 | 0.26 |
| Meadow Pond 28C | 11.98 | 4.7 | 442.4 | 0.95 | 0.94 | Forest with heavy ground litter & meadow | 0.16 | 0.76 | 45.32 | 0.97 | 1.59 | 0.92 | 1.46 | 1.20 | 1.89 |
| Meadow Pond 1D | 0.53 | 2.8 | 42.9 | 0.35 | 0.34 | Nearly Bare Ground | 0.51 | 0.08 | 5.00 | 0.05 | 0.09 | 0.05 | 0.08 | 0.07 | 0.10 |
| Meadow Pond 2D | 0.89 | 1.3 | 157.8 | 0.37 | 0.37 | Nearly Bare Ground | 0.35 | 0.13 | 7.62 | 0.08 | 0.13 | 0.07 | 0.11 | 0.09 | 0.15 |
| Meadow Pond 3D | 3.48 | 2.8 | 195.9 | 0.64 | 0.63 | Nearly Bare Ground | 0.51 | 0.11 | 6.44 | 0.57 | 0.93 | 0.53 | 0.84 | 0.69 | 1.09 |
| Meadow Pond 4D | 0.32 | 5 | 44.9 | 0.33 | 0.33 | Nearly Bare Ground | 0.68 | 0.08 | 5.00 | 0.03 | 0.05 | 0.03 | 0.05 | 0.04 | 0.06 |
| Meadow Pond 5D | 2.91 | 1.9 | 131.5 | 0.57 | 0.57 | Nearly Bare Ground | 0.42 | 0.09 | 5.25 | 0.48 | 0.78 | 0.44 | 0.70 | 0.58 | 0.91 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | Return Period | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Meadow Pond 1E | 2.59 | 5 | 162.8 | 0.57 | 0.56 | Nearly Bare Ground | 0.68 | 0.08 | 5.00 | 0.43 | 0.71 | 0.40 | 0.63 | 0.52 | 0.82 |
| Meadow Pond 2E | 0.89 | 2.1 | 52.7 | 0.48 | 0.47 | Nearly Bare Ground | 0.44 | 0.08 | 5.00 | 0.12 | 0.20 | 0.12 | 0.18 | 0.15 | 0.24 |
| Meadow Pond 3E | 1.90 | 4.8 | 258.3 | 0.45 | 0.44 | Nearly Bare Ground | 0.66 | 0.11 | 6.49 | 0.22 | 0.36 | 0.20 | 0.32 | 0.26 | 0.42 |
| Meadow Pond 4E | 0.32 | 1.7 | 137.2 | 0.32 | 0.32 | Nearly Bare Ground | 0.39 | 0.10 | 5.79 | 0.03 | 0.05 | 0.03 | 0.04 | 0.03 | 0.05 |
| Meadow Pond 5E | 1.50 | 8.7 | 358.2 | 0.50 | 0.50 | Nearly Bare Ground | 0.89 | 0.11 | 6.69 | 0.19 | 0.31 | 0.17 | 0.28 | 0.23 | 0.36 |
| Meadow Pond 6E | 0.04 | 4.8 | 49.4 | 0.48 | 0.53 | Nearly Bare Ground | 0.66 | 0.08 | 5.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Meadow Pond 7E | 1.42 | 8.7 | 266.8 | 0.97 | 0.96 | Forest with heavy ground litter & meadow | 0.22 | 0.33 | 20.06 | 0.18 | 0.30 | 0.17 | 0.28 | 0.23 | 0.36 |
| Meadow Pond 8E | 0.28 | 7.9 | 32.1 | 0.48 | 0.47 | Forest with heavy ground litter & meadow | 0.21 | 0.08 | 5.00 | 0.04 | 0.07 | 0.04 | 0.06 | 0.05 | 0.08 |
| Meadow Pond 9E | 0.45 | 7.5 | 165.0 | 0.52 | 0.52 | Forest with heavy ground litter & meadow | 0.21 | 0.22 | 13.36 | 0.04 | 0.07 | 0.04 | 0.06 | 0.05 | 0.08 |
| Meadow Pond 10E | 0.49 | 8.3 | 63.7 | 0.62 | 0.61 | Forest with heavy ground litter & meadow | 0.22 | 0.08 | 5.00 | 0.09 | 0.14 | 0.08 | 0.13 | 0.11 | 0.17 |
