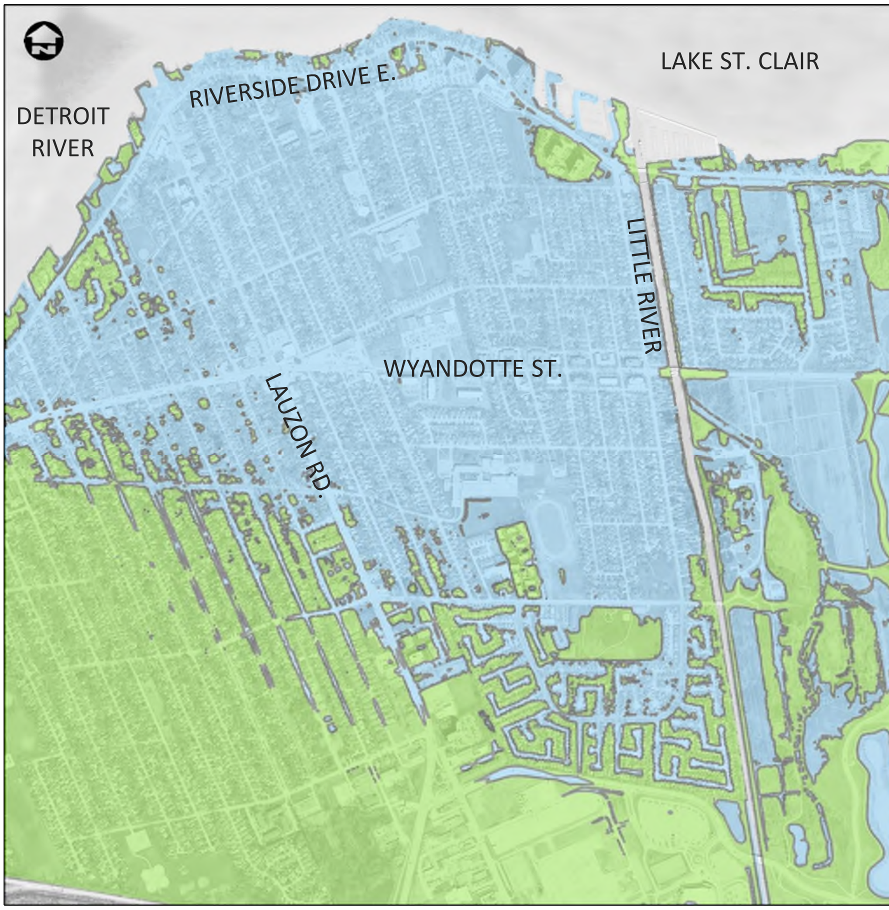
East Riverside Flood Risk Assessment



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THE CITY OF WINDSOR ONTARIO, CANADA

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EXECUTIVE SUMMARY

INTRODUCTION

In recent years, the issue of flooding has increasingly become a major concern in the City of Windsor. Extreme rainfall events in 2016 and 2017 each caused significant flooding of local roads, homes, and businesses – with thousands of reports of flooding received by the City as a result of each event. In response, the Mayor initiated an 8-Point Plan in September 2017, aimed at addressing flooding problems in the City of Windsor. This plan included several measures aimed at upgrading the City's sewer system and mitigating the risk of basement flooding.

With the recent return of record-high water levels on Lake St. Clair, the potential for overland flooding to occur in the East Riverside neighbourhood has also been identified by the City as a significant risk. To address this concern, the City of Windsor retained Landmark Engineers Inc. to carry out a flood risk assessment focused on:

- Documenting and assessing the condition of the existing flood control measures along Riverside Drive East from St. Rose Beach easterly to the City boundary with the Town of Tecumseh;
- Quantifying the risk to the flood-prone areas along Riverside Drive East and inland;
- Identifying alternative solutions for restoration of the flood protection measures within the study area;
- Preparing a prioritized action plan to address and mitigate the risk of overland flooding; and,
- Providing updated design recommendations and cost estimates for budgeting purposes.

METHODOLOGY

In conformance with the terms of reference for this study, Landmark made use of the *PIEVC Engineering Protocol for Infrastructure Vulnerability Assessment and Adaptation to a Changing Climate,* which was developed by Engineers Canada to provide a step-by-step methodology for risk assessment of public infrastructure in response to climate change. The procedures set out in this protocol set the overall framework for carrying out this risk assessment study.

CLIMATE PARAMETERS

As one of the initial steps in the *PIEVC Protocol*, the climate parameters most likely to contribute to the vulnerability of the subject infrastructure needed to be identified. In this case, water levels on Lake St. Clair were identified as the primary parameter of concern. Wind-driven waves on Lake St. Clair and heavy rain events were also identified as potential contributors to the vulnerability of the existing flood control measures within the study area - although these were generally considered to be secondary parameters that would contribute to infrastructure vulnerability in combination with high water levels.

In order to establish a climate baseline for water levels on Lake St. Clair, Landmark retained a climate subconsultant (RWDI Consulting Engineers & Scientists) to analyze the historic water level gauge records for Lake St. Clair and establish an updated 1:100-year instantaneous peak water level for current conditions. In carrying out their analyses, RWDI also utilized established climate change models to predict future 1:100-year water levels for the years 2030 and 2050. These time horizons were selected based on the presumed level of accuracy of the available climate change models.

Based on the analyses carried out by RWDI, the current baseline for the 1:100-year instantaneous peak water level on Lake St. Clair was determined to be at an elevation of 176.5m. Accounting for the potential influence of climate change, the future 1:100-year instantaneous peak water level (projected to the year 2050) was predicted to be at an elevation of 176.8m. These two water level elevations were used to assess the vulnerability of the City's existing flood protection measures within the study area.

INFRASTRUCTURE ASSESSMENT

Using information from past studies and LiDAR data provided by the City of Windsor, Landmark compiled an inventory of the existing dike system in place along Riverside Drive East within the study area. The existing 6km-long dike system was established in the mid-1980s and primarily consists of earth berms located on the south side of Riverside Drive East. The dike system was originally built to protect the low-lying inland areas of East Riverside from overland flooding from Lake St. Clair and the Detroit River.

For the purposes of this assessment, the study area was divided into two distinct sections:

a) the area west of Little River (i.e., from St. Rose Beach to Little River); and,
b) the area east of Little River (i.e., from Little River to the City boundary with the Town of Tecumseh).

The condition of the existing dike system in these two sections varies considerably.

West of Little River, approximately 32% of the existing dike is at or above the current 1:100-year instantaneous peak water level on Lake St. Clair (i.e., at elevation 176.5m or higher). Accounting for climate change (using the 1:100-year water level of 176.8m for the year 2050), only about 13% of the existing dike system is at or above the predicted flood level.

East of Little River, the existing dike system is in considerably better condition. Approximately 99% of the existing dike is at or above the current 1:100-year flood level of 176.5m. When accounting for the potential impacts of climate change to the year 2050, however, only about 37% of the existing dike system is at or above the predicted flood level of 176.8m.

Given the above, it is apparent that the existing dike system is vulnerable to overtopping west of Little River should water levels on Lake St. Clair approach the current 1:100-year instantaneous peak. Should lake levels approach the 1:100-year instantaneous peak predicted for the year

2050, then the existing dike system would be vulnerable to overtopping throughout the entire study area.

In addition to the deficiencies noted above, a review of the City's Sewer Atlas revealed that there are numerous locations where storm sewers cross under the existing dikes and provide an opportunity for flood waters to bypass the existing flood protection system. In the event that wind-driven waves and/or high water levels on Lake St. Clair cause flooding of Riverside Drive, the roadside catch basins would convey flood waters into the storm sewers and surcharge the system. This surcharged condition would then convey water through the sewers and catch basin leads to the low-lying areas inland – regardless of whether the flood waters were high enough to overtop the dikes.

West of Little River, storm sewer crossings under the dike were identified at 7 separate locations. East of Little River, 12 storm sewer crossings and 21 catch basin lead crossings were noted – all of which with the potential to convey flood waters inland under the dike system. Thus, the entire dike system within the study area is potentially vulnerable to being bypassed.

RISK ASSESSMENT

In accordance with the procedures set out in the *PIEVC Protocol*, a Risk Assessment Workshop was carried out in consultation with City of Windsor staff from various departments.

Using the previously-identified climate parameters of: high water levels, wind-driven waves, and heavy rainfall, the workshop participants assigned probability scores to various scenarios where the existing dike system could be overtopped and/or bypassed in the segments of the study area west and east of Little River. This exercise was first carried out based on current climate conditions, and then again based on projected conditions due to climate change.

To help quantify the flood risks, the workshop participants were then asked to assign severity scores to each of the above scenarios in terms of three performance measures:

- the impact of the climate scenario on the integrity of the dike and sewer systems;
- the degree of emergency response that would be required to address the effects of the climate scenario; and,
- the amount of property damage, social effects, and insurance claims that would result from the climate scenario.

The results of the risk assessment were then compiled, with total risk scores for each scenario calculated using the following equation:

RISK SCORE = PROBABILITY SCORE x SEVERITY SCORE

The various scenarios were then ranked from highest risk score to lowest to assist in identifying patterns of weather events and climate trends that contribute to high flood risks within the study area.

Based on our review of the tabulated risk profiles, it appears that for current climate conditions:

- the highest-risk scenarios generally involve inland flooding due to bypassing of the dike system through interconnected storm sewers.

Whereas for future climate conditions:

- the highest-risk scenarios generally involve inland flooding due to bypassing of the dike system for areas east of Little River.
- west of Little River, the highest-risk scenarios involve inland flooding due to both bypassing of the dike system and overtopping of the existing dikes.

Regardless of the location (west or east of Little River), the highest-risk scenarios for both current and future climate conditions were associated with high severity scores for emergency flood mitigation and property damage.

ALTERNATIVE SOLUTIONS

In order to address the vulnerabilities identified in the existing dike system, several alternative design solutions were developed, aimed at preventing overtopping or bypassing of the dikes.

To address the potential for dike overtopping, it is recommended that the existing dike system be reconstructed along its existing alignment to ensure a continuous top elevation of 177.1m. Depending upon the specific location along the dike and the associated site constraints (e.g., buildings, roadways, driveways, etc.), establishing this top of dike elevation can be achieved using a combination of the following design alternatives:

- Earth berms;
- Walls backed with earth berms;
- Walls;
- Automated mechanical gates;
- Raising Riverside Drive.

Advantages and disadvantages for each of the above alternatives have been identified.

To address the potential for bypassing of the dikes through the sewer system, design alternatives were developed for various scenarios - each involving the installation of backflow prevention devices or sluice gates at the cross-connection points in the sewer system to prevent the flow of flood waters inland.

PUBLIC CONSULTATION

On 26 June 2019, a Public Information Centre (PIC) was convened at the WFCU Centre to present the initial findings of the East Riverside Flood Risk Assessment. A series of 22 display panels were prepared, outlining the relevant climate parameters, the inventory of the existing dike system, the areas potentially affected by a failure of the dike system, and several alternative solutions for re-establishing a continuous dike system along Riverside Drive.

Over the course of the 3-hour PIC, approximately 100 members of the public signed in to record their attendance. Members of the Project Team from both Landmark Engineers and the City of Windsor were available throughout the PIC to help clarify the information presented in the display panels and to answer questions from the public. Comment sheets were also made available for attendees to provide written feedback regarding the study, although only 5 completed comment sheets were submitted by the public.

Although most of the feedback received over the course of the PIC was quite supportive of the proposed solutions, several attendees expressed concerns regarding the potential for flooding outside of the areas protected by the existing dike system. Residents with properties on the north side of Riverside Drive, in particular, expressed dissatisfaction that the scope of this study did not include measures to protect waterfront properties from overland flooding and erosion.

RECOMMENDATIONS

Based on the outcomes of the assessments described above, Landmark recommends that the following measures be implemented to address the vulnerability of the City's existing flood protection infrastructure in East Riverside:

- As a first priority, the City should carry out functional and detailed design of backflow prevention measures for each of the locations identified in this report where the storm sewer system crosses under the diking system. Design works should be carried out in coordination with the ongoing Sewer Master Plan and should incorporate automated controls and/or alert systems wherever sluice gates are included in the design.
- Upon completion of functional and detailed design, the new backflow prevention measures should be implemented in the field as soon as possible. The preliminary total construction estimate for these works (including engineering and administrative costs) is in the order of approximately $1,300,000. If a phased approach to construction is deemed necessary, the sewer works east of Little River should be given first priority, based on the outcome of the risk assessment presented in this report.
- Secondary only to the implementation of the backflow prevention works, functional and detailed design of the proposed dike improvements for the area west of Little River should be carried out as soon as possible. This work should be coordinated with the ongoing Class Environmental Assessment for the Sewer Master Plan in order to provide a mechanism for property acquisition along Riverside Drive, where needed.
- Upon completion of functional and detailed design, property and/or easements should be acquired where needed for the construction of the proposed dike improvements. Construction of the recommended dike improvements west of Little River should then proceed as soon as possible. The preliminary construction estimate for these works

(including engineering and administrative costs) is in the order of approximately $8,700,000. If a phased approach to construction is desired, the segments of the dike alignment where no discernable dike currently exists (i.e., west of St. Rose Beach, from St. Rose to Fairview Boulevard, and from the St. Paul Pumping Station to Watson Avenue) should be given first priority.

- Upon completion of the backflow prevention measures and the dike improvements west of Little River, functional and detailed design of the dike improvements east of Little River should proceed, followed by construction. The preliminary construction estimate for these works (including engineering and administrative costs) is in the order of approximately $8,700,000.
- The City should budget for and implement a policy requiring regular inspections of the diking system and any backflow prevention measures that are implemented as a result of this report. We would recommend a initial minimum inspection schedule of once every 3 years.
- The City should also include an item in its operating budget for regular maintenance and repair of the diking system and any new backflow prevention measures. The amount of this budget should be determined in consultation with the City’s Contracts, Field Services & Maintenance Division.

In addition to the above, we recommend that a follow-up analysis of the water levels on Lake St. Clair be carried out prior to the year 2030 to confirm whether the predicted effects of climate change remain valid.

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1.0 INTRODUCTION

In recent years, the issue of flooding has increasingly become a major concern in the City of Windsor. Extreme rainfall events in 2016 and 2017 each caused significant flooding of local roads, homes, and businesses – with thousands of reports of flooding received by the City as a result of each event. In response, the Mayor initiated an 8-Point Plan in September 2017, aimed at addressing flooding problems in the City of Windsor. This plan included several measures aimed at upgrading the City's sewer system and mitigating the risk of basement flooding.

With the recent return of record-high water levels on Lake St. Clair, the potential for overland flooding to occur in the East Riverside neighbourhood of Windsor has also been identified by the City as a significant risk. Although this flooding risk is not directly related to the increasing occurrence of heavy rainfall events, the current high water levels and history of substantial flooding in the East Riverside area due to inundation from Lake St. Clair suggests that the condition of the existing protective dikes and drainage systems should be assessed.

This report has been prepared to document our vulnerability assessment of the existing dikes along the City's Lake St. Clair and Detroit River shorelines (adjacent to East Riverside) for both the current condition and the future, accounting for the potential effects of climate change.

1.1 BACKGROUND

Historically, flooding in East Riverside has been a threat mainly due to the flat, low-lying topography of the area relative to the adjacent waterbodies. The history of overland flooding from Lake St. Clair and the Detroit River has been documented and studied in various shoreline studies and damage surveys over the years. Significant flooding events occurred in the early 1950s, and again in 1973, 1986, and 1998. The extent and severity of these overland flooding events has varied with the water level on Lake St. Clair, the incidence of wind-driven waves, and the condition of the inland dike systems.

The existing dike system protecting the inland areas of East Riverside was constructed in the mid-1980s and is generally located along the south side of Riverside Drive East. East of Little River, the dike generally follows the alignment of the Ganatchio Trail, while west of Little River it is primarily located within the Riverside Drive right-of-way. It is our understanding that there have not been any coordinated improvements or alterations made to the overall dike system since the last significant occurrence of high water levels on Lake St. Clair in the late 1990s.

Since 2013, water levels on Lake St. Clair have been steadily rising, and by the summer of 2018 they were again starting to approach near-record highs. In response to this potential threat, the City of Windsor applied for and received funding through the *Federation of Canadian Municipalities – Municipalities for Climate Innovation Program (FCM-MCIP)* to carry out a flood risk assessment for the area of East Riverside. Landmark Engineers was subsequently retained by the City to carry out this assessment.

1.2 PURPOSE & SCOPE

The primary purpose of this study is to quantify the risk of overland flooding from Lake St. Clair and the Detroit River along a 6km-long segment of shoreline in east Windsor and the adjacent inland areas.

The scope of the assessment includes:

- Documenting and assessing the condition of the existing flood control measures along Riverside Drive East from St. Rose Beach easterly to the City boundary with the Town of Tecumseh;
- Quantifying the risk to the flood-prone areas along Riverside Drive East and inland;
- Identifying alternative solutions for restoration of the flood protection measures within the study area;
- Preparing a prioritized action plan to address and mitigate the risk of overland flooding; and,
- Providing updated design recommendations for the flood protection measures, complete with cost estimates for budgeting purposes.

Since the focus of this study is on assessing the flood risk from Lake St. Clair and the Detroit River, the scope of this report does not include any substantial evaluation of the local storm drainage system or the associated risk of flooding due to heavy rainfall. It is our understanding that these risks are currently being addressed through the City's ongoing Sewer Master Plan modeling study.

Furthermore, it is acknowledged that the neighbourhoods of East Riverside could potentially be affected by flooding from Little River, which flows into Lake St. Clair at the mouth of the Detroit River and bisects the current study area. We understand that the City has recently taken steps to undertake a separate study of the flood protection dikes along the banks of Little River. This was therefore not included as part of the current scope of work.

1.3 METHODOLOGY – PIEVC PROTOCOL

In conformance with the terms of reference for this study, Landmark Engineers made use of the *PIEVC Engineering Protocol for Infrastructure Vulnerability Assessment and Adaptation to a Changing Climate,* which was developed by Engineers Canada to provide a step-by-step methodology for risk assessment of public infrastructure in response to climate change. The protocol stresses the importance of professional judgment and documentation, and creates a framework to support effective decision-making regarding infrastructure operation, maintenance, planning, and development.

A flowchart, depicting the basic steps that comprise the PIEVC Protocol is provided in Figure 1. Each step in the PIEVC Protocol is supported by an associated PIEVC Worksheet, which have been completed by Landmark (in consultation with City administration) and have been included here as Appendix A. These worksheets generally parallel the PIEVC Protocol steps and provide a paper trail to document each decision and assumption that was made over the course of this risk assessment study.

2.0 PROJECT DEFINITION (PIEVC STEP 1)

The first step in the PIEVC Protocol is to define the project parameters and boundary conditions for the engineering vulnerability assessment. As detailed in PIEVC Worksheet Step 1 (see Appendix A), this process involves:

- Identifying the specific infrastructure to be assessed;
- Identifying the location of the infrastructure and is specific use(s); and,
- Identifying climatic and geographic considerations that could affect the subject infrastructure.

In carrying out the above, it is the intention of this step in the process to narrow the focus of the assessment and thus allow for a more efficient condition inventory to be compiled for further analysis.

2.1 INFRASTRUCTURE TO BE ASSESSED

Given that the purpose of this study is to assess the risk of overland flooding from Lake St. Clair and the Detroit River, it was decided (in consultation with City administration) that the primary focus of the assessment would be on the existing flood protection system itself. This system consists of a series of interconnected dikes and berms that were originally constructed in the mid-1980s, as illustrated in Figure 2. It should be noted that the flood protection system depicted in this figure includes several elements that have been specifically excluded from the current scope of work, such as the diking system along Little River and the Lake St. Clair shoreline berms - both of which are primarily located on private property.

Therefore, for the purposes of this assessment, the flood protection systems to be evaluated include:

- The existing flood protection dike along Riverside Drive East between St. Rose Beach and the City boundary with the Town of Tecumseh;
- The existing flood protection dike that runs inland along the boundary with the Town of Tecumseh; and,
- The components of the minor and major drainage systems (i.e., the storm sewer network and overland surface drainage systems) that cross under or over the existing dike system.

Detailed information regarding the all of the above (including LiDAR and GIS information) has been provided by the City of Windsor to assist with the assessment.

2.2 CLIMATE PARAMETERS

As one of the initial steps in the *PIEVC Protocol*, the climate parameters most likely to contribute to the vulnerability of the subject infrastructure needed to be identified. In this case, water levels on Lake St. Clair were identified as the primary parameter of concern. Wind-driven waves on Lake St. Clair and heavy rain events were also identified as potential contributors to the vulnerability of the existing flood control measures within the study area, although these were generally considered to be secondary parameters that would contribute to infrastructure vulnerability in combination with high water levels. This is consistent with the known history of overland flooding events in the area.

In addition to the above, consideration was given to assessing the potential for the flood protection infrastructure to be affected by: temperature, lake ice, and freeze/thaw cycles. As indicated in the PIEVC Worksheet, however, it was concluded that the potential effects of these parameters would be insignificant in comparison with the primary and secondary parameters noted above. These were therefore discarded from further consideration for the purposes of this assessment.

2.3 TIME HORIZON

The design life of the various flood protection system components was reviewed with City staff, as required by the PIEVC Protocol. It was noted that both the design life and the ages of the various dikes, berms, and interconnected sewers under assessment varies considerably, making it exceedingly difficult to set a specific time horizon for the risk assessment based on the age and/or condition of the existing infrastructure.

In discussions with City staff and Landmark's climate subconsultant (i.e., RWDI Inc. – refer to Section 3.2 of this report), it was noted that the available climate change projection models become increasingly less reliable as the time horizon extends further into the future. For this reason, a time horizon extending to the year 2050 was selected for the purposes of this risk assessment. It was judged that this time horizon would allow for the planning of future dike improvements (accounting for the potential impacts of climate change), without committing the City to overly-conservative design parameters in the short- to medium-term. It is recommended that this assumption be reviewed and re-evaluated sometime around the year 2030.

2.4 GEOGRAPHY / STUDY AREA

Given the extents of the existing flood protection system being assessed, the study area has been defined as the area between St. Rose Beach and the City boundary with the Town of Tecumseh, and the areas potentially affected inland as far as the Via Rail corridor south of McHugh Street. For the purposes of this assessment, the study area has also been divided into the areas west and east of the Little River corridor.

A visual summary of the study area and limits is provided in Figure 3.

2.5 DATA SUFFICIENCY

For the primary climate parameter under consideration (i.e., water levels on Lake St. Clair), a considerable amount of data has been collected and compiled from the existing network of gauge stations on Lake St. Clair – including Fisheries and Oceans Canada's gauge station at Belle River and the US National Oceanic and Atmospheric Administration's gauge station at Windmill Point (at the mouth of the Detroit River). Given that the Windmill Point station is the closest and most relevant gauge to the study area, a summary of historic yearly high and low water levels was compiled and is attached here as Figure 4.

In order to evaluate appropriate thresholds for design of the dike system, in keeping with *Ontario Regulation 158/06* under the Conservation Authorities Act, the 1:100 year peak instantaneous water level needs to be assessed. The last available analysis for this value was obtained from the City's 1986 Shoreline Management Plan. Given that over 30 years of water level data has been compiled since the preparation of that report, it was noted that an update to the 1:100 year peak instantaneous water level for Lake St. Clair is warranted. This was identified as a data gap in accordance with the PIEVC Protocol.

To address this data gap, a climate subconsultant (i.e., RWDI Inc.) was retained by Landmark to carry out an updated analysis of the water level information on Lake St. Clair. As part of their assignment, RWDI was also instructed to make use of established climate change models in order to predict the future 1:100 year peak instantaneous water levels for the time horizon of this risk assessment. A copy of RWDI's report is attached here as Appendix C.