| Meadow Pond 11E | 0.49 | 6.5 | 101.7 | 0.85 | 0.85 | Forest with heavy ground litter & meadow | 0.19 | 0.15 | 8.85 | 0.09 | 0.15 | 0.08 | 0.13 | 0.11 | 0.17 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Return Period | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Meadow Pond 12E | 0.32 | 14.1 | 38.4 | 0.66 | 0.65 | Forest with heavy ground litter & meadow | 0.28 | 0.08 | 5.00 | 0.06 | 0.10 | 0.06 | 0.09 | 0.08 | 0.12 |
| Meadow Pond 13E | 0.89 | 8.7 | 293.9 | 1.30 | 1.29 | Forest with heavy ground litter & meadow | 0.22 | 0.37 | 22.10 | 0.15 | 0.24 | 0.14 | 0.17 | 0.18 | 0.29 |
| Meadow Pond 14E | 0.08 | 3.8 | 37.0 | 0.60 | 0.60 | Forest with heavy ground litter & meadow | 0.15 | 0.08 | 5.00 | 0.01 | 0.02 | 0.01 | 0.02 | 0.02 | 0.03 |
| Meadow Pond 15E | 0.24 | 6.7 | 82.3 | 0.39 | 0.40 | Forest with heavy ground litter & meadow | 0.19 | 0.12 | 7.05 | 0.02 | 0.04 | 0.02 | 0.04 | 0.03 | 0.05 |
| Meadow Pond 16E | 0.32 | 10 | 146.9 | 0.72 | 0.70 | Forest with heavy ground litter & meadow | 0.24 | 0.17 | 10.29 | 0.05 | 0.07 | 0.04 | 0.07 | 0.06 | 0.09 |
| Meadow Pond 17E | 0.36 | 9.2 | 127.7 | 0.45 | 0.43 | Forest with heavy ground litter & meadow | 0.23 | 0.16 | 9.33 | 0.03 | 0.05 | 0.03 | 0.05 | 0.04 | 0.06 |
| Meadow Pond 18E | 0.57 | 13.1 | 111.8 | 0.55 | 0.54 | Forest with heavy ground litter & meadow | 0.27 | 0.11 | 6.84 | 0.08 | 0.12 | 0.07 | 0.11 | 0.09 | 0.15 |
| Meadow Pond 19E | 0.45 | 9.6 | 157.9 | 0.51 | 0.49 | Forest with heavy ground litter & meadow | 0.23 | 0.19 | 11.30 | 0.04 | 0.07 | 0.04 | 0.06 | 0.05 | 0.08 |
| Meadow Pond 20E | 1.13 | 10 | 283.5 | 0.67 | 0.66 | Forest with heavy ground litter & meadow | 0.24 | 0.33 | 19.88 | 0.10 | 0.17 | 0.10 | 0.15 | 0.13 | 0.20 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Return Period | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Meadow Pond 21E | 0.49 | 9.2 | 87.9 | 0.39 | 0.39 | Forest with heavy ground litter & meadow | 0.23 | 0.11 | 6.42 | 0.05 | 0.08 | 0.05 | 0.07 | 0.06 | 0.09 |
| Meadow Pond 22E | 0.32 | 8.3 | 82.7 | 0.58 | 0.55 | Forest with heavy ground litter & meadow | 0.22 | 0.11 | 6.36 | 0.05 | 0.08 | 0.05 | 0.07 | 0.06 | 0.09 |
| Meadow Pond 23E | 0.40 | 9.3 | 136.9 | 0.46 | 0.46 | Forest with heavy ground litter & meadow | 0.23 | 0.17 | 9.95 | 0.04 | 0.06 | 0.03 | 0.06 | 0.04 | 0.07 |
| Meadow Pond 24E | 0.28 | 10.4 | 134.2 | 0.43 | 0.43 | Forest with heavy ground litter & meadow | 0.24 | 0.15 | 9.22 | 0.03 | 0.04 | 0.02 | 0.04 | 0.03 | 0.05 |
| Meadow Pond 25E | 0.28 | 10.1 | 102.4 | 0.42 | 0.40 | Forest with heavy ground litter & meadow | 0.24 | 0.12 | 7.14 | 0.03 | 0.05 | 0.03 | 0.04 | 0.03 | 0.05 |