3.0 DATA GATHERING & SUFFICIENCY (PIEVC STEP 2)

As detailed in PIEVC Worksheet Step 2 (see Appendix A), a complete inventory of the existing dike system, the areas protected by the dike system, and the relevant climate parameters used in this risk assessment has been compiled.

Details of the dike inventory are provided in Appendix B as Technical Brief TB1. A summary of the historical flooding events that have impacted the study area is presented in Appendix B as Technical Brief TB2. An inventory of the areas potentially affected by flooding at the various water levels under consideration here is presented in Appendix B as Technical Brief TB3.

3.1 DIKE SYSTEM INVENTORY

Using information from past studies and LiDAR data provided by the City of Windsor, Landmark compiled an inventory of the existing dike system in place along Riverside Drive East within the study area. The existing 6km-long dike system was established in the mid-1980s and primarily consists of earth berms located on the south side of Riverside Drive East. The dike system was originally built to protect the low-lying inland areas of East Riverside from overland flooding from Lake St. Clair and the Detroit River. Visual depictions of the areas that could potentially be affected by overland flooding (at various water levels) are presented in Figures 5 and 6.

For the purposes of this assessment, the study area was divided into two distinct sections:

a) the area west of Little River (i.e., from St. Rose Beach to Little River); and,
b) the area east of Little River (i.e., from Little River to the City boundary with the Town of Tecumseh).

A visual summary these two sections of the study area is presented visually as Figures 7 and 8. The detailed inventory of the dike through each of these sections is presented in Figures 9 through 18, complete with representative photographs. As indicated in these figures, the condition of the existing dike system in these two sections varies considerably.

3.1.1 DIKE CONTINUITY

West of Little River, approximately 32% of the existing dike is at or above the current 1:100-year instantaneous peak water level on Lake St. Clair (i.e., at elevation 176.5m or higher). Accounting for climate change (using the 1:100-year water level of 176.8m for the year 2050), only about 13% of the existing dike system is at or above the predicted flood level.

East of Little River, the existing dike system is in considerably better condition. Approximately 99% of the existing dike is at or above the current 1:100-year flood level of 176.5m. When accounting for the potential impacts of climate change to the year 2050, however, only about 37% of the existing dike system is at or above the predicted flood level of 176.8m.

A breakdown of the adequacy of the existing dike system, measured against various water levels, is presented in Table 1.

Given the above, it is apparent that the existing dike system is vulnerable to overtopping west of Little River should water levels on Lake St. Clair approach the current 1:100-year instantaneous peak. Should lake levels approach the 1:100-year instantaneous peak predicted for the year 2050, then the existing dike system would be vulnerable to overtopping throughout the entire study area.

3.1.2 SEWER BYPASSING

In addition to the deficiencies noted above, a review of the City's Sewer Atlas revealed that there are numerous locations where storm sewers cross under the existing dikes and provide an opportunity for flood waters to bypass the existing flood protection system. In the event that wind-driven waves and/or high water levels on Lake St. Clair cause flooding of Riverside Drive, the roadside catch basins would convey flood waters into the storm sewers and surcharge the system. This surcharged condition would then convey water through the sewers and catch basin leads to the low-lying areas inland – regardless of whether the flood waters were high enough to overtop the dikes.

West of Little River, storm sewer crossings of the dike were identified at 7 separate locations. East of Little River, 12 storm sewer crossings and 21 catch basin lead crossings were noted – all of which with the potential to convey flood waters inland under the dike system. Thus, the entire dike system within the study area is potentially vulnerable to being bypassed.

An inventory of the potential sewer crossings (including catch basins) is provided in Tables 2 and 3.

3.2 CLIMATE PARAMETERS / CLIMATE CHANGE ASSUMPTIONS

In order to establish a climate baseline for water levels on Lake St. Clair, Landmark retained a climate subconsultant (RWDI Consulting Engineers & Scientists) to analyze the historic water level gauge records for Lake St. Clair and establish an updated 1:100-year instantaneous peak water level for current conditions. In carrying out their analyses, RWDI also utilized established climate change models to predict future 1:100-year water levels for the years 2030 and 2050. These time horizons were selected based on the presumed level of accuracy of the available climate change models.

Based on the analyses carried out by RWDI, the current baseline for the 1:100-year instantaneous peak water level on Lake St. Clair was determined to be at an elevation of 176.5m. Accounting for the potential influence of climate change, the future 1:100-year instantaneous peak water level (projected to the year 2050) was predicted to be at an elevation of 176.8m. These two water level elevations were used to assess the vulnerability of the City's existing flood protection measures within the study area.

3.3 SYNERGISTIC EFFECTS

In accordance with the requirements of the PIEVC Protocol, the climate parameters with the greatest potential to affect the frequency and/or severity of overland flooding were reviewed and evaluated in terms of their potential to combine and/or sequence in a manner that could yield a higher impact within the study area. As indicated in PIEVC Worksheet Step 2 (see Appendix A), it was noted that high lake levels could potentially act in combination with the following factors to aggravate flooding in East Riverside:

- High, sustained winds – particularly from the north or northeast; and,
- Heavy rainfall.

These two factors could also potentially act together in combination with high lake levels to amplify the effects of overland flooding.

In reviewing these potential synergies, it was noted that since the effect of wind on lake set-up is already accounted for in the instantaneous high-water elevations, the primary synergistic effects of wind would be felt from wave action in areas where the dike is located close to the water's edge. The potential for wind-driven waves to push water inland as far as the dike and then enter the sewer system was also identified as an aggravating factor.

In assessing the potential impact of heavy rainfall, it was noted that the effects of overland flooding could be intensified or sustained should the local storm sewer system become overloaded due to intense precipitation.

3.4 DATA SUFFICIENCY

With the completion of the RWDI report, the data gap previously identified with respect to water elevations on Lake St. Clair has been addressed.

The topographic LiDAR data of the study area provided by the City of Windsor was also reviewed for accuracy and validated in the field via GPS surveys carried out by Landmark Engineers.

4.0 RISK ASSESSMENT (PIEVC STEP 3)

In accordance with the procedures set out in the *PIEVC Protocol*, a Risk Assessment Workshop was carried out in consultation with City of Windsor staff from various departments. A summary of the procedures followed is detailed in PIEVC Worksheet Step 3 (see Appendix A), with further details of the Risk Assessment Workshop provided in Appendix B (as Technical Brief TB4) and Appendix D.

Using the previously-identified climate parameters of: high water levels, wind-driven waves, and heavy rainfall, the workshop participants assigned probability scores to various scenarios where the existing dike system could be overtopped and/or bypassed in the segments of the study area west and east of Little River. This exercise was first carried out based on current climate conditions, and then again based on projected conditions due to climate change.

To help quantify the flood risks, the workshop participants were then asked to assign severity scores to each of the above scenarios in terms of three performance measures:

- the impact of the climate scenario on the integrity of the dike and sewer systems;
- the degree of emergency response that would be required to address the effects of the climate scenario; and,
- the amount of property damage, social effects, and insurance claims that would result from the climate scenario.

The results of the risk assessment were then compiled, with total risk scores for each scenario calculated using the following equation:

RISK SCORE = PROBABILITY SCORE x SEVERITY SCORE

The various scenarios were then ranked from highest risk score to lowest to assist in identifying patterns of weather events and climate trends that contribute to high flood risks within the study area.

4.1 RISK SCORING – CURRENT CONDITIONS

As indicated in Appendix D, the scenarios with the highest risk scores for the existing conditions within the study area were found to be:

a) West of Little River

Flooding Mechanism	*Performance Measure*	*Risk Score*	*Risk Category*
Sewer conveyance	Property Damage	30	Medium-high
Sewer conveyance	Emergency Flood Mitigation	25	Medium-high
Dike overtopping	Property Damage	24	Medium-high

b) East of Little River

Flooding Mechanism	*Performance Measure*	*Risk Score*	*Risk Category*
Sewer conveyance	Property Damage	36	Medium-high
Sewer conveyance	Emergency Flood Mitigation	30	Medium-high

4.2 RISK SCORING – FUTURE CONDITIONS

As indicated in Appendix D, the scenarios with the highest risk scores for the future conditions within the study area were found to be:

a) West of Little River

Flooding Mechanism	*Performance Measure*	*Risk Score*	*Risk Category*
Sewer conveyance	Property Damage	42	High
Sewer conveyance	Emergency Flood Mitigation	36	Medium-high
Dike overtopping	Property Damage	35	Medium-high
Dike overtopping	Emergency Flood Mitigation	30	Medium-high

b) East of Little River

Flooding Mechanism	*Performance Measure*	*Risk Score*	*Risk Category*
Sewer conveyance	Property Damage	42	High
Sewer conveyance	Emergency Flood Mitigation	36	Medium-high
Dike overtopping	Property Damage	35	Medium-high
Dike overtopping	Emergency Flood Mitigation	30	Medium-high

4.3 RISK SCORING – SUMMARY

Based on our review of the tabulated risk profiles, it appears that for current climate conditions:

- the highest-risk scenarios generally involve inland flooding due to bypassing of the dike system through interconnected storm sewers.

Whereas for future climate conditions:

- the highest-risk scenarios generally involve inland flooding due to bypassing of the dike system for areas east of Little River.
- west of Little River, the highest-risk scenarios involve inland flooding due to both bypassing of the dike system and overtopping of the existing dikes.

Regardless of the location (west or east of Little River), the highest-risk scenarios for both current and future climate conditions were associated with high severity scores for emergency flood mitigation and property damage.

5.0 ENGINEERING ANALYSIS / ALTERNATIVE SOLUTIONS (PIEVC STEP 4)

In order to address the vulnerabilities identified in the existing dike system, several alternative design solutions were developed, aimed at preventing bypassing or overtopping of the dikes. It should be noted (as indicated in PIEVC Worksheet Step 4 – see Appendix A) that the load and capacity analyses presented in the PIEVC Protocol were deemed not to be applicable to the subject infrastructure.

5.1 ALTERNATIVE SOLUTIONS FOR SEWER BYPASSING

To address the potential for bypassing of the dikes through the sewer system, design alternatives were developed for various scenarios - each involving the installation of backflow prevention devices or sluice gates at the cross-connection points in the sewer system to prevent the flow of flood waters inland. These design alternatives are presented in Figures 19 through 21, complete with the rationale for each alternative.

Details regarding the various types of backflow prevention devices under consideration are provided in Appendix B as Technical Brief TB5.

5.2 ALTERNATIVE SOLUTIONS FOR DIKE RESTORATION

To address the potential for dike overtopping, it is recommended that the existing dike system be reconstructed along its existing alignment to ensure a continuous top elevation of 177.1m. Depending upon the specific location along the dike and the associated site constraints (e.g., buildings, roadways, driveways, trees, etc.), establishing this top of dike elevation can be achieved using a combination of the following design alternatives:

- Earth berms;
- Walls backed with earth berms;
- Walls;
- Automated mechanical gates;
- Raising Riverside Drive.

Conceptual drawings depicting each of the above alternatives have been provided in Figures 22 through 24. These figures include a list of opportunities/advantages and constraints/disadvantages for each of the alternatives identified for dike restoration.

For the area west of Little River, the dike restoration solutions presented herein are likely to require some land acquisition by the City, since the existing Riverside Drive right-of-way would not accommodate these additional works. Although the precise limits of the land required will not be known until completion of functional design, a general depiction of the potentially affected properties is depicted here in Figures 25 and 26 for information purposes.

A preliminary budget estimate for implementing the recommended solutions is presented in Table 4. Please note that these estimates do not include allowances for property acquisition.

6.0 PUBLIC CONSULTATION

On 26 June 2019, a Public Information Centre (PIC) was convened at the WFCU Centre to present the initial findings of the East Riverside Flood Risk Assessment. A series of 22 display panels were prepared, outlining the relevant climate parameters, the inventory of the existing dike system, the areas potentially affected by a failure of the dike system, and several alternative solutions for re-establishing a continuous dike system along Riverside Drive.

Over the course of the 3-hour PIC, approximately 100 members of the public signed in to record their attendance. Members of the Project Team from both Landmark Engineers and the City of Windsor were available throughout the PIC to help clarify the information presented in the display panels and to answer questions from the public. Comment sheets were also made available for attendees to provide written feedback regarding the study, although only 5 completed comment sheets were submitted by the public.

Although most of the feedback received over the course of the PIC was quite supportive of the proposed solutions, several attendees expressed concerns regarding the potential for flooding outside of the areas protected by the existing dike system. Residents with properties on the north side of Riverside Drive, in particular, expressed dissatisfaction that the scope of this study did not include measures to protect waterfront properties from overland flooding and erosion.

A full summary of the PIC is attached to this report as Technical Brief TB7 in Appendix B.

7.0 RECOMMENDATIONS & CONCLUSIONS (PIEVC STEP 5)

Based on the outcomes of the assessments described in the foregoing sections of this report, Landmark recommends that the following measures be implemented to address the vulnerability of the City's existing flood protection infrastructure in East Riverside:

- As a first priority, the City should carry out functional and detailed design of backflow prevention measures for each of the locations identified in this report where the storm sewer system crosses under the diking system. Design works should be carried out in coordination with the ongoing Sewer Master Plan and should incorporate automated controls and/or alert systems wherever sluice gates are included in the design.
- Upon completion of functional and detailed design, the new backflow prevention measures should be implemented in the field as soon as possible. The preliminary total construction estimate for these works (including engineering and administrative costs) is in the order of approximately $1,300,000. If a phased approach to construction is deemed necessary, the sewer works east of Little River should be given first priority, based on the outcome of the risk assessment presented in this report.
- Secondary only to the implementation of the backflow prevention works, functional and detailed design of the proposed dike improvements for the area west of Little River should be carried out as soon as possible. This work should be coordinated with the ongoing Class Environmental Assessment for the Sewer Master Plan in order to provide a mechanism for property acquisition along Riverside Drive, where needed.
- Upon completion of functional and detailed design, property and/or easements should be acquired where needed for the construction of the proposed dike improvements. Construction of the recommended dike improvements west of Little River should then proceed as soon as possible. The preliminary construction estimate for these works (including engineering and administrative costs) is in the order of approximately $8,700,000. If a phased approach to construction is desired, the segments of the dike alignment where no discernable dike currently exists (i.e., west of St. Rose Beach, from St. Rose to Fairview Boulevard, and from the St. Paul Pumping Station to Watson Avenue) should be given first priority.
- Upon completion of the backflow prevention measures and the dike improvements west of Little River, functional and detailed design of the dike improvements east of Little River should proceed, followed by construction. The preliminary construction estimate for these works (including engineering and administrative costs) is in the order of approximately $8,700,000.
- The City should budget for and implement a policy requiring regular inspections of the diking system and any backflow prevention measures that are implemented as a result of this report. We would recommend an initial minimum inspection schedule of once every 3 years.

- The City should also include an item in its operating budget for regular maintenance and repair of the diking system and any new backflow prevention measures. The amount of this budget should be determined in consultation with the City's Contracts, Field Services & Maintenance Division.

In addition to the above, we recommend that a follow-up analysis of the water levels on Lake St. Clair be carried out prior to the year 2030 to confirm whether the predicted effects of climate change remain valid.

The rationale and basis for the above recommendations and conclusions is detailed in PIEVC Worksheet Step 5 (see Appendix A), along with a formal statement of vulnerability.

8.0 OBSERVATIONS & IMPACTS – SUMMER 2019

The execution of this flood risk assessment was complicated by the return of record-high water levels on Lake St. Clair over the late spring and summer of 2019. The previous instantaneous record high level of 176.033m that had been observed at the Windmill Point gauge station in 1986 was exceeded several times over June and July of 2019 – reaching an observed peak level of 176.107m on 28 June 2019.

Given the potential for inland flooding to occur during periods of high water levels, Landmark put a priority on developing detailed topographic contour maps of the existing dike system, aimed at identifying weak points and areas where temporary measures such as sandbagging should be implemented. Preliminary versions of the maps depicted in Figures 9 through 18 of this report were shared with the City's Operations Department in May 2019 to assist with the City's emergency preparation measures, and site inspections of the dike system were carried out in cooperation with City staff.

Although water levels did not reach the point where extensive inland flooding was observed over the summer of 2019, some minor flooding issues on Riverside Drive (on the north side of the dike) were observed on several occasions. These observations are summarized in Figures 27 and 28. It is fortunate that strong, sustained winds from the north or northeast did not occur during this period of high water levels, or the observed flooding issues could have been much more extensive.

A graphical representation of the observed water levels at the Windmill Point gauge over the past three summers is provided in Figure 29. As indicated therein, water levels appear to have begun their usual seasonal decline after peaking in early summer. Nevertheless, the levels remain unusually high and lingering high water levels on the upper Great Lakes suggest that this issue could recur next summer. We strongly recommend that the City take steps to implement the flood protection measures outlined in this report as soon as possible.

TABLES

Table 1: Relative Assessment of Top of Dike Elevations

Design Criteria	Designated Elevations	Percentage of Existing Dike System Above Designated Elevation	
		West of Little River	East of Little River
Original Dike Design (1986)	176.4m (Flood Level)	39.2%	99.1%
	176.7m (Flood Level plus 0.3m freeboard)	15.4%	52.5%
Current Conditions (2019)	176.5m (Flood Level)	31.9%	98.6%
	176.8m (Flood Level plus 0.3m freeboard)	12.7%	37.1%
Projected Future Conditions (2050)	176.8m (Flood Level)	12.7%	37.1%
	177.1m (Flood Level plus 0.3m Freeboard)	0.8%	3.4%

TABLE 2: STORM SEWERS WITH CROSS-CONNECTIONS UNDER THE DIKE							
Connecting Storm Sewer		**City of Windsor Sewer Atlas Manhole ID at Dike**	**Pipe Diameter (mm)**	**Design Flow direction**	**Easting**	**Northing**	**Drainage Area**
S1	Outfall – west of St. Rose Beach	MH#6R36R3	750	North	338699.727	4688563.023	Local stormwater sewer extending south to Wyandotte St.; catchment area is not defined
S2	Outfall – St. Rose Beach	MH#6R780	3050x1525	North	338886.225	4688612.275	Gravity outfall with approximate catchment area between Jefferson Blvd. and Parkview Ave., bounded on the south by the VIA rail tracks
S3	Pumping Station – St. Paul	MH#6RPS2254	2250	North	339391.386	4689220.428	Catchment area approximately bounded to the east by Parkview Ave., to the west by Lauzon Rd., Watson Ave and Dieppe St.; bounded on the south by the VIA rail tracks
S4	Riverside Dr. Sewer	MH#6R4287 MH#6S4323	450 250	East East	339668.622	4689518.009	Along Riverside Dr. from Lauzon to the approximate northing and easting point where mains cross under the proposed berm
S5	Watson Ave.	MH# 6R4477	450	South	339770.346	4689517.399	Main along Watson is receiving flows from main along Riverside Drive from east and west of Watson Ave.
S6	Dieppe St.	MH# 6R4481	350	South	340017.969	4689507.567	Main along Dieppe is receiving flows from main along Riverside Drive, west of Dieppe St.
S7	Riverdale Ave.	MH# 6R699	1050	South	340880.661	4689234.913	Receives flows form along Riverside Drive
S8	Mountbatten Cres.	MH# 6R3687	600	North	341223.893	4689186.220	Flows into main along Riverside Drive, catchment area is from residences along Mountbatten Cres.

TABLE 2: STORM SEWERS WITH CROSS-CONNECTIONS UNDER THE DIKE (CONTINUED):							
S9	Vanderbilt Cres.	MH# 6R3538	600	North	341544.300	4689180.006	Flows into main along Riverside Drive, catchment area is from residences along Vanderbilt Cres.
S10	Sand Point Crt.	MH# 6R3458	675	North	341617.514	4689178.295	Flows into main along Riverside Drive, catchment area is from immediate area of Sand Point Crt.
S11	Florence Ave.	MH# 6R889	375	North	341885.116	4689077.303	Flows into main along Riverside Drive, catchment area is along Florence including side streets to the west and extending south to Wyandotte St.
S12	John M. St.	MH# 6R654	300	North	341973.972	4689030.624	Flows into main along Riverside Drive, catchment area is immediate area of John M. St. and Menard St. east of Florence Ave.
S13	Elinor St.	MH#6RP998	N/A	North	342048.942	4688989.803	Short segment of main – appears to terminate at a catch basin along Clairview Ave. that collects surface flows from Clairview Ave. and Elinor St.
S14	Clover St.	MH# 6RP1082	900	North	342128.890	4688920.355	Short segment of main – appears to terminate at a catch basin along Clairview Ave. in front of Stop 26 Ice Cream
S15	Clover St.	MH# 6R989	375	North	342156.310	4688941.305	Flows into main along Riverside Drive, catchment area is along Clover Ave. south to Wyandotte St. E.
S16	Outfall to East Marsh Pumping Stn.	MH#6R658	1800	North	342397.424	4688875.490	Conveys flows from main east and west of Riverside Drive to East Marsh pumping station

TABLE 2: STORM SEWERS WITH CROSS-CONNECTIONS UNDER THE DIKE (CONTINUED):

S17	Amalfi Crt.	MH# 6R3711	375	N/A	343110.773	4688639.370	Direction of flow not identified. Connected to main along Riverside Drive with note in sewer atlas indicating "Sluice gate". This may need to be verified
S18	Jarvis Ave.	MH# 6R665	300	North	343248.528	4688600.452	Flows into main along Riverside Drive, catchment area is area along Jarvis south to Castle Hill Rd.
S19	Outfall East of Rendezvous Park	MH#6RPS3312	350	North	343786.301	4688404.822	Not connected to main along Riverside Drive. Runs along Rendezvous Dr. and is connected via main on Little River to Blue Heron Lake

NOTE:
1) NAD83, UTM Zone 17 reference datum used for northing and easting;
2) Sewer locations and identification numbering referenced from the City of Windsor Sewer Atlas dated 2017;
3) Description of catchment areas have been generalized.

TABLE 3: CATCH BASIN LOCATIONS WITH CROSS-CONNECTIVITY UNDER THE DIKE					
Catch Basin Location Description		City of Windsor Sewer Atlas Identification	Connecting Pipe Diameter (mm)	Easting	Northing
C1	In pkg lot of St. Clair Towers, west side of building	6R974	N/A	340362.766	4689590.766
C2	At rear property line of 410 Mountbatten	CB-6R03950	375	341268.017	4689162.001
C3	East of Martinique Ave., south side of berm	CB-6R03951	500	341470.084	4689178.888
C4	West of Vanderbilt Cres., south side of berm	CB-6R03952	200	341492.326	4689173.276
C5	27m west of Sand Point Crt, 5m south of storm sewer	CB-6R03953	200	341589.689	4689173.279
C6	39m east of Sand Point Crt, 7m south of storm sewer	CB-6R03954	200	341655.314	4689167.233
C7	18m west of Sand Point Beach pkg lot, 10m south of storm sewer	CB-6R03955	400	341712.302	4689153.881
C8	36m west of Florence Ave., 31m south of sewer main	CB-6R03956	400	341850.999	4689059.016
C9	9m west of Clover Ave., at north edge of asphalt of Clairview Ave.	BV-140 CB-6R03957	200	342120.340	4688938.586
C10	51m east of Clover Ave., 3m south of Clairview Ave.	BV-141 CB-6R03958	200	342200.943	4688877.359
C11	North-west side of Sportsman Club parking lot	BV-142 CB-6R03959	250	342377.718	4688791.281
C12	8m south of sewer main, 38m east of Sportsman Club parking lot	BV-143 (6R0891)	900	342420.489	4688808.421
C13	168m east of Sportsman Club parking lot, 10m south of storm sewer	BV-144CB-6R03960	250	342547.484	4688771.865
C14	232m east of Sportsman Club parking lot 5m south of storm sewer	BV-145 CB-6R03961	250	342609.463	4688761.468
C15	136m west of Greenpark Blvd., 5m south of storm sewer	BV-146 CB-6R03962	300	342759.157	4688722.012
C16	6m north of Amalfi Crt., 103m west of Jarvis Ave.	BV-147 CB-6R03963	400	343140.333	4688625.792
C17	48m west of Jarvis Ave., 4m south of storm sewer	BV-148 CB-6R03964	375	343192.227	4688613.433

TABLE 3: CATCH BASIN LOCATIONS (CONTINUED):					
C18	80m west of Cora Greenwood Dr., 10m south of storm sewer	BV-149 CB-6R03965	150	34.370.323	4688552.776
C19	50m east of Cora Greenwood Dr., 6m south of storm sewer	BV-150 CB-6R03966	150	343511.667	4688516.173
C20	44m west of Lakeview Ave., 12m south of storm sewer	BV-151 CB-6R03967	200	343615.168	4688481.497
C21	24m west of Lakeview Ave., 8m south of storm sewer	BV-152 CB-6R03968	200	343633.219	4688481.142
C22	48m east of Lakeview Ave., 15m south of storm sewer	BV-154 CB-6R03970	200	343717.417	4688451.803

NOTE:

1) NAD83, UTM Zone 17 reference datum used for northing and easting
2) Sewer locations and identification numbering referenced from the City of Windsor Sewer Atlas dated 2017
3) Description of catch basin location is approximate
4) Catchment area has not been described for individual catch basins; catch basins provide general drainage for local areas south of dike.

Table 4 : Preliminary Budget Estimate

Dike Modifications West of Little River					
Item	**Description of Work**	**Quantity**	**Unit**	**Unit Price**	**Total Price**
1	Earth Berm with Heavy Landscaping	320	M	550	$170,000
2	Earth Berm with Heavy Landscaping and Fence	640	M	750	$480,000
3	Earth berm in Park Area	340	M	250	$80,000
4	Earth Berm with path along the peak	620	M	300	$190,000
5	Driveway Berm	130	M	850	$110,000
6	Wall	320	M	2,100	$680,000
7	Wall with Berm	560	M	2,200	$1,230,000
8	Mechanical Gate	37	Each	100,000	$3,700,000
9	Road Crossing at Intersections	3	Each	20,000	$60,000
10	Berm Crossing Riverside Drive	2	Each	1,000,000	$2,000,000
			Total West of Little River =		**$8,700,000**

Dike Modifications East of Little River					
Item	**Description of Work**	**Quantity**	**Unit**	**Unit Price**	**Total Price**
1	Earth Berm with path along the peak	2000	M	350	$700,000
2	Earth Berm	820	M	250	$200,000
3	Raise roadways south of Riverside	13	Each	600,000	$7,800,000
			Total East of Little River =		**$8,700,000**

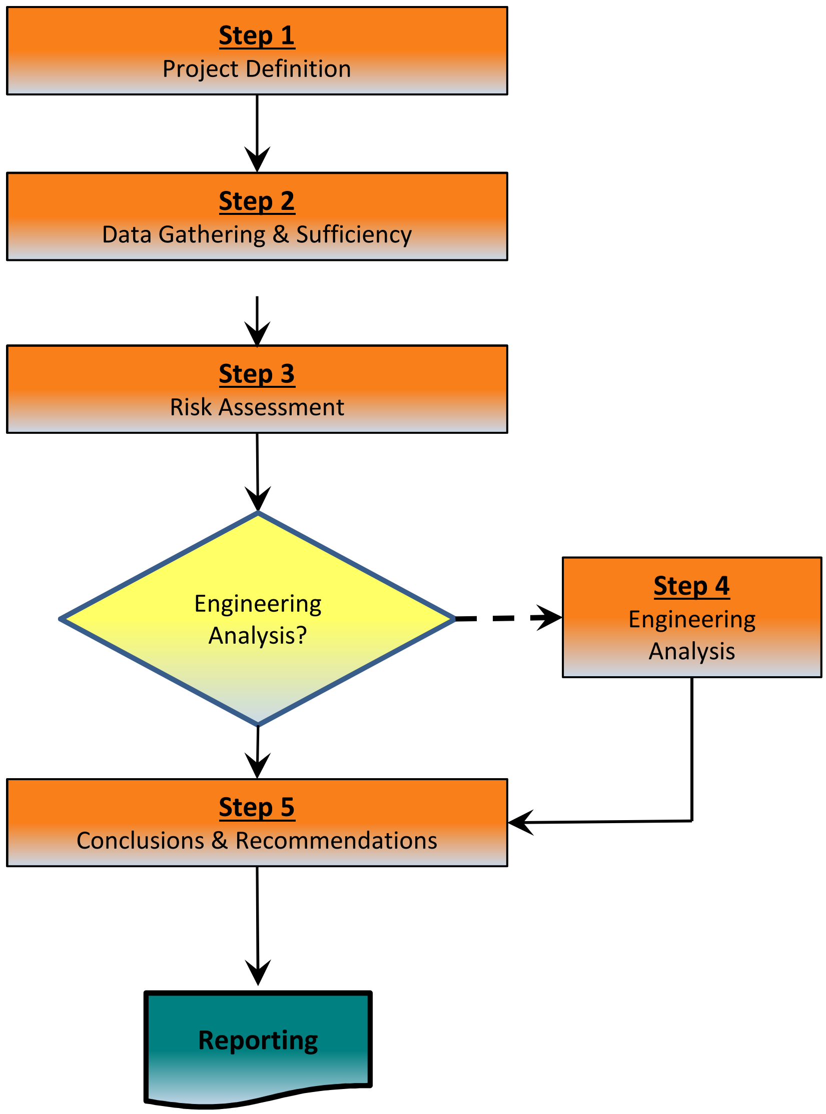
Sewer Modification / Backflow Protection Measures					
Item	**Description of Work**	**Quantity**	**Unit**	**Unit Price**	**Total Price**
1	Manhole with sluice gate	5	Each	25,000	$120,000
2	Manhole with duckbill	10	Each	20,000	$200,000
3	Catchbasin with duckbill	27	Each	15,000	$420,000
4	Storm sewer crossings	56	Each	10,000	$560,000
		Total Sewer Mod./Backflow Measures =			**$1,300,000**

Total West of Little River =	**$8,700,000**
Total East of Little River =	**$8,700,000**
Total Sewer Mod./Backflow Measures =	**$1,300,000**
Total Project Estimate =	**$18,700,000**

Note: The above estimates do NOT include allowances for property acquisition

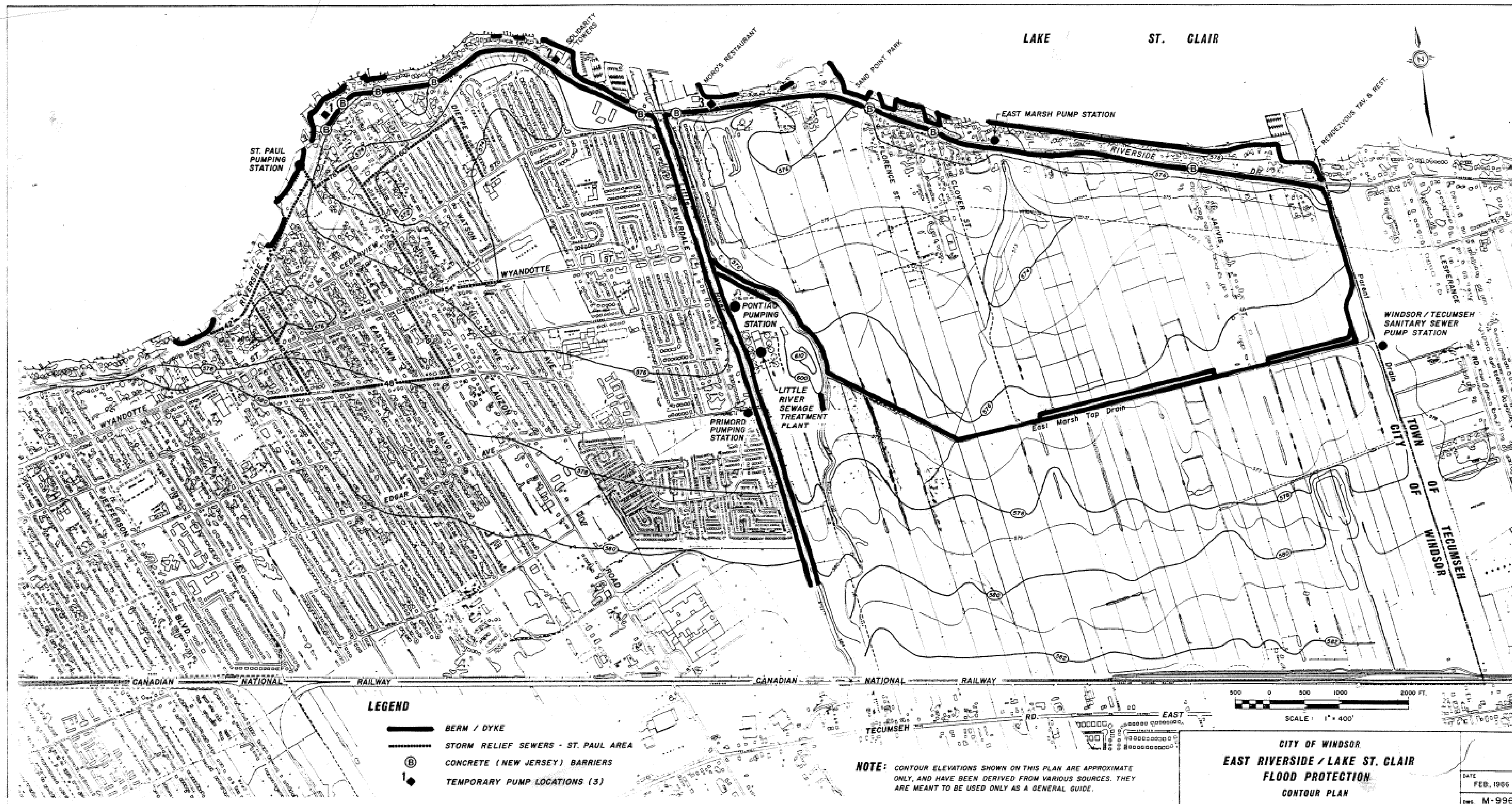
FIGURES

Vulnerability Assessment Module



Landmark Engineers Inc.	Title: OVERVIEW OF PIEVC PROTOCOL	Date: 6 AUG 2019	FIGURE
		Scale: NTS	1
	Project: EAST RIVERSIDE FLOOD RISK ASSESSMENT	Project No. 18-033	

The City of Windsor, Ontario, Canada



EAST RIVERSIDE FLOOD PROTECTION MAP (1986)

Landmark Engineers Inc.

THE CITY OF WINDSOR ONTARIO, CANADA

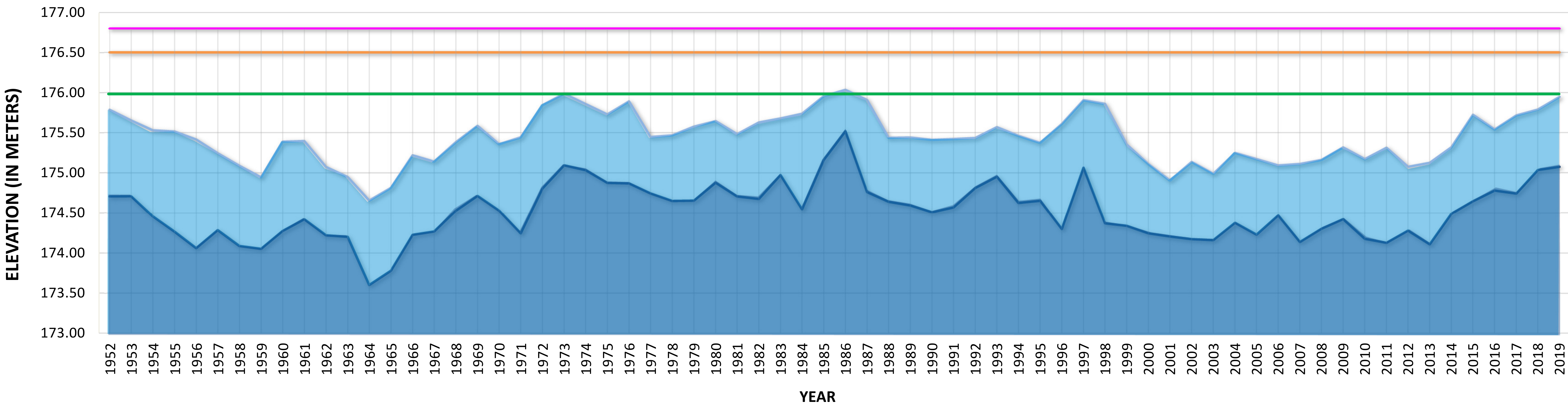
Title	Date	FIGURE
EAST RIVERSIDE FLOOD PROTECTION MAP	6 AUG 19	2
	Scale: NTS	
Project: EAST RIVERSIDE FLOOD RISK ASSESSMENT	Project No. 18-033	

Landmark Engineers Inc.

THE CITY OF WINDSOR ONTARIO, CANADA

Title: STUDY AREA - LOCATION AND LIMITS		Date: 6 AUG 2019	FIGURE 3
		Scale: NTS	
Project: EAST RIVERSIDE FLOOD RISK ASSESSMENT		Project No. 18-033	

Yearly Instantaneous High Water Elevations (Windmill Point Gauge Station – Lake St. Clair / Detroit River)



LEGEND

- HISTORICAL YEARLY INSTANTANEOUS HIGH WATER LEVELS
- HISTORICAL YEARLY INSTANTANEOUS LOW WATER LEVELS
- CURRENT (AUG. 2019) WATER LEVEL (176.0m)
- 176.5m (CURRENT 1:100-YEAR INSTANTANEOUS PEAK WATER LEVEL)
- 176.8m (2050 FUTURE 1:100-YEAR INSTANTANEOUS PEAK WATER LEVEL)

Landmark Engineers Inc.

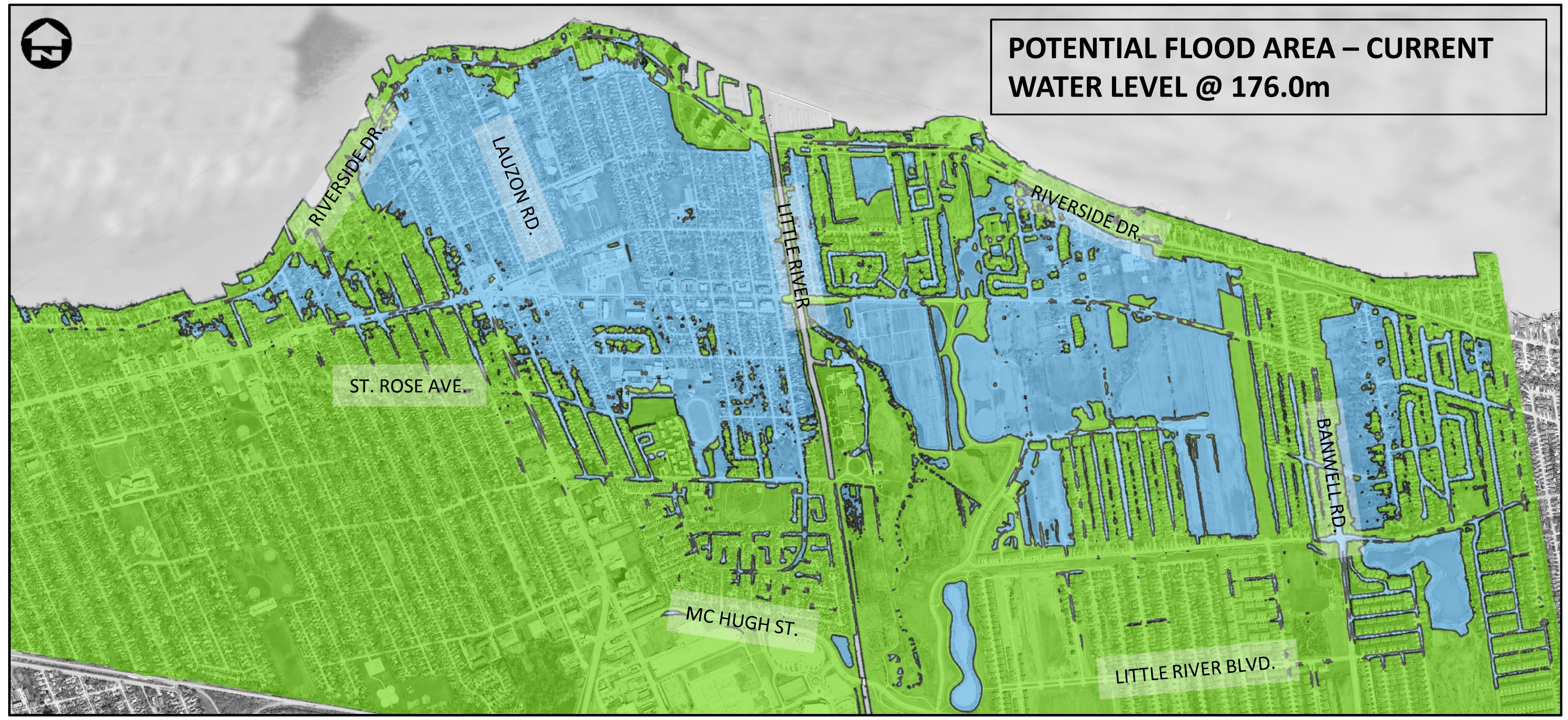
THE CITY OF WINDSOR ONTARIO, CANADA

Title	Date	FIGURE
HISTORIC WATER LEVELS ON LAKE ST. CLAIR	6 AUG 19	4
	Scale: NTS	
Project: EAST RIVERSIDE FLOOD RISK ASSESSMENT	Project No. 18-033	

LEGEND

GROUND ELEVATION BELOW 176.0m

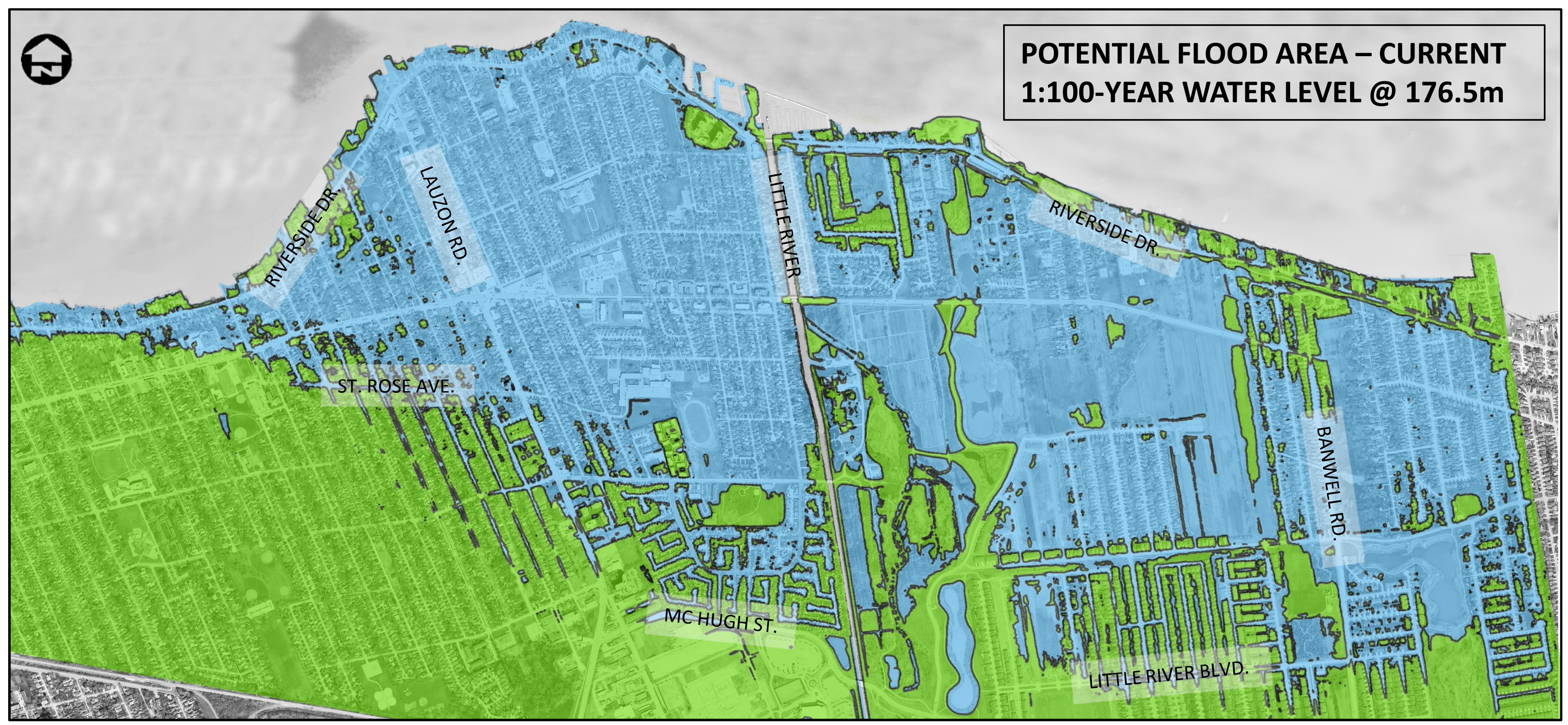
GROUND ELEVATION ABOVE 176.0m



LEGEND

GROUND ELEVATION BELOW 176.5m

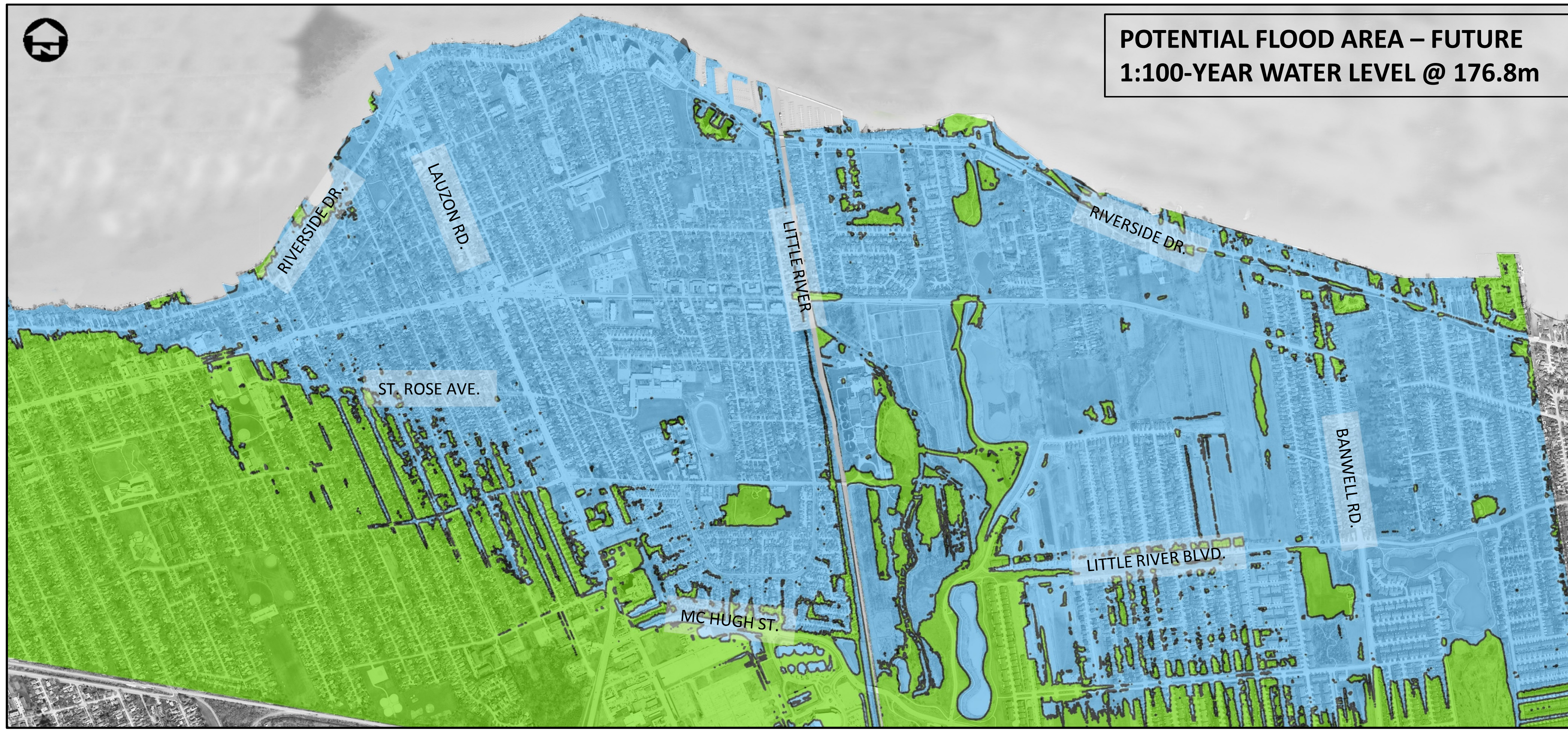
GROUNG ELEVATION ABOVE 176.5m



Landmark Engineers Inc.