| Meadow Pond 26E | 1.01 | 11.6 | 204.9 | 0.55 | 0.54 | Forest with heavy ground litter & meadow | 0.26 | 0.22 | 13.34 | 0.09 | 0.15 | 0.09 | 0.14 | 0.11 | 0.18 |
| Meadow Pond 27E | 0.28 | 14.8 | 69.8 | 0.51 | 0.49 | Forest with heavy ground litter & meadow | 0.29 | 0.08 | 5.00 | 0.04 | 0.07 | 0.04 | 0.06 | 0.05 | 0.08 |
| Meadow Pond 28E | 8.22 | 4.6 | 692.0 | 1.00 | 1.00 | Forest with heavy ground litter & meadow | 0.16 | 1.19 | 71.66 | 0.60 | 0.99 | 0.51 | 0.82 | 0.74 | 1.18 |
| Meadow Pond 29E | 1.46 | 6.7 | 218.2 | 0.65 | 0.65 | Forest with heavy ground litter & meadow | 0.19 | 0.31 | 18.71 | 0.13 | 0.22 | 0.13 | 0.20 | 0.16 | 0.26 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Return Period | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Meadow Pond 30E | 0.36 | 13.1 | 67.3 | 0.34 | 0.33 | Forest with heavy ground litter & meadow | 0.27 | 0.08 | 5.00 | 0.04 | 0.06 | 0.03 | 0.05 | 0.04 | 0.07 |
| Meadow Pond 31E | 0.93 | 5.3 | 187.6 | 0.64 | 0.64 | Forest with heavy ground litter & meadow | 0.17 | 0.30 | 18.10 | 0.08 | 0.14 | 0.08 | 0.13 | 0.10 | 0.17 |
| Meadow Pond 32E | 0.77 | 7.7 | 190.9 | 0.61 | 0.59 | Forest with heavy ground litter & meadow | 0.21 | 0.25 | 15.26 | 0.07 | 0.12 | 0.07 | 0.11 | 0.09 | 0.14 |
| Meadow Pond 33E | 0.32 | 7.3 | 63.0 | 0.36 | 0.35 | Forest with heavy ground litter & meadow | 0.20 | 0.09 | 5.17 | 0.03 | 0.05 | 0.03 | 0.05 | 0.04 | 0.06 |
| Meadow Pond 34E | 0.40 | 8.6 | 93.3 | 0.41 | 0.40 | Forest with heavy ground litter & meadow | 0.22 | 0.12 | 7.05 | 0.04 | 0.07 | 0.04 | 0.06 | 0.05 | 0.08 |
| Meadow Pond 35E | 0.36 | 6.5 | 88.7 | 0.41 | 0.41 | Forest with heavy ground litter & meadow | 0.19 | 0.13 | 7.72 | 0.03 | 0.06 | 0.03 | 0.05 | 0.04 | 0.07 |
| Meadow Pond 36E | 0.77 | 8.6 | 69.5 | 0.34 | 0.33 | Forest with heavy ground litter & meadow | 0.22 | 0.09 | 5.26 | 0.07 | 0.12 | 0.07 | 0.11 | 0.09 | 0.14 |
| Meadow Pond 37E | 6.76 | 6.7 | 492.7 | 0.93 | 0.92 | Forest with heavy ground litter & meadow | 0.19 | 0.70 | 42.24 | 0.56 | 0.91 | 0.53 | 0.84 | 0.69 | 1.09 |
| Meadow Pond 38E | 39.98 | 7 | 572.8 | 0.92 | 0.91 | Forest with heavy ground litter & meadow | 0.20 | 0.80 | 48.04 | 3.04 | 4.99 | 2.89 | 4.57 | 3.76 | 5.94 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Return Period | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Meadow Pond 1F | 1.21 | 11 | 117.3 | 0.33 | 0.32 | Nearly Bare Ground | 1.00 | 0.08 | 5.00 | 0.12 | 0.19 | 0.11 | 0.17 | 0.14 | 0.22 |