THE CITY OF WINDSOR ONTARIO, CANADA

Title	FLOOD LEVEL MAPPING (CURRENT)	Date 6 AUG 19	FIGURE 5
		Scale NTS	
Project	EAST RIVERSIDE FLOOD RISK ASSESSMENT	Project No. 18-033	



LEGEND

(blue)	GROUND ELEVATION BELOW 176.8m
(green)	GROUND ELEVATION ABOVE 176.8m

Landmark Engineers Inc.

THE CITY OF WINDSOR ONTARIO, CANADA

Title: FLOOD LEVEL MAPPING (FUTURE - 2050)	Date: 6 AUG 19 / Scale: NTS	FIGURE 6
Project: EAST RIVERSIDE FLOOD RISK ASSESSMENT	Project No. 18-033	

LEGEND:

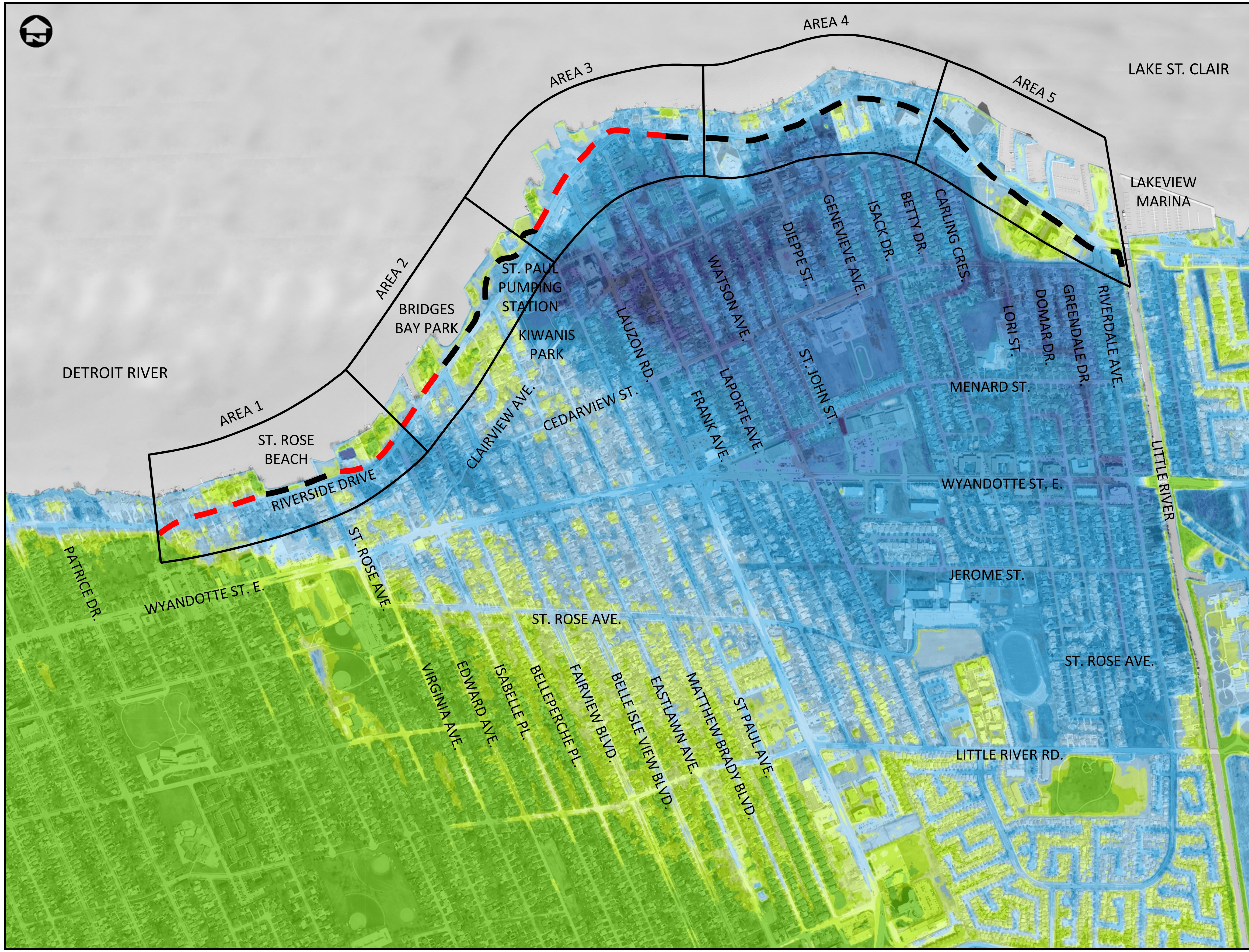
EXISTING BERM ALIGNMENT

- NO DISCERNABLE BERM (red dashed line)
- EARTH BERM (black dashed line)

EXISTING GROUND ELEVATIONS

177.1m	2050 WATER LEVEL WITH FREEBOARD
176.8m	2050 PROJECTED HIGH WATER LEVEL
176.5m	CURRENT HIGH WATER LEVEL
176.2m	
175.9m	
175.6m	
175.3m	
175.0m	
174.7m	
174.4m	
174.1m	

NOTE:
DETAILED MAPPING OF AREAS 1 THROUGH 5 IS PROVIDED IN FIGURES 9 THROUGH 13 OF THIS REPORT.



Landmark Engineers Inc.

THE CITY OF WINDSOR ONTARIO, CANADA

Title	Date	FIGURE
EXISTING CONDITIONS – WEST OF LITTLE RIVER	6 AUG 19	7
	Scale: NTS	
Project: EAST RIVERSIDE FLOOD RISK ASSESSMENT	Project No. 18-033	

LEGEND:

EXISTING BERM ALIGNMENT

- NO DISCERNABLE BERM
- EARTH BERM

EXISTING GROUND ELEVATIONS

177.1m	2050 WATER LEVEL WITH FREEBOARD
176.8m	2050 PROJECTED HIGH WATER LEVEL
176.5m	CURRENT HIGH WATER LEVEL
176.2m	
175.9m	
175.6m	
175.3m	
175.0m	
174.7m	
174.4m	
174.1m	

NOTE:
DETAILED MAPPING OF AREAS 6 THROUGH 10 IS PROVIDED IN FIGURES 14 THROUGH 18 OF THIS REPORT.

Landmark Engineers Inc.

THE CITY OF WINDSOR ONTARIO, CANADA

Title: EXISTING CONDITIONS – EAST OF LITTLE RIVER	Date: 6 AUG 19	FIGURE 8
	Scale: NTS	
Project: EAST RIVERSIDE FLOOD RISK ASSESSMENT	Project No. 18-033	

LEGEND

EXISTING BERM ALIGNMENT

- NO DISCERNABLE BERM
- EARTH BERM

EXISTING DRAINAGE

- STORM SEWER
- CATCH BASIN (CROSS-CONNECTION, SEE TABLE 3)
- STORM SEWER (CROSS-CONNECTION, SEE TABLE 2)

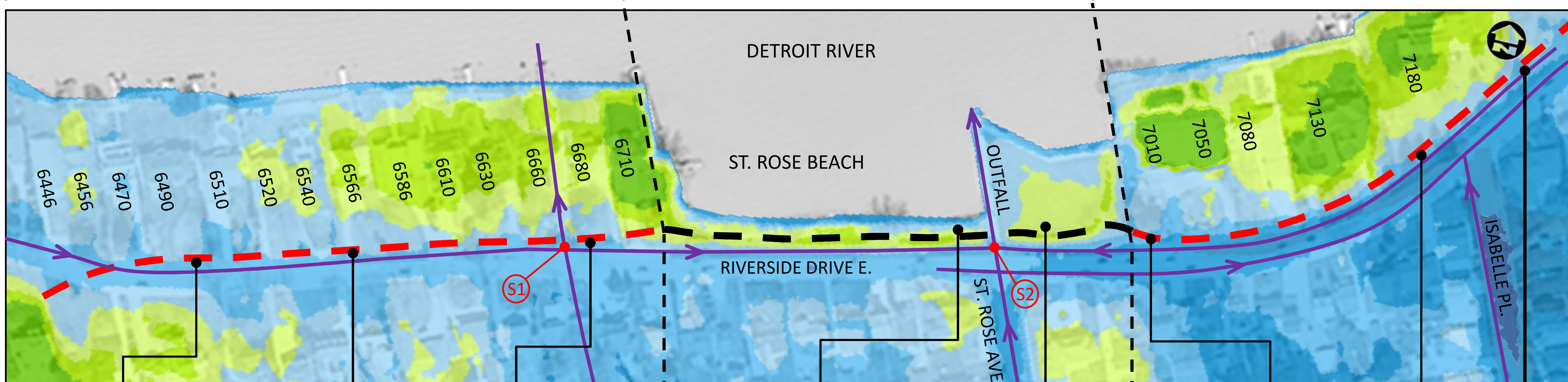
EXISTING GROUND ELEVATIONS

- 177.1m – 2050 WATER LEVEL WITH FREEBOARD
- 176.8m – 2050 PROJECTED HIGH WATER LEVEL
- 176.5m – CURRENT HIGH WATER LEVEL
- 176.2m
- 175.9m
- 175.6m
- 175.3m
- 175.0m
- 174.7m
- 174.4m
- 174.1m

- Residential area on both sides of Riverside Drive
- Generally low lying with some individual properties at higher elevations
- No discernable berm
- Modify berm with Alternatives 1, 3, 4, or 5

- St. Rose Park area north of Riverside Drive; Residential area south of Riverside Drive
- Outfall for drainage from St. Rose area
- Earth berm with discontinuity at pedestrian walkway crossing
- Modify berm with Alternatives 1 and 4

- Residential on both sides of Riverside Drive
- Generally low lying area
- Berm is non-discernable
- Modify berm with Alternatives 1, 3, 4, or 5




LOOKING WEST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Landmark Engineers Inc.

THE CITY OF WINDSOR ONTARIO, CANADA

Title: AREA 1 – ST. ROSE BEACH AREA	Date: 6 AUG 19	Scale: NTS	FIGURE 9
Project: EAST RIVERSIDE FLOOD RISK ASSESSMENT	Project No. 18-033		

LEGEND

EXISTING BERM ALIGNMENT

- NO DISCERNABLE BERM (red dashed line)
- EARTH BERM (black dashed line)

EXISTING DRAINAGE

- STORM SEWER
- CATCH BASIN (CROSS-CONNECTION, SEE TABLE 3)
- STORM SEWER (CROSS-CONNECTION, SEE TABLE 2)

EXISTING GROUND ELEVATIONS

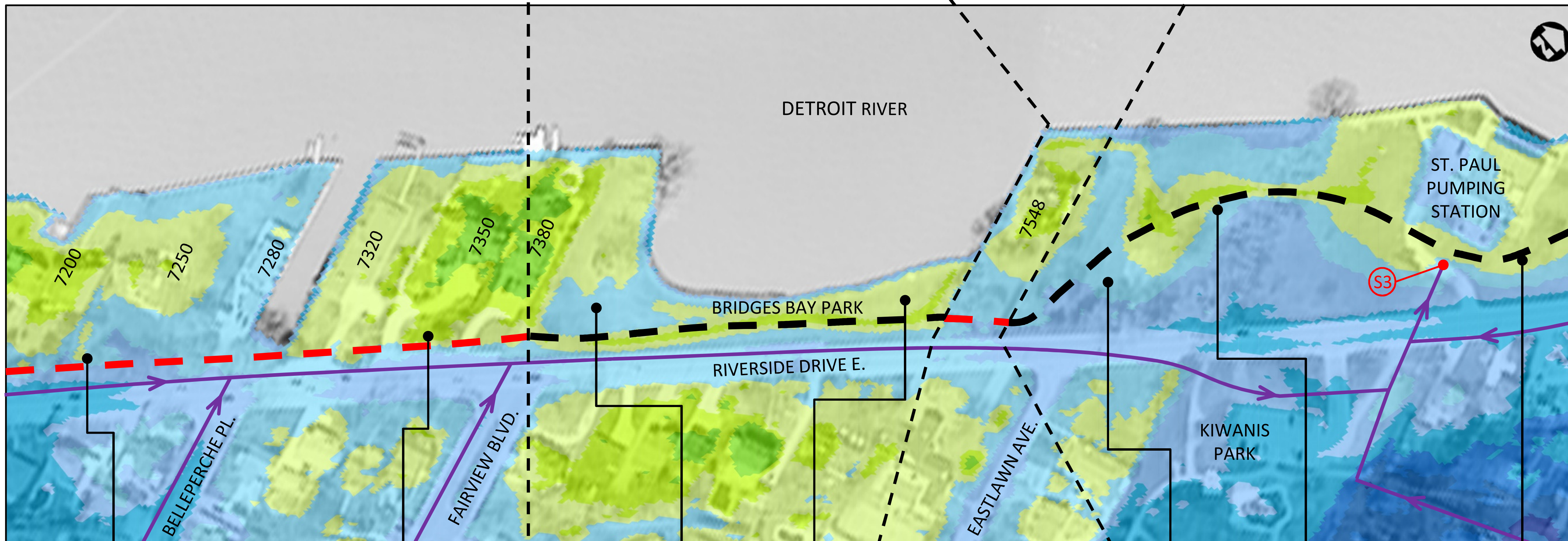
177.1m	2050 WATER LEVEL WITH FREEBOARD
176.8m	2050 PROJECTED HIGH WATER LEVEL
176.5m	CURRENT HIGH WATER LEVEL
176.2m	
175.9m	
175.6m	
175.3m	
175.0m	
174.7m	
174.4m	
174.1m	

- Residential area on both sides of Riverside Drive
- Generally low lying with some individual properties at higher elevations
- No discernable berm
- Modify berm with Alternatives 1, 3, 4, or 5

- Bridges Bay Public park area north of Riverside Drive; Residential area south of Riverside Drive
- Continuous earth berm meets existing criteria
- Modify existing berm with Alternative 1

- Residential areas on both sides of Riverside Drive
- Generally low lying
- No discernable berm
- Modify berm with Alternatives 1, 3, 4, or 5

- St. Paul Pumping Station and Kiwanis Park area north of Riverside Drive; Residential area south of Riverside Drive
- Existing earth berm, generally continuous but with narrow / low points
- Modify existing berm with Alternative 1

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LOOKING WEST


LOOKING WEST


LOOKING EAST


LOOKING NORTH


LOOKING WEST

Landmark Engineers Inc.

THE CITY OF WINDSOR ONTARIO, CANADA

Title	AREA 2 – BRIDGES BAY AREA
Project	EAST RIVERSIDE FLOOD RISK ASSESSMENT
Date	6 AUG 19
Scale	NTS
Project No.	18-033

FIGURE 10

LEGEND

EXISTING BERM ALIGNMENT

- NO DISCERNABLE BERM
- EARTH BERM

EXISTING DRAINAGE

- STORM SEWER
- CATCH BASIN (CROSS-CONNECTION, SEE TABLE 3)
- STORM SEWER (CROSS-CONNECTION, SEE TABLE 2)

EXISTING GROUND ELEVATIONS

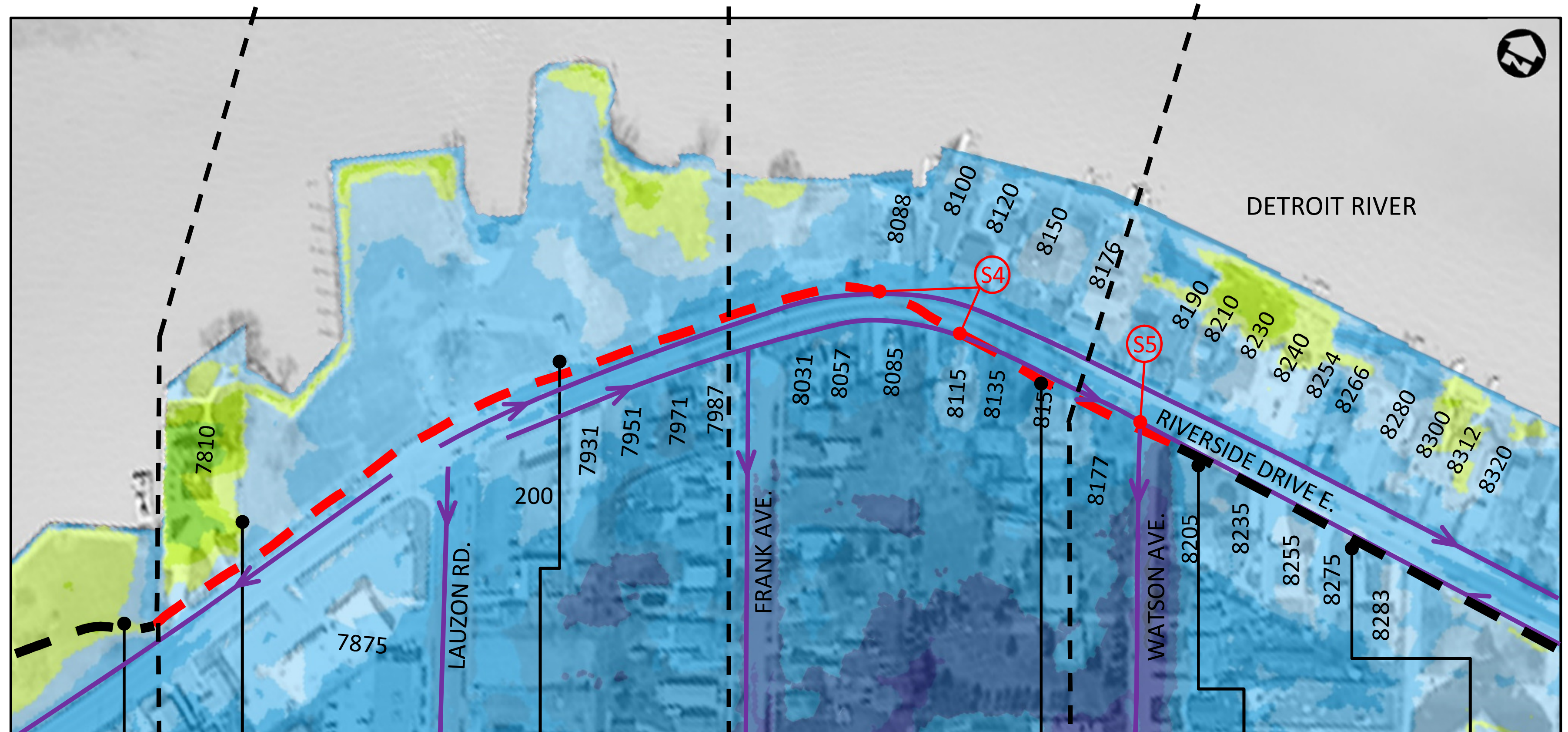
- 177.1m – 2050 WATER LEVEL WITH FREEBOARD
- 176.8m – 2050 PROJECTED HIGH WATER LEVEL
- 176.5m – CURRENT HIGH WATER LEVEL
- 176.2m
- 175.9m
- 175.6m
- 175.3m
- 175.0m
- 174.7m
- 174.4m
- 174.1m

- Kiwanis Park north of Riverside Drive
- Existing earth berm, generally continuous, but with narrow / low points
- Modify existing berm with Alternative 1

- Undeveloped area north of Riverside Drive; commercial and residential area south of Riverside Drive
- Generally low lying area with no discernable berm
- Modify berm with Alternatives 1, 3, 4, or 5

- Undeveloped area north of Riverside Drive; residential areas on both sides of Riverside Drive
- Generally low lying with no discernable berm
- Possible location for berm to cross Riverside Drive to maintain continuity
- Site-specific design solution required

- Residential area both sides of Riverside Drive
- Generally low lying with discontinuous berm
- Connected storm sewer on Watson - modify with sluice gate alternative
- Modify berm with Alternatives 1, 2, 3, 4



LOOKING NORTH

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LOOKING EAST

Landmark Engineers Inc.

THE CITY OF WINDSOR ONTARIO, CANADA

Title	AREA 3 – LAUZON AREA	Date: 6 AUG 19	FIGURE 11
Project	EAST RIVERSIDE FLOOD RISK ASSESSMENT	Scale: NTS; Project No. 18-033	

LEGEND

EXISTING BERM ALIGNMENT

- NO DISCERNABLE BERM
- EARTH BERM

EXISTING DRAINAGE

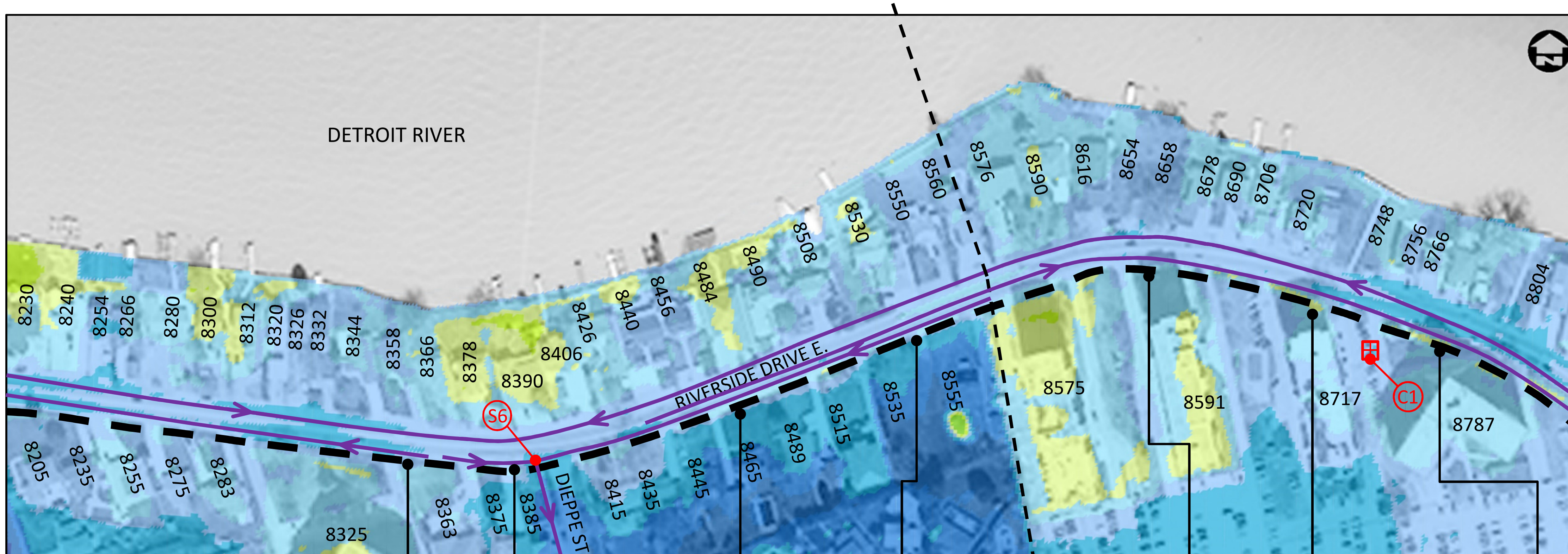
- STORM SEWER
- CATCH BASIN (CROSS-CONNECTION, SEE TABLE 3)
- S1 STORM SEWER (CROSS-CONNECTION, SEE TABLE 2)
- C1 CATCH BASIN (CROSS-CONNECTION, SEE TABLE 3)

EXISTING GROUND ELEVATIONS

177.1m – 2050 WATER LEVEL WITH FREEBOARD
176.8m – 2050 PROJECTED HIGH WATER LEVEL
176.5m – CURRENT HIGH WATER LEVEL
176.2m
175.9m
175.6m
175.3m
175.0m
174.7m
174.4m
174.1m

- Residential area on both sides of Riverside Drive
- Generally low lying with some properties at higher elevations
- Existing discontinuous berm on south side of Riverside Drive
- Connected storm sewer on Dieppe - modify with sluice gate alternative
- Modify berm with Alternatives 1, 2, 3, 4

- Residential area north of Riverside Drive; Apartment complexes south of Riverside Drive with below-grade parking structures
- Generally low lying with discontinuous berm
- Modify existing berm with Alternatives 1, 2, 3, 4




LOOKING WEST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Landmark Engineers Inc.