| Meadow Pond 2F | 1.21 | 1.3 | 28.2 | 0.78 | 0.76 | Nearly Bare Ground | 0.35 | 0.08 | 5.00 | 0.28 | 0.45 | 0.26 | 0.41 | 0.34 | 0.53 |
| Meadow Pond 3F | 3.28 | 6 | 124.7 | 0.46 | 0.45 | Nearly Bare Ground | 0.74 | 0.08 | 5.00 | 0.44 | 0.72 | 0.41 | 0.65 | 0.54 | 0.84 |
| Meadow Pond 4F | 0.49 | 5.7 | 67.1 | 0.75 | 0.75 | Nearly Bare Ground | 0.72 | 0.08 | 5.00 | 0.11 | 0.18 | 0.10 | 0.16 | 0.13 | 0.21 |
| Meadow Pond SF | 0.45 | 5.8 | 93.8 | 0.76 | 0.75 | Nearly Bare Ground | 0.73 | 0.08 | 5.00 | 0.10 | 0.16 | 0.09 | 0.15 | 0.12 | 0.19 |
| Meadow Pond 6F | 1.38 | 7.7 | 248.4 | 0.96 | 0.95 | Forest with heavy ground litter & meadow | 0.21 | 0.33 | 19.86 | 0.18 | 0.29 | 0.17 | 0.27 | 0.22 | 0.35 |
| Meadow Pond 7F | 1.05 | 8.6 | 218.1 | 0.88 | 0.86 | Forest with heavy ground litter & meadow | 0.22 | 0.27 | 16.50 | 0.14 | 0.23 | 0.13 | 0.21 | 0.17 | 0.27 |
| Meadow Pond 8F | 0.49 | 1.2 | 120.0 | 1.00 | 1.00 | Forest with heavy ground litter & meadow | 0.08 | 0.41 | 24.40 | 0.07 | 0.10 | 0.05 | 0.09 | 0.08 | 0.12 |
| Meadow Pond 9F | 1.05 | 6.6 | 113.5 | 1.00 | 1.00 | Forest with heavy ground litter & meadow | 0.19 | 0.16 | 9.80 | 0.23 | 0.38 | 0.20 | 0.31 | 0.28 | 0.44 |
| Meadow Pond 10F | 1.54 | 2 | 384.1 | 1.00 | 1.00 | Forest with heavy ground litter & meadow | 0.11 | 1.01 | 60.44 | 0.18 | 0.29 | 0.17 | 0.17 | 0.22 | 0.34 |
| Meadow Pond 11F | 4.17 | 5.9 | 438.4 | 0.87 | 0.86 | Forest with heavy ground litter & meadow | 0.18 | 0.67 | 40.06 | 0.33 | 0.54 | 0.31 | 0.50 | 0.41 | 0.65 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Return Period | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Meadow Pond 12F | 0.40 | 20 | 88.3 | 0.31 | 0.31 | Forest with heavy ground litter & meadow | 0.34 | 0.08 | 5.00 | 0.04 | 0.06 | 0.03 | 0.05 | 0.04 | 0.07 |
| Meadow Pond 13F | 0.12 | 6.5 | 60.1 | 0.31 | 0.34 | Forest with heavy ground litter & meadow | 0.19 | 0.09 | 5.23 | 0.01 | 0.02 | 0.01 | 0.02 | 0.01 | 0.02 |
| Meadow Pond 14F | 0.24 | 0.7 | 98.5 | 1.00 | 1.00 | Forest with heavy ground litter & meadow | 0.06 | 0.44 | 26.26 | 0.03 | 0.05 | 0.03 | 0.04 | 0.04 | 0.06 |
| Meadow Pond 15F | 2.10 | 2.4 | 162.2 | 0.71 | 0.70 | Forest with heavy ground litter & meadow | 0.12 | 0.39 | 23.30 | 0.18 | 0.30 | 0.17 | 0.28 | 0.23 | 0.36 |
| Meadow Pond 16F | 3.20 | 3.9 | 223.6 | 1.00 | 1.00 | Forest with heavy ground litter & meadow | 0.15 | 0.42 | 25.16 | 0.64 | 1.05 | 0.35 | 0.57 | 0.79 | 1.24 |
| Meadow Pond 17F | 14.00 | 5.4 | 477.6 | 0.96 | 0.95 | Forest with heavy ground litter & meadow | 0.17 | 0.76 | 45.63 | 1.14 | 1.87 | 1.12 | 1.72 | 1.41 | 2.23 |