THE CITY OF WINDSOR ONTARIO, CANADA

Title: AREA 4 – DIEPPE STREET AREA	Date: 6 AUG 19		FIGURE 12
	Scale: NTS		
Project: EAST RIVERSIDE FLOOD RISK ASSESSMENT	Project No. 18-033		

LEGEND

EXISTING BERM ALIGNMENT

- NO DISCERNABLE BERM (red dashed line)
- EARTH BERM (black dashed line)

EXISTING DRAINAGE

- STORM SEWER
- CATCH BASIN (CROSS – CONNECTION, SEE TABLE 3)
- STORM SEWER (CROSS – CONNECTION, SEE TABLE 2)

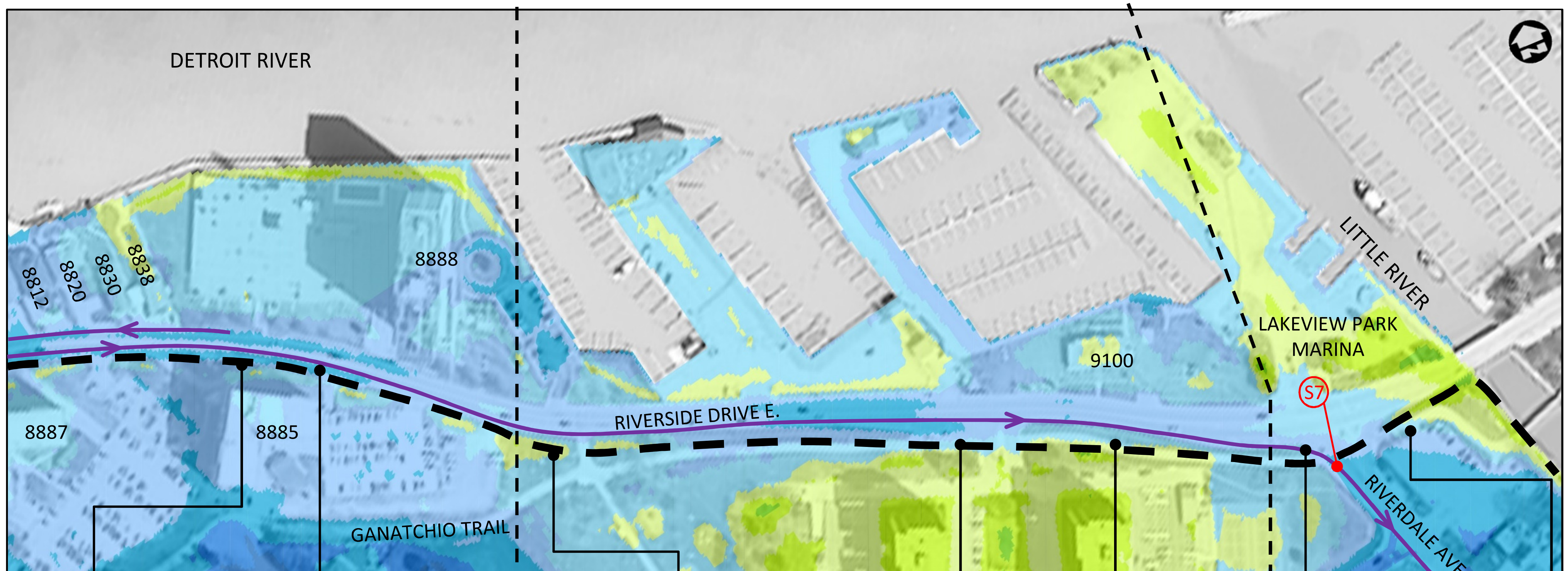
EXISTING GROUND ELEVATIONS

- 177.1m – 2050 WATER LEVEL WITH FREEBOARD
- 176.8m – 2050 PROJECTED HIGH WATER LEVEL
- 176.5m – CURRENT HIGH WATER LEVEL
- 176.2m
- 175.9m
- 175.6m
- 175.3m
- 175.0m
- 174.7m
- 174.4m
- 174.1m

- Apartment complexes and parking structures on both sides of Riverside Drive; Residential area north of Riverside Drive
- Generally low lying with existing discontinuous berm
- Modify existing berm with Alternatives 1, 2, 3, 4

- Marina and commercial area north of Riverside Drive; Apartment complexes and parking structures south of Riverside Drive
- Discontinuous existing berm on south side of Riverside Drive
- Modify existing berm with Alternative 1

- Intersection of Riverside Drive and Riverdale Ave.
- Existing berm is discontinuous at Riverdale
- Site-specific design solution required

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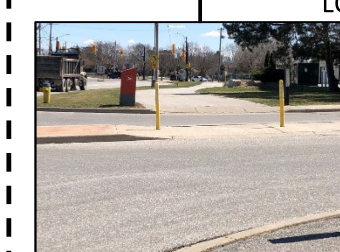
LOOKING EAST


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Landmark Engineers Inc.

THE CITY OF WINDSOR ONTARIO, CANADA

Title	AREA 5 – RIVERDALE AREA
Project	EAST RIVERSIDE FLOOD RISK ASSESSMENT
Date	6 AUG 19
Scale	NTS
Project No.	18-033

FIGURE 13

LEGEND

EXISTING BERM ALIGNMENT

- NO DISCERNABLE BERM (red dashed line)
- EARTH BERM (black dashed line)

EXISTING DRAINAGE

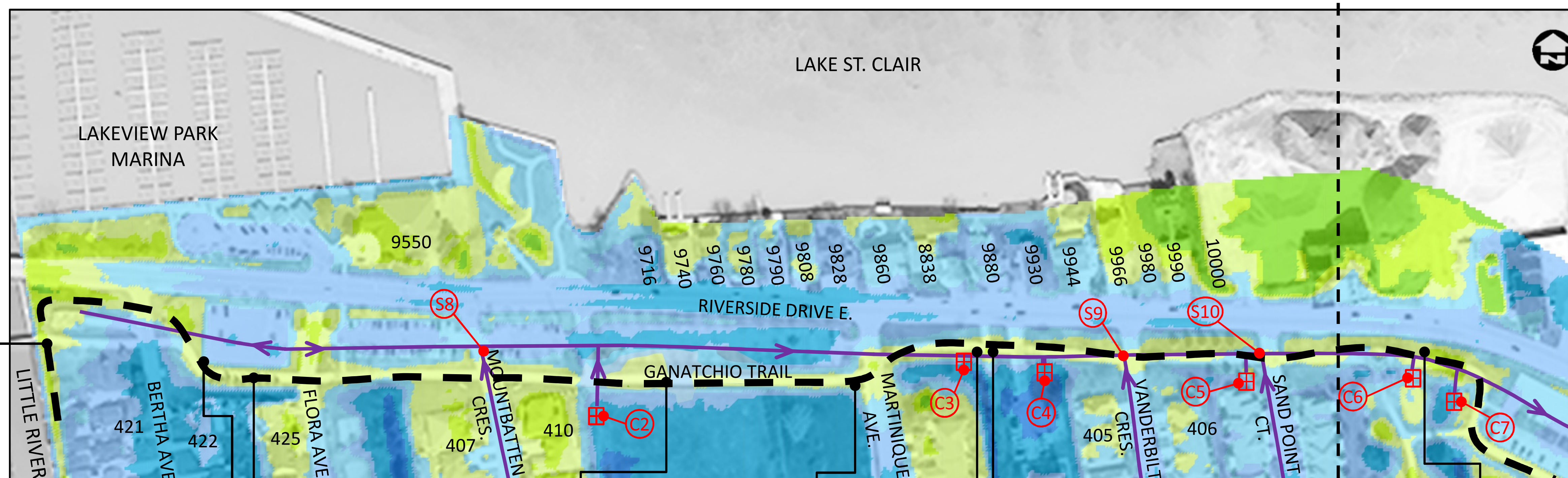
- STORM SEWER
- CATCH BASIN (CROSS-CONNECTION, SEE TABLE 3)
- S1 STORM SEWER (CROSS-CONNECTION, SEE TABLE 2)
- C1 CATCH BASIN (CROSS-CONNECTION, SEE TABLE 3)

EXISTING GROUND ELEVATIONS

- 177.1m — 2050 WATER LEVEL WITH FREEBOARD
- 176.8m — 2050 PROJECTED HIGH WATER LEVEL
- 176.5m — CURRENT HIGH WATER LEVEL
- 176.2m
- 175.9m
- 175.6m
- 175.3m
- 175.0m
- 174.7m
- 174.4m
- 174.1m

- Commercial area and marina north of Riverside Drive; Residential and parking areas on both sides of Riverside Drive
- Riverside Drive and parking areas are generally low lying. Berm is located on the south side of Riverside Drive along the Ganatchio Trail
- Connected storm sewers at Mountbatten, Vanderbilt and Sand Point – modify with backflow prevention alternative
- Modify existing berm with Alternative 1

- Public park and parking areas on both sides of Riverside Drive
- Generally low lying area with discontinuous berm
- Modify existing berm with Alternative 1




LOOKING SOUTH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Landmark Engineers Inc.

THE CITY OF WINDSOR ONTARIO, CANADA

Title	AREA 6 – LAKEVIEW MARINA AREA	Date: 6 AUG 19	FIGURE 14
Project	EAST RIVERSIDE FLOOD RISK ASSESSMENT	Scale: NTS; Project No. 18-033	

LEGEND

EXISTING BERM ALIGNMENT

- NO DISCERNABLE BERM
- EARTH BERM

EXISTING DRAINAGE

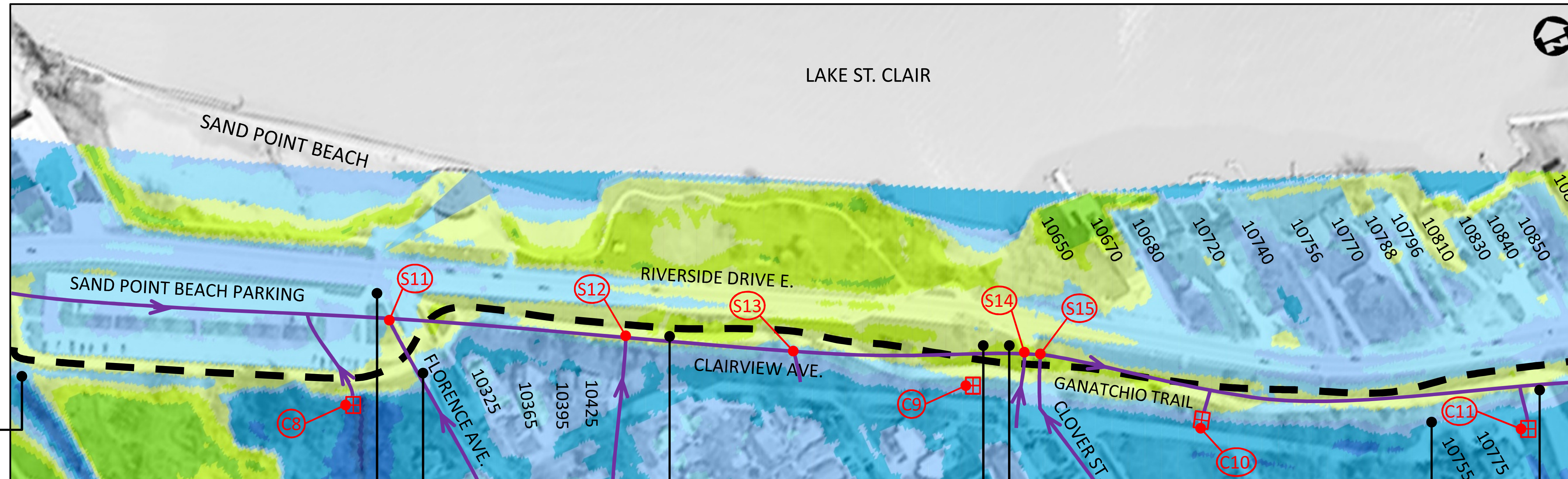
- STORM SEWER
- CATCH BASIN (CROSS-CONNECTION, SEE TABLE 3)
- S1 STORM SEWER (CROSS-CONNECTION, SEE TABLE 2)
- C1 CATCH BASIN (CROSS-CONNECTION, SEE TABLE 3)

EXISTING GROUND ELEVATIONS

- 177.1m – 2050 WATER LEVEL WITH FREEBOARD
- 176.8m – 2050 PROJECTED HIGH WATER LEVEL
- 176.5m – CURRENT HIGH WATER LEVEL
- 176.2m
- 175.9m
- 175.6m
- 175.3m
- 175.0m
- 174.7m
- 174.4m
- 174.1m

- Public beach and park north of Riverside Drive; Parking area south of Riverside Drive
- Generally low lying with intermittent discontinuities in existing berm
- Connected storm sewers under berm - modify with backflow prevention alternative
- Modify existing berm with Alternative 1

- Public beach and park north of Riverside Drive; Residential on both sides of Riverside Drive
- Generally low lying with intermittent discontinuities in berm
- Connected storm sewers and catch basins under berm - modify with backflow prevention alternative
- Modify existing berm with Alternative 1



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LOOKING WEST

Landmark Engineers Inc.

THE CITY OF WINDSOR ONTARIO, CANADA

Title: AREA 7 – SAND POINT BEACH AREA	Date: 6 AUG 19	Scale: NTS	FIGURE 15
Project: EAST RIVERSIDE FLOOD RISK ASSESSMENT	Project No. 18-033		

LEGEND

EXISTING BERM ALIGNMENT

- NO DISCERNABLE BERM
- EARTH BERM

EXISTING DRAINAGE

- STORM SEWER
- CATCH BASIN (CROSS-CONNECTION, SEE TABLE 3)
- S1 STORM SEWER (CROSS-CONNECTION, SEE TABLE 2)
- C1 CATCH BASIN (CROSS-CONNECTION, SEE TABLE 3)

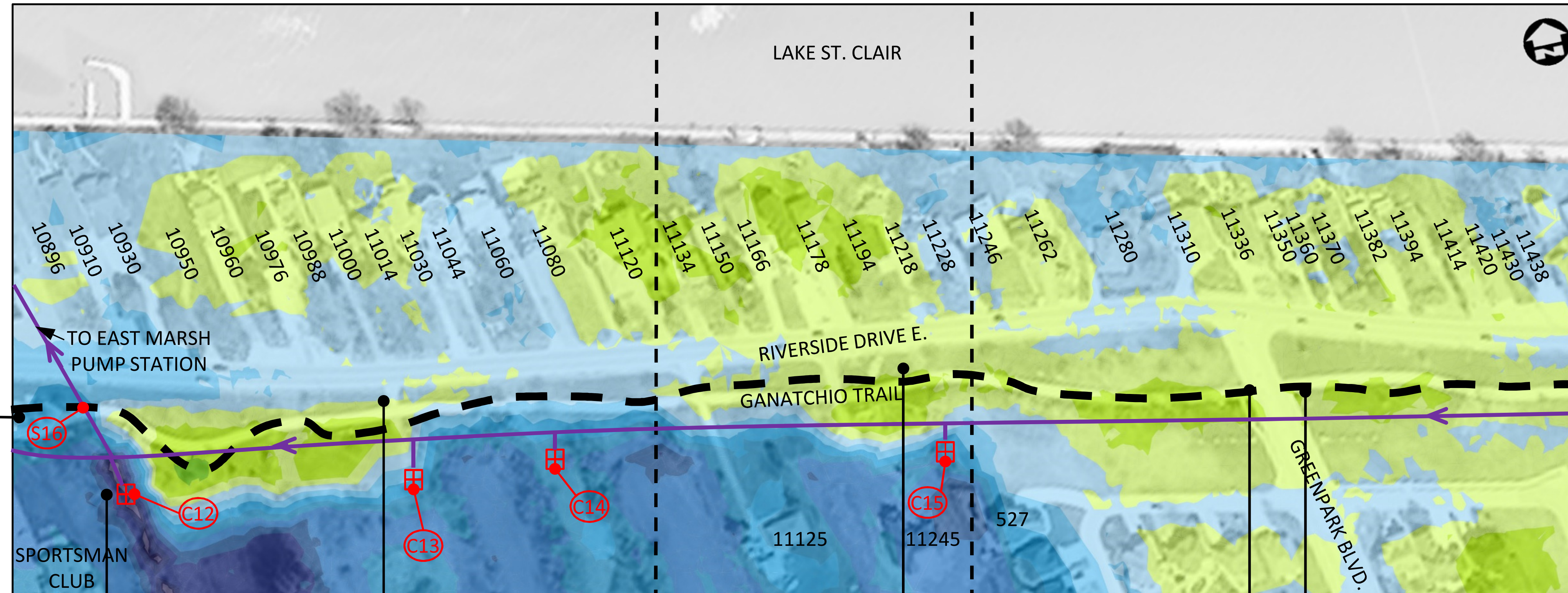
EXISTING GROUND ELEVATIONS

177.1m – 2050 WATER LEVEL WITH FREEBOARD
176.8m – 2050 PROJECTED HIGH WATER LEVEL
176.5m – CURRENT HIGH WATER LEVEL
176.2m
175.9m
175.6m
175.3m
175.0m
174.7m
174.4m
174.1m

- Residential area north of Riverside Drive; Mixed use developments south of Riverside Drive with residential neighbourhoods further inland
- Continuous earth berm with minor deficiencies
- Connected catch basins under berm, modify with backflow prevention alternative
- Modify existing berm with Alternative 1

- Residential areas on both sides of Riverside Drive
- Continuous berm with minor deficiencies
- Modify existing berm with Alternative 1

- Residential areas both sides of Riverside Drive
- Continuous berm with minor deficiencies
- Modify existing berm with Alternative 1



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Landmark Engineers Inc.

THE CITY OF WINDSOR ONTARIO, CANADA

Title	AREA 8 – GREENPARK AREA
Project	EAST RIVERSIDE FLOOD RISK ASSESSMENT
Date	6 AUG 19
Scale	NTS
Project No.	18-033

FIGURE 16

LEGEND

EXISTING BERM ALIGNMENT

- NO DISCERNABLE BERM (red dashed line)
- EARTH BERM (black dashed line)

EXISTING DRAINAGE

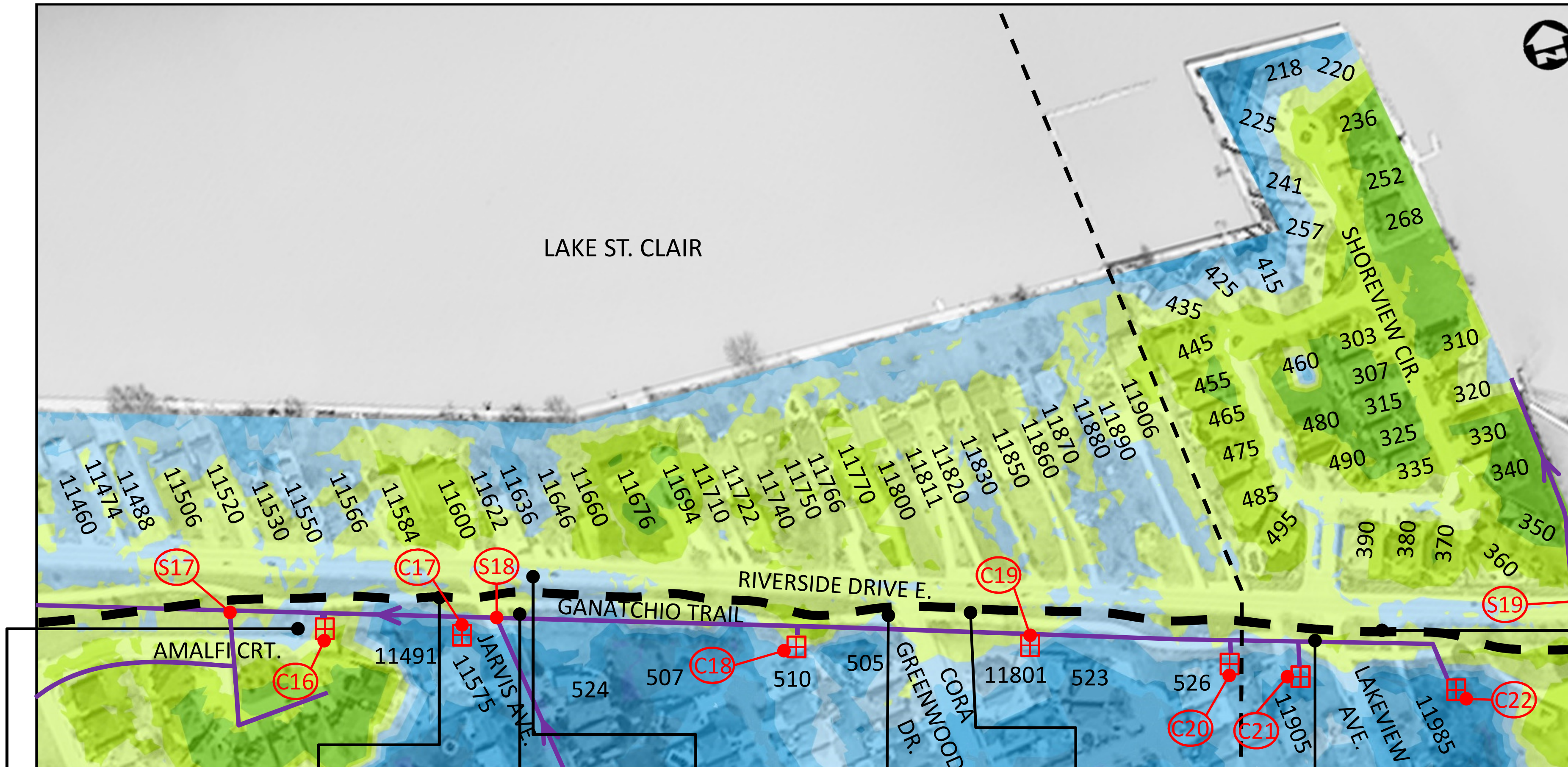
- STORM SEWER
- CATCH BASIN (CROSS-CONNECTION, SEE TABLE 3)
- S1 — STORM SEWER (CROSS-CONNECTION, SEE TABLE 2)
- C1 — CATCH BASIN (CROSS-CONNECTION, SEE TABLE 3)

EXISTING GROUND ELEVATIONS

177.1m	2050 WATER LEVEL WITH FREEBOARD
176.8m	2050 PROJECTED HIGH WATER LEVEL
176.5m	CURRENT HIGH WATER LEVEL
176.2m	
175.9m	
175.6m	
175.3m	
175.0m	
174.7m	
174.4m	
174.1m	

- Residential areas on both sides of Riverside Drive
- Generally low lying on the south side of the berm
- Existing continuous berm with minor deficiencies
- Connected catch basins and storm sewers under berm – modify with backflow prevention alternative
- Modify existing berm with Alternative 1

- Residential areas on both sides of Riverside Drive
- Continuous berm with minor deficiencies
- Connected catch basins under berm – modify with backflow prevention alternative
- Modify existing berm with Alternative 1

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Landmark Engineers Inc.