| Meadow Pond 18F | 2.27 | 1.7 | 199.9 | 1.00 | 1.00 | Forest with heavy ground litter & meadow | 0.10 | 0.57 | 34.14 | 0.27 | 0.45 | 0.21 | 0.34 | 0.34 | 0.53 |
| Meadow Pond 19F | 1.86 | 3.7 | 213.5 | 1.00 | 1.00 | Forest with heavy ground litter & meadow | 0.14 | 0.41 | 24.66 | 0.37 | 0.61 | 0.21 | 0.33 | 0.46 | 0.72 |
| Meadow Pond 20F | 7.24 | 2 | 578.8 | 1.00 | 1.00 | Forest with heavy ground litter & meadow | 0.11 | 1.52 | 91.07 | 0.70 | 1.15 | 0.39 | 0.63 | 0.87 | 1.37 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Return Period | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Meadow Pond 21F | 2.47 | 1.2 | 315.4 | 1.00 | 1.00 | Forest with heavy ground litter & meadow | 0.08 | 1.07 | 64.15 | 0.26 | 0.43 | 0.16 | 0.26 | 0.32 | 0.51 |
| Meadow Pond 22F | 5.26 | 2.5 | 316.7 | 1.00 | 1.00 | Forest with heavy ground litter & meadow | 0.12 | 0.74 | 44.55 | 1.04 | 1.70 | 0.43 | 0.68 | 1.28 | 2.02 |
| Meadow Pond 23F | 7.04 | 1.6 | 525.4 | 1.00 | 1.00 | Forest with heavy ground litter & meadow | 0.09 | 1.54 | 92.48 | 0.46 | 0.76 | 0.38 | 0.61 | 0.57 | 0.91 |
| Meadow Pond 24F | 8.01 | 1.7 | 396.6 | 1.00 | 0.99 | Forest with heavy ground litter & meadow | 0.10 | 1.13 | 67.72 | 0.55 | 0.90 | 0.51 | 0.82 | 0.68 | 1.07 |
| Meadow Pond 25F | 4.90 | 2 | 259.0 | 1.00 | 1.00 | Forest with heavy ground litter & meadow | 0.11 | 0.68 | 40.76 | 0.58 | 0.96 | 0.42 | 0.66 | 0.72 | 1.14 |
| Meadow Pond 26F | 9.75 | 1.2 | 373.9 | 1.00 | 1.00 | Forest with heavy ground litter & meadow | 0.08 | 1.27 | 76.05 | 1.59 | 2.62 | 0.59 | 0.94 | 1.98 | 3.13 |
| Meadow Pond 27F | 42.01 | 1.7 | 752.1 | 1.00 | 1.00 | Forest with heavy ground litter & meadow | 0.10 | 2.14 | 128.42 | 2.55 | 4.20 | 1.89 | 3.02 | 3.19 | 5.06 |
| Meadow Pond 28F | 45.00 | 1.4 | 954.5 | 1.00 | 1.00 | Forest with heavy ground litter & meadow | 0.09 | 2.99 | 179.69 | 2.44 | 4.01 | 1.68 | 2.68 | 3.05 | 4.84 |
| Meadow Pond 29F | 11.98 | 1.5 | 385.2 | 1.00 | 1.00 | Forest with heavy ground litter & meadow | 0.09 | 1.17 | 70.04 | 0.87 | 1.44 | 0.75 | 1.20 | 1.08 | 1.72 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Return Period | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Meadow Pond 30F | 3.97 | 1 | 236.1 | 0.99 | 0.98 | Forest with heavy ground litter & meadow | 0.07 | 0.88 | 52.64 | 0.31 | 0.50 | 0.29 | 0.47 | 0.38 | 0.60 |
| Meadow Pond 31F | 53.99 | 0.9 | 1189.7 | 1.00 | 1.00 | Forest with heavy ground litter & meadow | 0.07 | 4.66 | 279.62 | 2.56 | 4.22 | 1.58 | 2.52 | 3.22 | 5.13 |