THE CITY OF WINDSOR ONTARIO, CANADA

Title	AREA 9 – RENDEZVOUS AREA
Project	EAST RIVERSIDE FLOOD RISK ASSESSMENT
Date	6 AUG 19
Scale	NTS
Project No.	18-033
FIGURE	17

LEGEND

EXISTING BERM ALIGNMENT

- NO DISCERNABLE BERM
- EARTH BERM

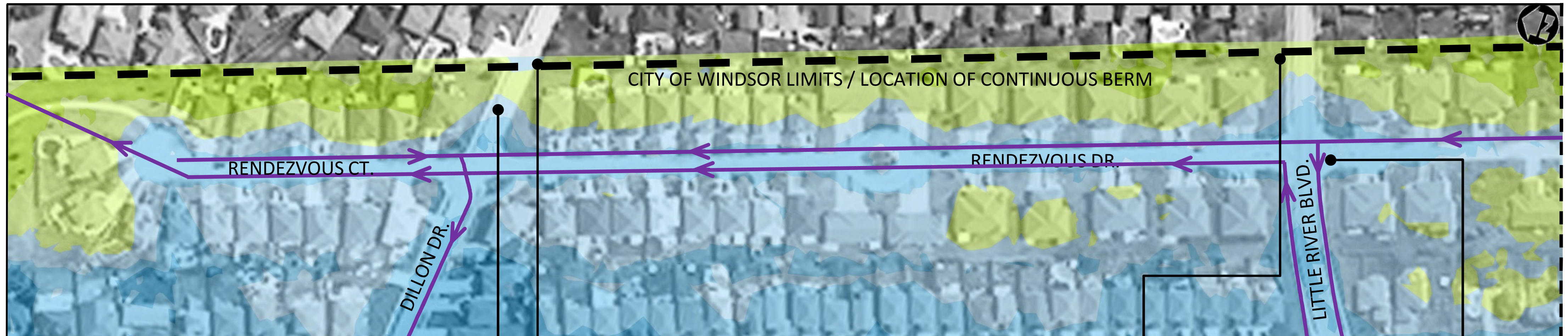
EXISTING DRAINAGE

- STORM SEWER
- CATCH BASIN (CROSS-CONNECTION, SEE TABLE 3)
- S1 STORM SEWER (CROSS-CONNECTION, SEE TABLE 2)
- C1 CATCH BASIN (CROSS-CONNECTION, SEE TABLE 3)

EXISTING GROUND ELEVATIONS

- 177.1m – 2050 WATER LEVEL WITH FREEBOARD
- 176.8m – 2050 PROJECTED HIGH WATER LEVEL
- 176.5m – CURRENT HIGH WATER LEVEL
- 176.2m
- 175.9m
- 175.6m
- 175.3m
- 175.0m
- 174.7m
- 174.4m
- 174.1m

- Residential area on west side of berm, bounded on the east by the City of Windsor limits
- A continuous berm exists along the rear yards of properties abutting the City of Windsor limits
- Minor deficiencies with existing berm



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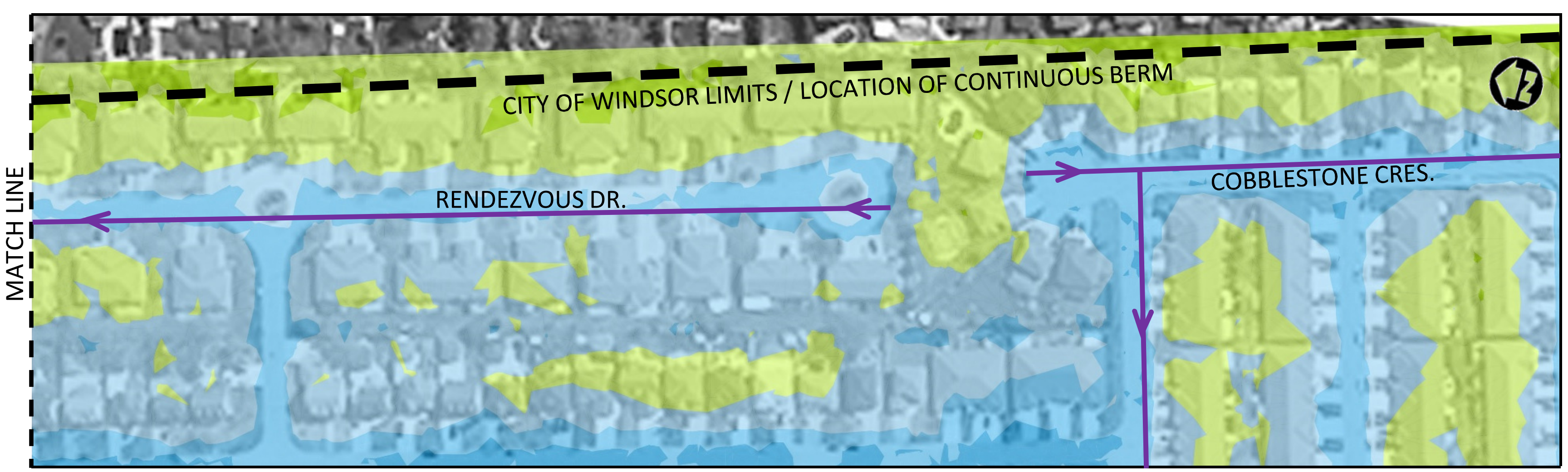
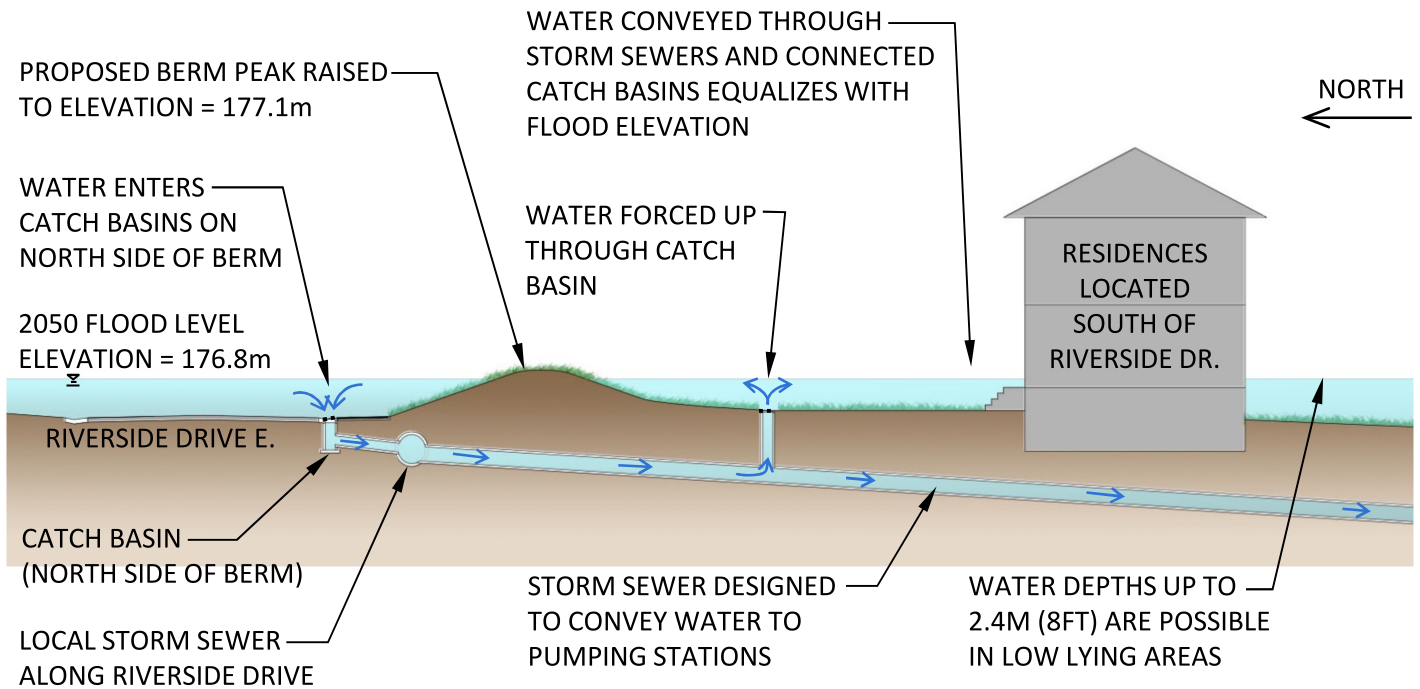


Landmark Engineers Inc.

THE CITY OF WINDSOR ONTARIO, CANADA

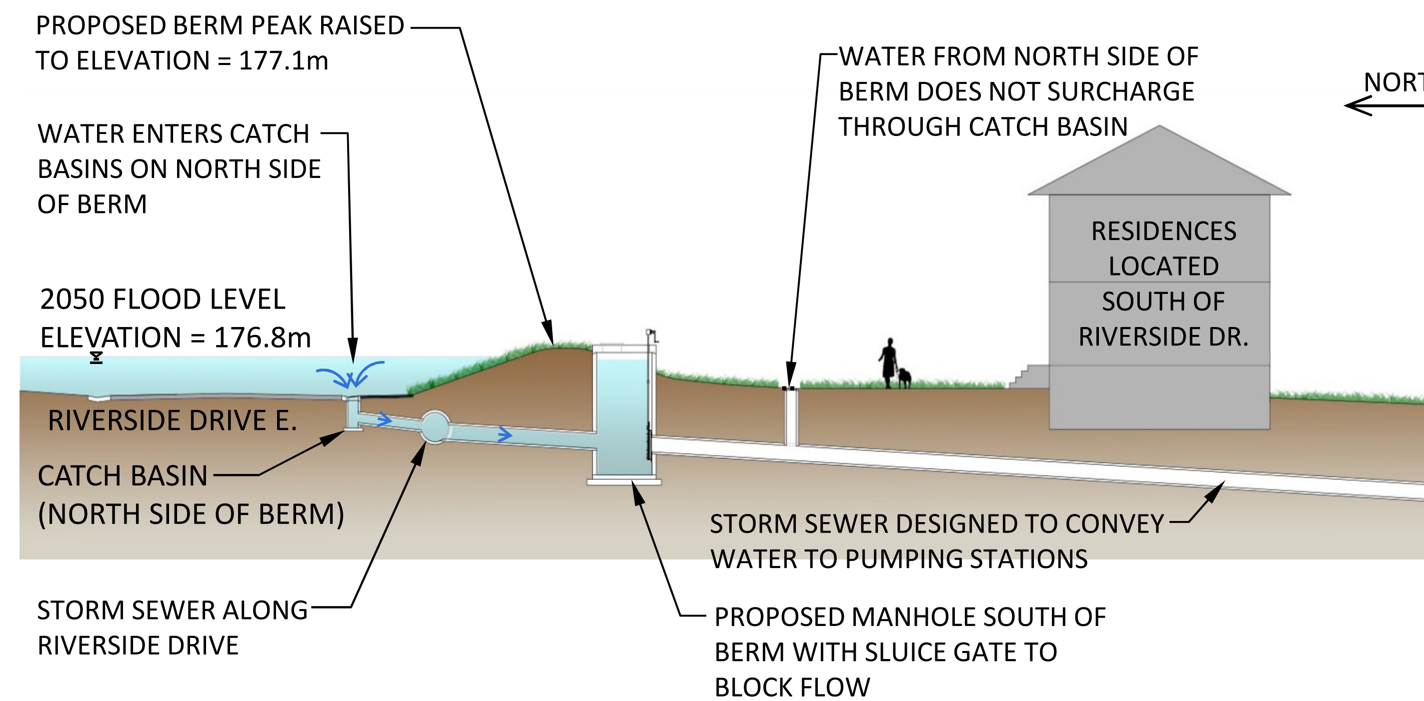
Title	AREA 10 – CITY LIMIT (INLAND DIKE)
Project	EAST RIVERSIDE FLOOD RISK ASSESSMENT
Date	6 AUG 19
Scale	NTS
Project No.	18-033
FIGURE	18

EXISTING CONDITION: Storm sewer on south side of berm that receives flows from storm sewers on north side of berm



- During a high water event, catch basins along Riverside Drive may fill with water and surcharge the storm sewers.
- The water on the south side of the berm has the potential to equalize with the lake water level.
- Inland water levels may reach a depth of 2.4m (8ft) in some areas.
- Potential to cause basement and even first floor flooding in low lying areas.

POTENTIAL SOLUTION: Install sluice gate inline with storm sewer to prevent flow of water to inland areas during flood conditions



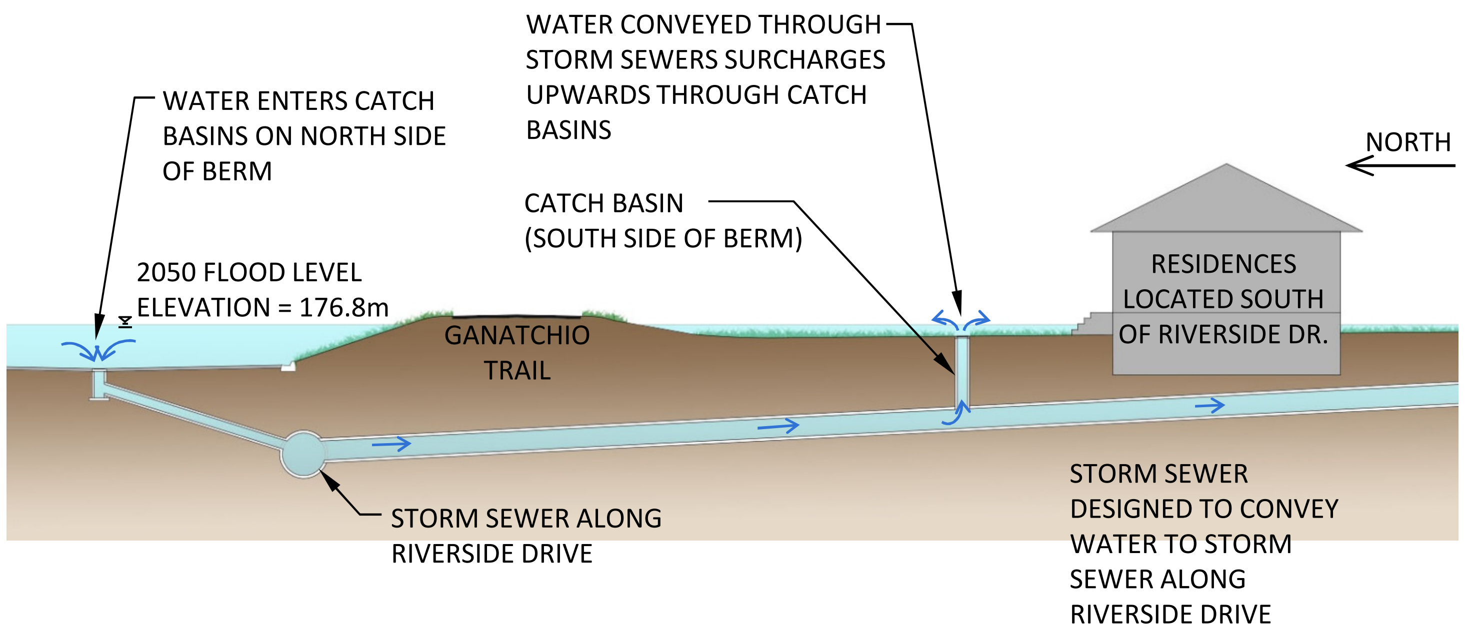
- During a high water event, the sluice gate is lowered to block flow of water into storm sewer on south side of berm.
- Water may rise in manhole to equalize with the Lake levels, but does not flow into neighbourhoods.
- Once the flow to the sewers is blocked south of the berm, water will remain on the north side of the berm.
- Catch basins and storm sewers on south side of berm continue to function and collect surface water and direct this to pumping stations.

Landmark Engineers Inc.

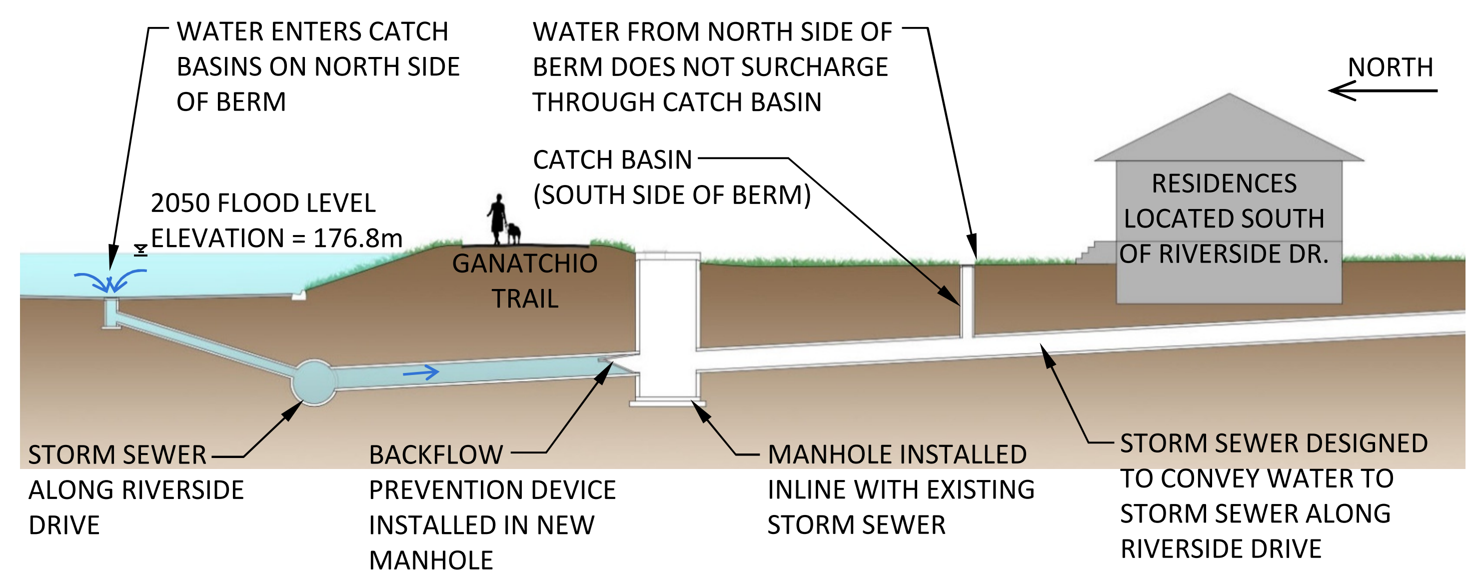
THE CITY OF WINDSOR ONTARIO, CANADA

Title	Date	FIGURE
STORM SEWER CROSS-CONNECTION - CONFIGURATION 1	6 AUG 19	19
	Scale: NTS	
Project: EAST RIVERSIDE FLOOD RISK ASSESSMENT	Project No.: 18-033	

EXISTING CONDITION: Storm sewer on south side of berm that directs flow into storm sewer on north side of berm



POTENTIAL SOLUTION: Install backflow prevention device (duckbill) inline with storm sewer on south side of berm



- During high water events, water enters storm sewers through catch basins along Riverside Drive and in adjacent parking lots.
- Water is forced upwards through connected sewers and exits through catch basins on south side of berm.
- Water on south side of berm has the potential to equalize with lake water level.

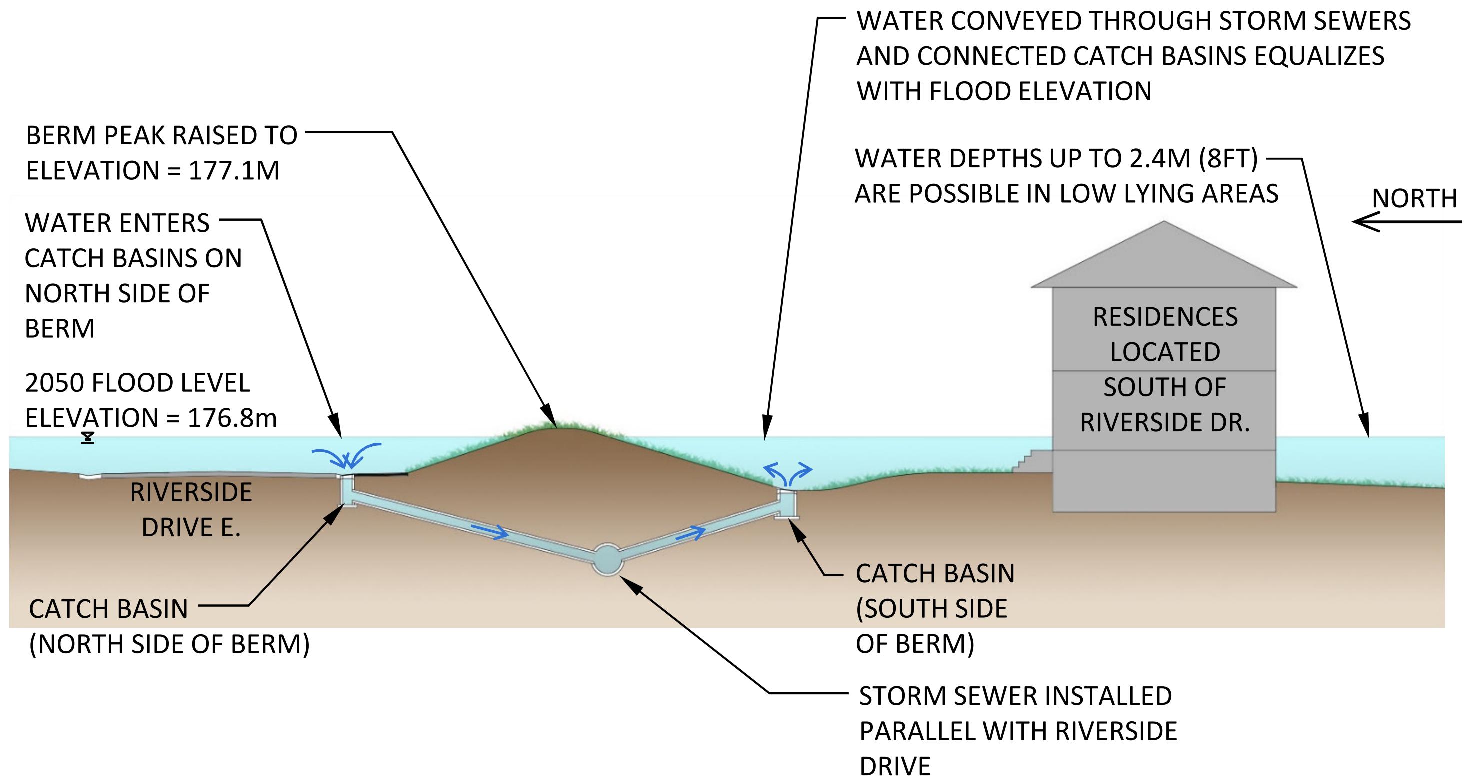
- Backflow prevention device installed inline with sewer inhibits surcharging of water on south side of berm.
- During high water events, water will enter the storm sewer, but the backflow prevention device will restrict the flow beyond the berm.

Landmark Engineers Inc.

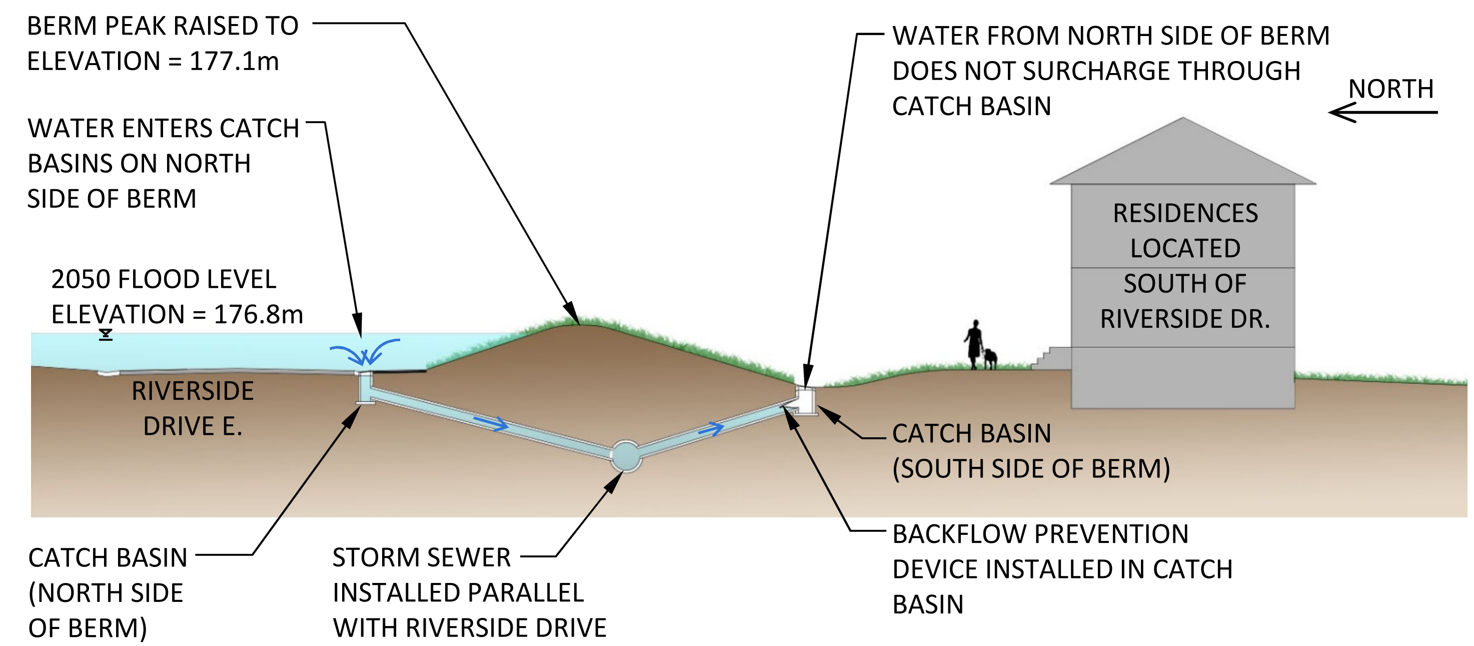
THE CITY OF WINDSOR ONTARIO, CANADA

Title	Date	FIGURE
STORM SEWER CROSS-CONNECTION - CONFIGURATION 2	6 AUG 19	20
	Scale: NTS	
Project: EAST RIVERSIDE FLOOD RISK ASSESSMENT	Project No. 18-033	

EXISTING CONDITION: Catch basin on south side of berm that directs flow into storm sewer on north side of berm



POTENTIAL SOLUTION: Modify inlet of catch basin with backflow prevention device (duckbill)



- During high water events, water enters sewers through catch basins adjacent to Riverside Drive.
- Water flows through cross-connected catch basins on south side of berm and floods neighbourhoods.
- Water on south side of berm has the potential to equalize with lake water level.

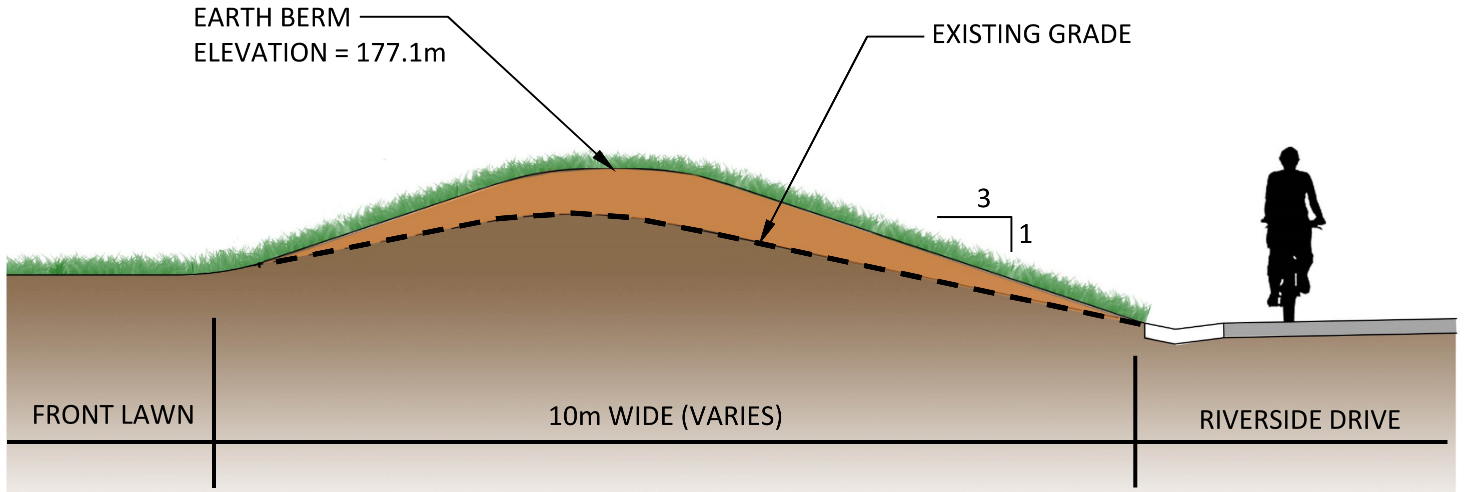
- During high water events, water enters sewers through catch basins adjacent to Riverside Drive.
- Backflow prevention device installed in catch basins on south side of berm inhibits surcharging of water on south side of berm.

Landmark Engineers Inc.

THE CITY OF WINDSOR ONTARIO, CANADA

Title	Date	FIGURE
STORM SEWER CROSS-CONNECTION - CONFIGURATION 3	6 AUG 19	21
	Scale: NTS	
Project: EAST RIVERSIDE FLOOD RISK ASSESSMENT	Project No. 18-033	

DIKE RESTORATION
ALTERNATIVE 1 - EARTH BERM



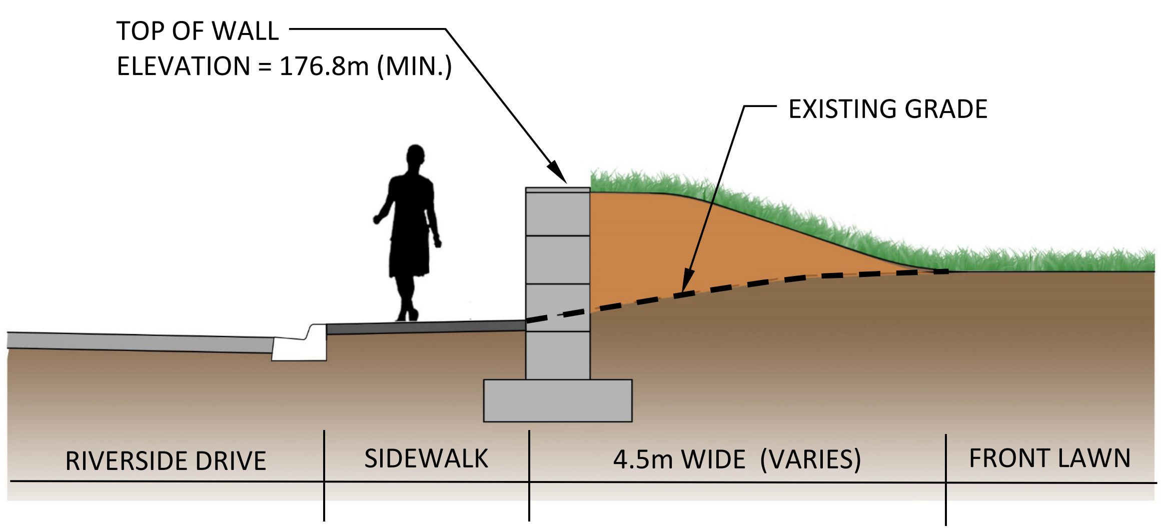
OPPORTUNITIES / ADVANTAGES

- Permanent feature
- Low maintenance / low construction cost
- Existing berm already in place along substantial portions of the dike system – requiring only minor upgrades
- Opportunity to enhance features along the Ganatchio Trail (landscaping, benches, etc.)

CONSTRAINTS / DISADVANTAGES

- Requires substantial encroachment onto private properties
- Will disrupt existing landscaping, trees and fences
- May require property acquisition and / or landowner agreements
- Steep slope for mowing (max at 3H:1V)

DIKE RESTORATION
ALTERNATIVE 2 - WALL WITH EARTH BERM



OPPORTUNITIES / ADVANTAGES

- Permanent structure
- Low maintenance / moderate construction cost
- Reduced footprint compared to Earth Berm
- Increased privacy for property owners (from pedestrians and road)
- Wall facing could incorporate designs / features to improve aesthetics

CONSTRAINTS / DISADVANTAGES

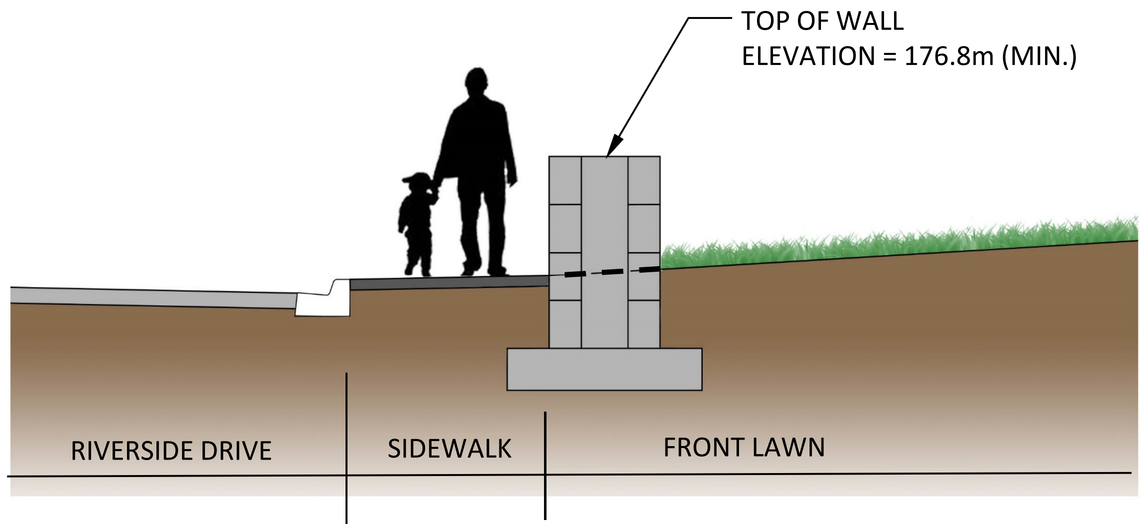
- Needs to be used in conjunction with mechanical gates at driveways
- Installation may disrupt underground utilities
- Steep slope for mowing (max at 3H:1V)
- May require property acquisition and / or landowner agreements

Landmark Engineers Inc.

THE CITY OF WINDSOR ONTARIO, CANADA

Title: DIKE RESTORATION ALTERNATIVES 1 AND 2	Date: 6 AUG 19	Scale: NTS	FIGURE 22
Project: EAST RIVERSIDE FLOOD RISK ASSESSMENT	Project No. 18-033		

DIKE RESTORATION
ALTERNATIVE 3 - WALL



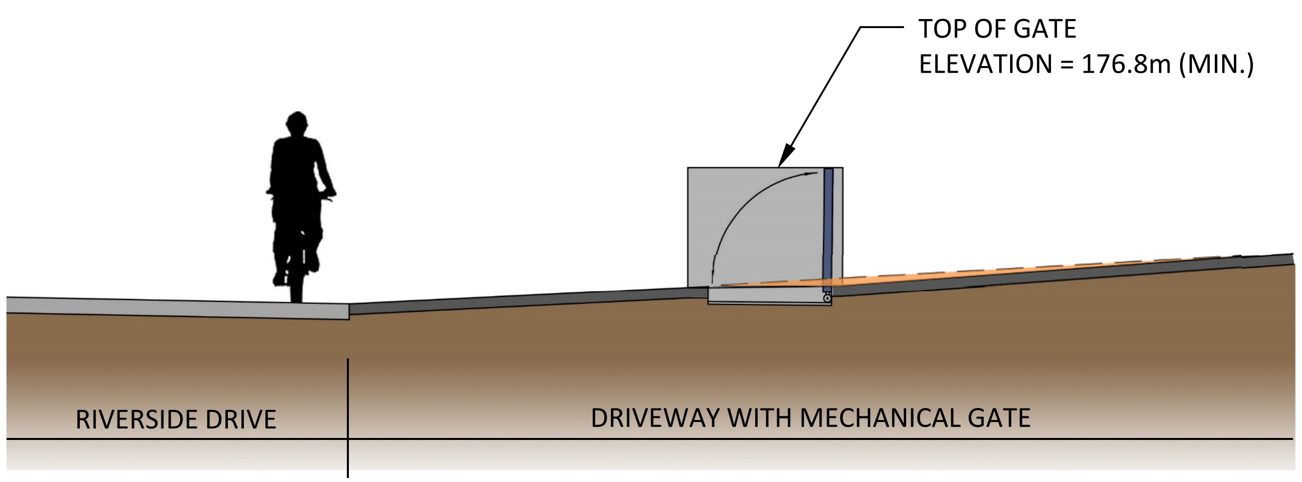
OPPORTUNITIES / ADVANTAGES

- Permanent structure
- Low maintenance / moderate construction costs
- Potential to substitute for existing fence at property line
- Minimal space required for installation
- Wall facing could incorporate designs / features to improve aesthetics

CONSTRAINTS / DISADVANTAGES

- Needs to be used in conjunction with mechanical gates at driveways
- High construction cost
- Installation may disrupt underground utilities
- May disrupt existing landscaping

DIKE RESTORATION
ALTERNATIVE 4 - MECHANICAL GATE



OPPORTUNITIES / ADVANTAGES

- Can be installed in areas constrained for space
- Maintains accessibility to protected properties

CONSTRAINTS / DISADVANTAGES

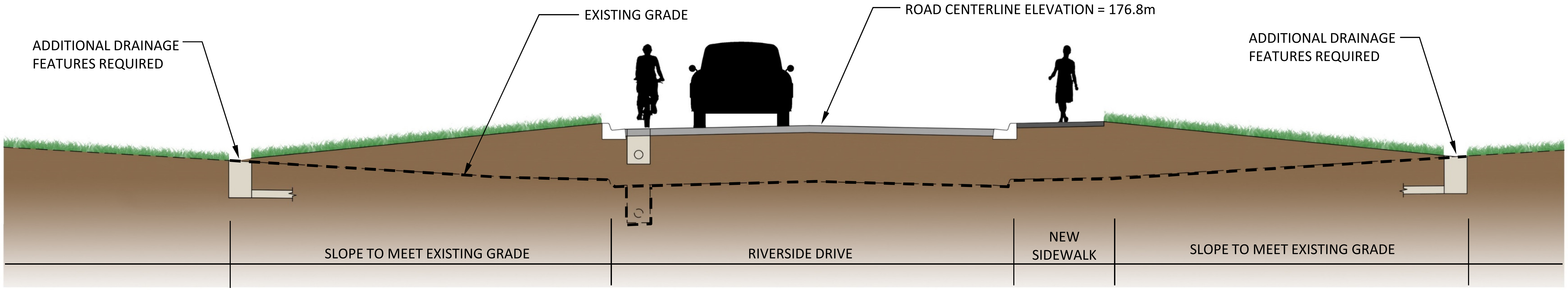
- Not a permanent fixed structure / potential for failure if not maintained
- High construction and maintenance costs
- Installation may disrupt underground utilities
- Can only be used for short opening such as driveways
- When gate is deployed, vehicle access to property is not available
- Regular inspections and maintenance required

Landmark Engineers Inc.

THE CITY OF WINDSOR ONTARIO, CANADA

Title	Date	FIGURE
DIKE RESTORATION ALTERNATIVES 3 AND 4	6 AUG 19	23
Project: EAST RIVERSIDE FLOOD RISK ASSESSMENT	Scale: NTS; Project No. 18-033	

DIKE RESTORATION
ALTERNATIVE 5 - RAISE RIVERSIDE DRIVE



<u>OPPORTUNITIES / ADVANTAGES</u>

- Permanent structure
- Less impact on adjacent properties and landscaping
- Could be reconstructed within road allowance (in some areas)
- Reduced need for property acquisition and landowner agreements

<u>CONSTRAINTS / DISADVANTAGES</u>

- Highest associated cost
- Utilities and drainage within the right-of-way will be affected
- This option is not feasible where homes are close to the roadway
- Will require alterations to front yards and driveways
- Additional front yard drainage will be required

Landmark Engineers Inc.

THE CITY OF WINDSOR ONTARIO, CANADA

Title	Date	FIGURE
DIKE RESTORATION ALTERNATIVE 5	6 AUG 19	24
	Scale: NTS	
Project: EAST RIVERSIDE FLOOD RISK ASSESSMENT	Project No. 18-033	

WESTERN STUDY LIMITS TO BELLEPERCHE PL.

FAIRVIEW BLVD. TO FRANK AVE.

LEGEND

- PROPERTY LINES
- (1234) MUNICIPAL ADDRESS
- POSSIBLE LAND ACQUISITION REQUIRED (APPROX 10m STRIP - WIDTH MAY VARY)

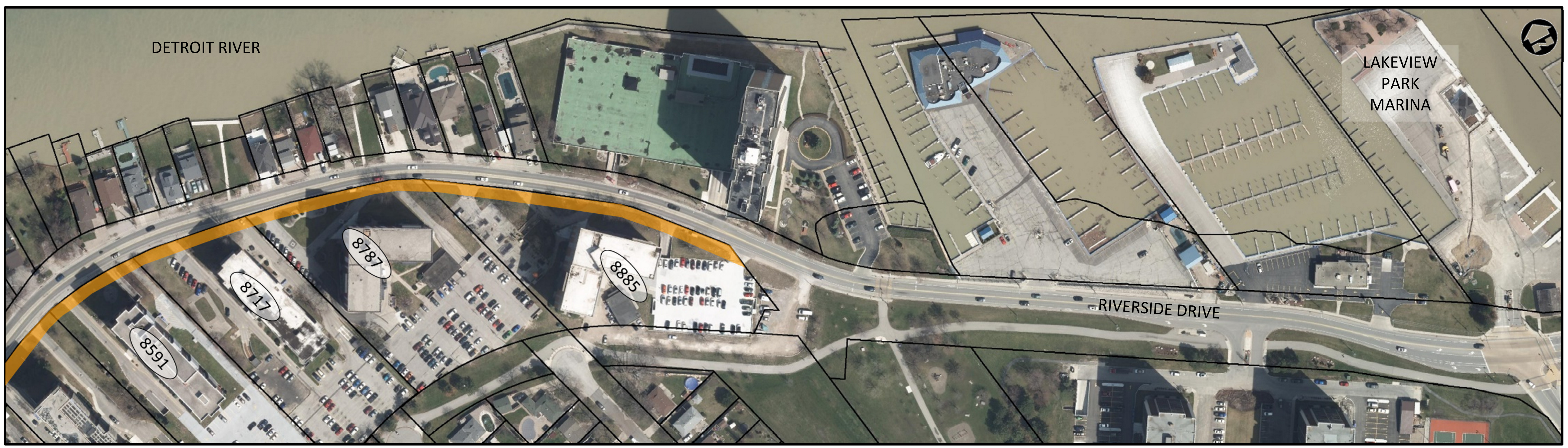
NOTE:
AREAS INDICATED FOR POSSIBLE LAND ACQUISITION DO NOT ACCOUNT FOR PRESERVATION OF EXISTING TREES AND TOPOGRAPHICAL FEATURES. ADDITIONAL LAND ACQUISITION NEEDS TO BE IDENTIFED THROUGH FUNCTIONAL DESIGN PROCESS.

Landmark Engineers Inc.

THE CITY OF WINDSOR ONTARIO, CANADA

Title	Date	FIGURE
POSSIBLE LAND ACQUISITION REQUIREMENTS PART 1	6 AUG 19	25
Project: EAST RIVERSIDE FLOOD RISK ASSESSMENT	Scale: NTS; Project No. 18-033	

WEST OF FRANK AVE. TO EAST OF DIEPPE ST.



EAST OF DIEPPE ST. TO RIVERDALE AVE.

LEGEND

PROPERTY LINES

1234 MUNICIPAL ADDRESS

POSSIBLE LAND ACQUISITION REQUIRED (APPROX 10m STRIP - WIDTH MAY VARY)

NOTE:
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Landmark Engineers Inc.

THE CITY OF WINDSOR ONTARIO, CANADA

Title: POSSIBLE LAND ACQUISITION REQUIREMENTS PART 2	Date: 6 AUG 19	FIGURE 26
	Scale: NTS	
Project: EAST RIVERSIDE FLOOD RISK ASSESSMENT	Project No. 18-033	

ST. ROSE BEACH – Water level elevation of 175.7m on July 7th. Observed shallow waves overtopping pedestrian walkway and spilling water and debris onto Riverside Drive.

8717 RIVERSIDE DRIVE – Water level elevation of 175.6m on Aug 2nd. Observed water flowing onto Riverside Drive from storm sewer manhole. This manhole is connected with outfall from 8717 Riverside Drive to the Detroit River.

Landmark Engineers Inc.