| Meadow Pond 32F | 26.99 | 3.9 | 1225.9 | 1.00 | 1.00 | Forest with heavy ground litter & meadow | 0.15 | 2.30 | 137.92 | 1.67 | 2.74 | 1.17 | 1.86 | 2.08 | 3.30 |
| Meadow Pond 33F | 35.01 | 3.6 | 1377.6 | 1.00 | 1.00 | Forest with heavy ground litter & meadow | 0.14 | 2.69 | 161.36 | 2.06 | 3.39 | 1.39 | 2.22 | 2.58 | 4.08 |
| Meadow Pond 34F | 28.00 | 1.4 | 645.8 | 1.00 | 1.00 | Forest with heavy ground litter & meadow | 0.09 | 2.03 | 121.58 | 1.83 | 3.01 | 1.30 | 2.07 | 2.28 | 3.62 |
| Meadow Pond 35F | 28.00 | 1.3 | 650.0 | 1.00 | 1.00 | Forest with heavy ground litter & meadow | 0.09 | 2.12 | 127.00 | 1.83 | 3.01 | 1.27 | 2.02 | 2.28 | 3.62 |
| Meadow Pond 36F | 25.01 | 3.3 | 813.9 | 1.00 | 1.00 | Forest with heavy ground litter & meadow | 0.14 | 1.66 | 99.58 | 1.71 | 2.82 | 1.30 | 2.07 | 2.13 | 3.38 |
| Meadow Pond 37F | 80.01 | 4.1 | 1358.2 | 1.00 | 1.00 | Forest with heavy ground litter & meadow | 0.15 | 2.48 | 149.02 | 4.84 | 7.97 | 3.32 | 5.29 | 6.05 | 9.60 |
| Wolfe Street 1A | 1.42 | 4 | 286.8 | 0.82 | 0.81 | Nearly Bare Ground | 0.61 | 0.13 | 7.89 | 0.26 | 0.43 | 0.25 | 0.39 | 0.32 | 0.51 |
| Wolfe Street 2A | 1.78 | 4.3 | 270.7 | 0.78 | 0.77 | Nearly Bare Ground | 0.63 | 0.12 | 7.19 | 0.33 | 0.55 | 0.31 | 0.49 | 0.40 | 0.64 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | Return Period | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Wolfe Street 3A | 1.09 | 6.7 | 125.4 | 0.59 | 0.58 | Nearly Bare Ground | 0.78 | 0.08 | 5.00 | 0.19 | 0.31 | 0.18 | 0.28 | 0.23 | 0.36 |
| Wolfe Street 4A | 0.24 | 8.6 | 62.0 | 0.44 | 0.44 | Nearly Bare Ground | 0.89 | 0.08 | 5.00 | 0.03 | 0.05 | 0.03 | 0.05 | 0.04 | 0.06 |
| Wolfe Street 5A | 0.24 | 10.7 | 105.5 | 0.71 | 0.71 | Nearly Bare Ground | 0.99 | 0.08 | 5.00 | 0.05 | 0.08 | 0.05 | 0.08 | 0.06 | 0.10 |
| Wolfe Street 6A | 0.36 | 11 | 94.2 | 0.69 | 0.68 | Nearly Bare Ground | 1.00 | 0.08 | 5.00 | 0.07 | 0.12 | 0.07 | 0.11 | 0.09 | 0.14 |
| Wolfe Street 1B | 0.16 | 6.1 | 136.2 | 0.60 | 0.60 | short grass pasture and lawns | 0.53 | 0.08 | 5.00 | 0.03 | 0.05 | 0.03 | 0.04 | 0.03 | 0.05 |
| Wolfe Street 2B | 0.12 | 1.5 | 147.9 | 1.13 | 1.08 | short grass pasture and lawns | 0.26 | 0.16 | 9.34 | 0.03 | 0.05 | 0.02 | 0.04 | 0.03 | 0.05 |
| Wolfe Street 3B | 0.36 | 6.9 | 142.5 | 0.58 | 0.58 | short grass pasture and lawns | 0.57 | 0.08 | 5.00 | 0.06 | 0.10 | 0.06 | 0.09 | 0.08 | 0.12 |
| Wolfe Street 4B | 0.20 | 4.4 | 91.6 | 0.57 | 0.57 | short grass pasture and lawns | 0.45 | 0.08 | 5.00 | 0.03 | 0.06 | 0.03 | 0.05 | 0.04 | 0.07 |
| Wolfe Street 5B | 0.08 | 3.6 | 65.1 | 0.71 | 0.64 | short grass pasture and lawns | 0.41 | 0.08 | 5.00 | 0.02 | 0.03 | 0.02 | 0.02 | 0.02 | 0.03 |
| Wolfe Street 6B | 0.69 | 3.5 | 139.2 | 0.49 | 0.48 | short grass pasture and lawns | 0.40 | 0.10 | 5.75 | 0.09 | 0.15 | 0.08 | 0.13 | 0.11 | 0.17 |
| Wolfe Street 7B | 1.94 | 4.7 | 426.5 | 0.75 | 0.74 | short grass pasture and lawns | 0.47 | 0.25 | 15.21 | 0.23 | 0.38 | 0.22 | 0.34 | 0.28 | 0.44 |
| Wolfe Street 8B | 0.16 | 6.8 | 54.6 | 0.30 | 0.30 | short grass pasture and lawns | 0.56 | 0.08 | 5.00 | 0.01 | 0.02 | 0.01 | 0.02 | 0.02 | 0.03 |
| Wolfe Street 9B | 0.61 | 7 | 99.5 | 0.32 | 0.30 | short grass pasture and lawns | 0.57 | 0.08 | 5.00 | 0.06 | 0.09 | 0.05 | 0.08 | 0.07 | 0.11 |
| Wolfe Street 10B | 2.43 | 5.3 | 445.3 | 0.73 | 0.72 | short grass pasture and lawns | 0.50 | 0.25 | 14.96 | 0.28 | 0.46 | 0.26 | 0.42 | 0.34 | 0.54 |

| Watershed Identifier | Area | Slope | Stream Length | Runoff Coefficient Back Calculated from the 1993 Report | | Determined Representative Land Use | Velocity | Time of Concentration | Time of Concentration | Flow (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Return Period | | | | | | 1993 | | 2019 | | Future Conditions | |
| | | | | | | | | | | Return Period | | Return Period | | Return Period | |
| | hectre | % | meter | 5 year | 100 year | | m/s | hours | minutes | 5 Year | 100 Year | 5 Year | 100 Year | 5 Year | 100 Year |
| Wolfe Street 11B | 0.73 | 4.5 | 232.7 | 0.41 | 0.40 | short grass pasture and lawns | 0.46 | 0.14 | 8.48 | 0.07 | 0.10 | 0.06 | 0.09 | 0.08 | 0.12 |
| Wolfe Street 12B | 0.73 | 5.4 | 113.6 | 0.33 | 0.32 | short grass pasture and lawns | 0.50 | 0.08 | 5.00 | 0.07 | 0.11 | 0.07 | 0.10 | 0.09 | 0.13 |
| Wolfe Street 13B | 22.01 | 4.4 | 1335.0 | 1.09 | 1.08 | short grass pasture and lawns | 0.45 | 0.82 | 49.21 | 1.95 | 3.21 | 1.68 | 2.94 | 2.42 | 3.82 |
| Wolfe Street 14B | 1.38 | 8.2 | 208.3 | 0.35 | 0.34 | short grass pasture and lawns | 0.62 | 0.09 | 5.63 | 0.13 | 0.21 | 0.12 | 0.19 | 0.16 | 0.25 |
| Wolfe Street 15B | 0.49 | 6.7 | 71.4 | 0.46 | 0.44 | short grass pasture and lawns | 0.56 | 0.08 | 5.00 | 0.07 | 0.10 | 0.06 | 0.09 | 0.08 | 0.12 |
| Wolfe Street 16B | 1.98 | 8.7 | 258.5 | 0.36 | 0.36 | short grass pasture and lawns | 0.64 | 0.11 | 6.78 | 0.18 | 0.29 | 0.17 | 0.26 | 0.22 | 0.34 |
| Wolfe Street 17B | 2.51 | 5.9 | 373.1 | 0.69 | 0.68 | short grass pasture and lawns | 0.52 | 0.20 | 11.88 | 0.31 | 0.51 | 0.29 | 0.46 | 0.38 | 0.60 |

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