THE CITY OF WINDSOR ONTARIO, CANADA

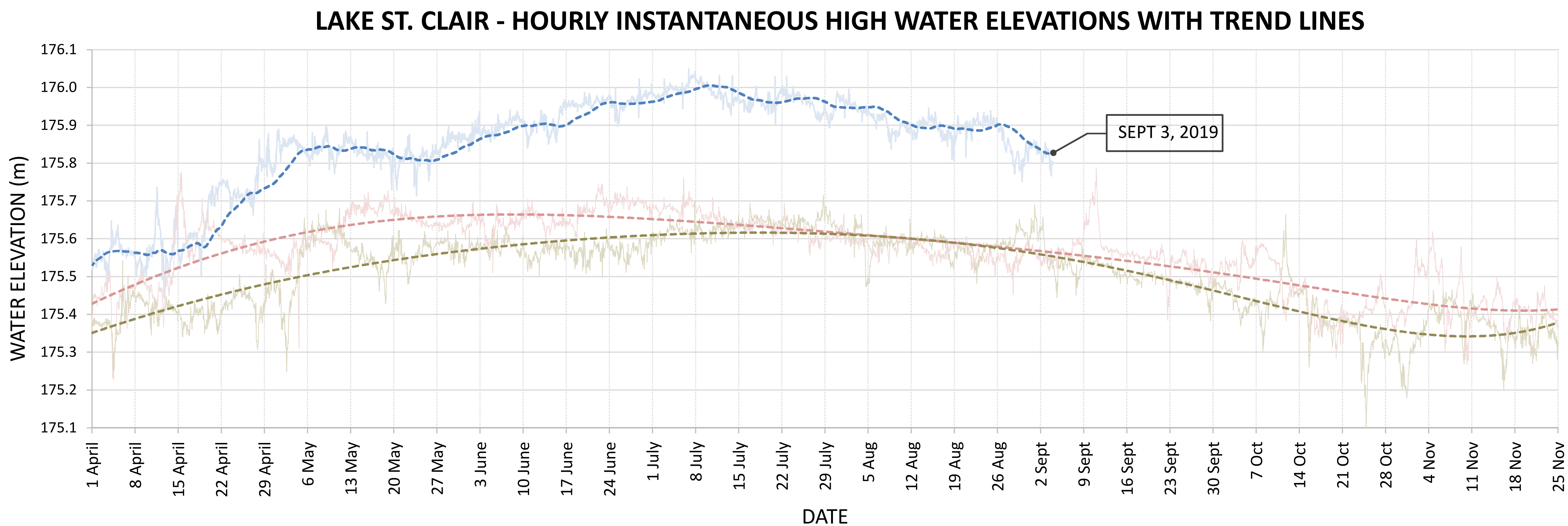
Title	Date	FIGURE
SUMMER 2019 – OBSERVED FLOODING ISSUES 1	6 AUG 19	27
	Scale: NTS	
Project: EAST RIVERSIDE FLOOD RISK ASSESSMENT	Project No. 18-033	



LAKEVIEW MARINA – Water level elevation of 175.6m on Aug 2nd. Observed pooling of water in the area between Armando's Pizzeria and the sheet piles boundary of the marina. Sandbagging in place limits flooding to this immediate area, but if allowed to flow freely, overland flow at this location would reach Riverside Drive and flow down Riverdale Ave.



SAND POINT BEACH – Water level elevation of 175.7m on July 7th (left and middle picture); water level elevation of 175.7m on April 14th with sustained North-easterly winds greater than 20km/h (right picture). Observed water flooding pavilion area on both days, with water flowing onto Riverside Drive on April 14th.



LEGEND

- 2019 HOURLY WATER LEVEL
- 2019 WATER LEVEL TREND LINE
- 2018 HOURLY WATER LEVEL
- 2018 WATER LEVEL TREND LINE
- 2017 HOURLY WATER LEVEL
- 2017 WATER TREND LINE

NOTE: WATER LEVEL DATA OBTAINED FROM WINDMILL POINT GAUGE STATION

Landmark Engineers Inc.

THE CITY OF WINDSOR ONTARIO, CANADA

Title: SUMMER 2019 – LAKE ST. CLAIR WATER LEVELS	Date: 6 AUG 19	FIGURE 29
	Scale: NTS	
Project: EAST RIVERSIDE FLOOD RISK ASSESSMENT	Project No. 18-033	

APPENDIX A

PIEVC Protocol Worksheets

PIEVC Engineering Protocol

For

Infrastructure Vulnerability Assessment and Adaptation to a Changing Climate

Worksheet Step 1

Project Definition

Revision 1.1

For further information about this ***Engineering Protocol*** or the ***National Engineering Vulnerability Assessment*** **Project** please contact Engineers Canada.

David Lapp, P.Eng.
Practice Lead, Engineering and Public Policy
Engineers Canada

300 – 55 Metcalfe Street
Ottawa, Ontario, K1P 6L5 Canada

Instructions

This worksheet is designed to allow practitioners to document that they have actively considered and evaluated each step of the Protocol. The worksheet also provides a document were practitioner considerations regarding each task of the Protocol are recorded.

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- Provide rational for the decision in the comments field of the task.

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Protocol for Changing Climate Infrastructure Vulnerability Assessment

Practitioners are strongly cautioned to avoid the following common pitfalls in executing a vulnerability assessment based on the Protocol.

i. ***Skipping Protocol tasks***.

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ii. ***Using previous case study reports as a template for the analysis.***

   Although previous studies provide an excellent reference, the application of the Protocol is highly specific to infrastructure. Applying previous case studies as a template can often lead the practitioner to miss key factors that contribute to the overall risk profile of the infrastructure.

iii. ***Using the worksheets without reference to the Protocol.***

   Although the worksheets parallel the Protocol, they do not provide supplementary context that may be necessary to correctly address the specified Protocol task.

1 Step 1 – Project Definition

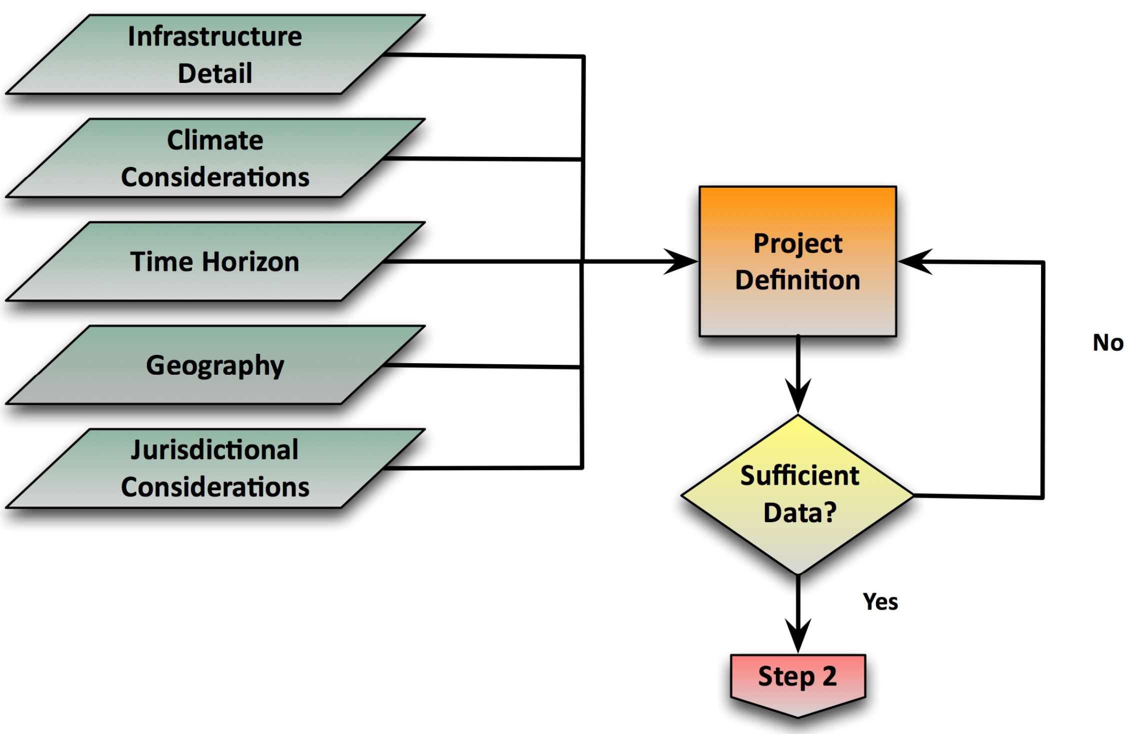
In this step the practitioner will define the global project parameters and boundary conditions for the engineering vulnerability assessment. This step will define:

- Which infrastructure is being assessed;
- Its location;
- Climatic, geographic considerations; and
- Uses of the infrastructure.

This is the first step of narrowing the focus to allow efficient data acquisition and vulnerability assessment.

The process flowchart for Step 1 of the Protocol is presented in **Figure 1**.

Figure 1: Step 1 – Project Definition Process Flowchart



1.1 Prepare Step 1 Worksheet

	Enter ***Yes*** or ***No***	
a. Use this ***Worksheet***; or	Yes	
b. Prepare practitioner specific documentation. i. Practitioner specific documentation ***MUST*** detail each task outlined in this step of the Protocol.		No
Comments and Observations N/A		

1.2 Identify the Infrastructure

a. Choose the infrastructure to be evaluated for changing climate vulnerability.	Flood protection for the East Riverside neighbourhood of Windsor has been selected for evaluation. Components of this flood protection consist of a dike system and interconnected drainage systems. These systems protect low-lying inland areas from surface flooding. The study area protected by the dike system is bounded to the west by St. Rose Beach; to the east by the City limit with the Town of Tecumseh; to the north by Lake St. Clair and the Detroit River; and to the south by the east-west rail corridor south of McHugh Street.
b. Provide a general description of the infrastructure.	The flood protection infrastructure systems generally include: • A series of landform barriers (earth berms & dikes) along Riverside Drive • Minor and major drainage systems (storm sewer network and overland surface drainage systems) where they cross over or under the landform barrier • Possibility of overland drainage relief to be accommodated through the landform barrier

c. Reference additional background and detailed information sources.	• City of Windsor Sewer Atlas • City of Windsor GIS • City of Windsor LiDAR • City of Windsor Pumping Station Operating Procedures Manuals • City of Windsor Shoreline Management Plan (1986) • Stormwater Management Plans for East Riverside developments • Essex Region Conservation Authority (ERCA) flood plain mapping

Comments and Observations

- Risk assessment of drainage systems could be further informed by the ongoing City of Windsor Sewer Master Plan and sewer modelling study by Dillon Consulting.
- Coordination / communication regarding proposed stormwater management projects in the area of St. Rose Beach may inform both projects.

1.3 *Identify Climate Parameters*

a. State the climate parameters that will be considered in the evaluation.

Add rows as necessary.

i. Based on professional judgement, identify which climate trends and weather events may contribute to infrastructure vulnerability.
The following Climate parameters were considered: <u>Temperature</u> • Generally increasing with climate change • No significant effect anticipated on dike system or flood control measures <u>Precipitation</u> • Annual precipitation is expected to increase and precipitation events are projected to become more intense and extreme with climate change • Capacity of drainage system to convey overland flooding may be affected <u>Wind Speed & Duration</u> • More variability / intensity is possible with climate change • Affects wave height and Lake set-up <u>Water Level Elevation</u> • Water levels on Lake St. Clair have been increasing since reaching near-record lows in 2013 and recently reached a new record high. • Lower average water levels with greater variability is expected in the long term • This parameter directly affects capacity / function of dike system <u>Lake Ice</u> • More variability is possible with climate change • No known history of ice affecting dike system <u>Frost Freeze / Thaw Cycle</u> • Number of cycles is expected to decrease with climate change • Could conceivably affect stability / integrity of dike system
ii. Based on professional judgement, identify which climatic trends and/or weather events may ***combine*** to create infrastructure vulnerability.

• High water levels combined with heavy precipitation • High water levels combined with sustained northeast winds • High water levels combined with sustained northeast wind speeds and heavy precipitation
Comments and Observations Assumptions and judgements regarding climate trends were informed by the City of Windsor's Climate Change Adaptation Plan.

1.4 *Identify the Time Horizon*

a. Define the period over which the infrastructure must operate and for which climate trends will be projected for the engineering vulnerability assessment.	Design life of flood protection system components were reviewed with City of Windsor staff. Based on reasonable reliability of climate change models, retained time horizons are: • Current day • 2030 • 2050
Comments and Observations Climate projections beyond 2050 vary greatly with less reliability. Overreliance on broadly changing climate projections may cause overdesign of current systems within the design life of the systems being evaluated.	

1.5 *Identify the Geography*

Add rows as necessary.

a. Summarize site-specific, local, and/or geographical features relevant to the evaluation.
• The Lake St. Clair / Detroit River shoreline within the study area is a managed

shoreline with varying combinations of cast in place concrete, sheet piles, and stone revetments in varying conditions – mostly located on private property. Smaller segments of unprotected beach are intermittently located within the area.

- The study area is bisected by Little River, which runs in a fairly linear channel from south to north, emptying into Lake St. Clair at the Mouth of the Detroit River.
- Interior to the Lake St. Clair / Detroit River shoreline the study area is mostly urban in character, comprised mainly of single-family residential dwellings with a significant pocket of high-density apartment buildings along Riverside Drive located to the west of Little River. There are several significant retail / commercial strips within the study area, located mostly along the Lauzon Road and Wyandotte Street corridors, west of Little River.
- Riverside Drive is a scenic route offset from the shoreline that functions as a collector road providing east-west access between residential neighbourhoods and the City's downtown core.
- The Ganatchio Trail is a multi-use trail that also functions as a landform barrier / dike, running parallel to Riverside Drive between Little River and the eastern boundary of the City of Windsor. A small portion of the trail / dike continues west of Little River.
- The topography of the area is generally flat with heavy clay surface soils. Low-lying flood-prone areas (with elevations significantly lower than current lake levels) are located to the south of the existing dike system.

b. Provide references.

- City of Windsor Zoning maps
- City of Windsor LiDAR
- City of Windsor Shoreline Inventory & Assessment Study (by Landmark Engineers, 2019)

Comments and Observations

Refer to Figure 1 in the main Flood Risk Assessment report for a visual depiction of the study area.

1.6 *Identify Jurisdictional Considerations*

Add rows as necessary.

a. List the jurisdictions, laws, regulations, guidelines and administrative processes that are applicable to the infrastructure.
• City of Windsor *i.* Planning policies (zoning) *ii.* City of Windsor By-laws *iii.* The City of Windsor manages all operations, maintenance and repairs of infrastructure within the study area. However, no set policy for inspection / maintenance of the dike currently exists. • Province of Ontario *i.* Ontario Regulation 158/06 (administered by the Essex Region Conservation Authority under section 28 of the Conservation Authorities Act - Regulation of Development, Interference with Wetlands and Alterations to Shorelines and Watercourses) *ii.* Drainage Act
b. Provide references.
N/A
<u>Comments and Observations</u> N/A

1.7 *Site Visit*

a. Conduct a site visit.
<u>If Site Visit Not Conducted – Explain Why and Provide Supporting Information</u> A site visit was not conducted until after completion of Step 1 • The initial site investigation focused on a literature review and analysis of the City's LiDAR elevation data

- Due to snow cover conditions, remote imagery was initially used for visual referencing
- Area mapping and as-built drawings for completed projects in the area provided a good reference for existing surface conditions
- Landmark Engineers staff have historical knowledge of the area

b. Based on information gathered to date, conduct interviews with facility owners and operating personnel in order to field-test and validate initial project definition findings.

Notes and Observations from Interviews

A site visit has been scheduled with the City of Windsor's Manager of Contracts, Field Services & Maintenance to review and confirm limits of study area, identify known gaps and problem areas in the dike system, and to identify any subsurface sewer interconnections that could compromise the integrity of the dikes.

c. Examine infrastructure and local geographical features as they may apply to the vulnerability assessment.

Notes and Observations from Infrastructure Examination

i. Note key observations and areas for follow-up in subsequent assessment steps.

Key Observations

The condition of the existing dike system varies greatly in geographically-separated segments of the assessment area. The dike system on the west side of Little River is discontinuous, is partially located on private property, and is generally lower in elevation than the dikes east of Little River; the dike east of Little River along the Ganatchio Trail is generally continuous and is constructed entirely on municipal property. An inland extension of the dike also runs along the eastern boundary of the City of Windsor, located primarily on private property.

Additional Comments and Observations

Corresponding to the natural geographic conditions, the assessment of the dike system has been separated into three distinct areas:

- West of Little River
- East of Little River
- Inland along the Windsor – Tecumseh boundary

City of Windsor staff indicated in a project review meeting on 20 February 2019 that the preferred location for reinstating the landform barrier / dike west of Watson Avenue is on the north side of Riverside Drive, to connect with the existing earth berms at St. Rose Beach, Bridges Bay Park, and at the St. Paul Pumping Station. This preference of dike location has directed the analysis of the most western segment of the study area.

1.8 *Assess Data Sufficiency*

Review the data set developed in **Sections 1.1 through 1.7**.

Add rows as necessary.

a. Where assumptions are proposed for the assessment, identify these as such and provide a rationale for their use.

Assumption	**Rationale**
Increased intensity / duration of precipitation events due to climate change has been accounted for in the sewer system hydraulic analyses performed by others.	Concurrent with this flood risk assessment, the City of Windsor has commissioned Dillon Consulting to carry out sewer modeling as part of its ongoing Sewer Master Plan. Dillon has confirmed that their modeling parameters account for increased rainfall intensity due to climate change.
LiDAR (Light Detection and Ranging) provided by the City of Windsor is accurate.	The City of Windsor provided the most recent LiDAR data for use with this assessment (dated 12 April 2017). This data was supplemented and generally confirmed by field surveys conducted by Landmark Engineers in March and April 2019.
Values for assumed critical wind speeds and wave heights on Lake St. Clair have been obtained from the City of Windsor's *Shoreline Management Plan* (authored by N.K. Becker and Associates Ltd., 1986).	The *Shoreline Management Plan* indicates that wave characteristics are affected by wind speed, direction and duration, water depth and the effective fetch length. In all cases for the selected off-shore design wave, fetch length was the governing factor for wave development. Fetch lengths do not vary with climate change as they are a measurement of a geographical characteristic. The maximum wave heights determined in the 1986 *Shoreline Management Plan* can be considered current.

b. Document where there is insufficient information currently available to proceed with an element of the assessment.

Insufficient Information	i. Where there is insufficient information currently available, identify a process to develop or infill that data.	ii. Where data cannot be developed, identify the data gap as a finding in Step 5 of the Protocol – Recommendations.
Lake water level Elevations	Water level elevations on Lake St. Clair established in the 1986 *Shoreline Management Plan* report are out of date. Landmark Engineers has commissioned an environmental subconsultant to update the analyses of Lake St. Clair water levels, taking into account recent water level data (ie, since 1986) and climate change models for projected water level elevations.	
Sewer system, ponds and pumping station capacity	These components are being studied separately as part of the City's Sewer Master Plan.	Report not available during the time frame of this risk assessment; Data gap exists. Recommend revisiting risk assessment as it pertains to the sewer system on completion of Sewer master plan.
Little River flows and dike protection	The Little River diking system is being studied separately by others. Windsor City Council resolution CR352/2019 authorized administration to retain a consultant to carry out this study.	Report not available during the time frame of this risk assessment; Data gap exists. Recommend revisiting risk assessment on completion of the Little River study.
Need / location for overland outlet for storm water flow relief from inland areas	At the 6 March 2019 project coordination meeting with Dillon Consulting, Landmark requested that any overland flow outlets deemed necessary through the Sewer Master Plan be identified.	Report for Sewer Master Plan wat not available during the time frame of this risk assessment. Recommend revisiting risk assessment as it pertains to the sewer system upon completion of Sewer Master Plan.

Ongoing construction / design work being done within the study area	Request construction drawings for projects in progress (segment of Riverside Drive between Watson Ave. and Riverdale Ave.). Area of Riverside Drive west of St. Rose Beach is under design – coordinated with Dillon Consulting to share information.	Gap identified. Construction not complete for segment between Watson Ave. and Riverdale Ave. Recommend revisiting risk assessment as it pertains to the sewer system and as-built berm elevations when construction is completed.

Date:	April 2019
Prepared by:	Jennifer Nicholls & David Killen, Landmark Engineers Inc.

PIEVC Engineering Protocol

For

Infrastructure Vulnerability Assessment and Adaptation to a Changing Climate

Worksheet Step 2

Data Gathering and Sufficiency

Revision 1.1

For further information about this ***Engineering Protocol*** or the ***National Engineering Vulnerability Assessment*** **Project** please contact Engineers Canada.

David Lapp, P.Eng.
Practice Lead, Engineering and Public Policy
Engineers Canada

300 – 55 Metcalfe
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2 Step 2 – Data Gathering and Sufficiency

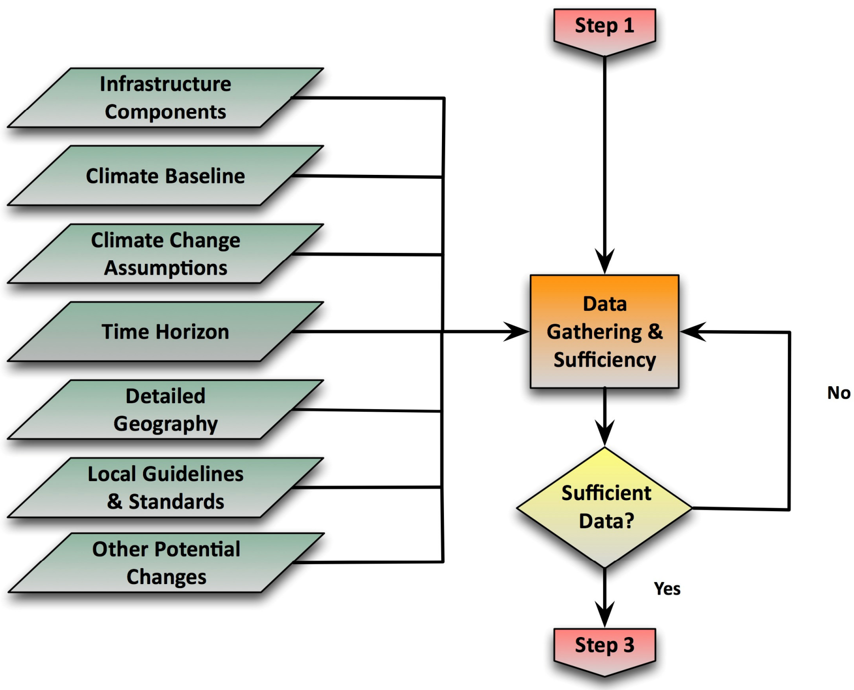
In this step the practitioner will provide further definition regarding the infrastructure and the particular climate trends that are being considered in the evaluation. The practitioner will undertake a data acquisition exercise and identify where, in their professional judgment, the data is insufficient. Data insufficiency may arise from:

- Poor quality;
- High levels of uncertainty; or
- Lack of data altogether.

This step further focuses the evaluation and starts to establish activities to infill poor quality or missing data.

The process flowchart for Step 2 of the Protocol is presented in **Figure 2**.

Figure 2: Step 2 – Data Gathering and Sufficiency Process Flowchart



2.1 *Prepare Step 2 Worksheet*

	Enter ***Yes*** or ***No***	
a. Use this ***Worksheet***; or	Yes	
b. Prepare practitioner specific documentation. i. Practitioner specific documentation ***MUST*** detail each task outlined in this step of the Protocol.		No
<u>Comments and Observations</u>		

2.2 *State Infrastructure Components*

Add rows as necessary.

a. List the major components of the infrastructure that are influenced by climate. i. Only select those infrastructure components that, in the practitioner's professional judgment, are relevant to this assessment. ii. Where available, review operations incident reports, daily logs and reports to assist in the identification of infrastructure components with a history that could result in vulnerability and are relevant to this process. iii. Interview infrastructure owner's operators and maintenance staff to identify historical events that may not be documented or retrievable from databases and evaluate if these events are relevant to this assessment.
Dike System • Ganatchio Trail landform barrier / dike system (east of Little River) • Riverside Drive dike system (west of Little River) • Inland dike along Windsor-Tecumseh boundary
Flood Control Measures & Drainage System • Stormwater sewers and catch basins crossing the dike • Stormwater outfalls
b. Provide references.
• City of Windsor digital Sewer Atlas • LiDAR surface elevation data (City of Windsor surveyed 12 April 2017) • Mountbatten Crescent Phase 2 (as-built drawings) • Amalfi / Riverside Drive Lots (as-Constructed drawings, HGS Ltd., 2002) • Mountbatten Crescent, Phase 2 Site Servicing Study (Dillon consulting, 2017) • Lakeview Development Plan; Lakeview Planning Area East of Riverside Planning District (M.M. Dillon Ltd., 1992) • Little River and Riverside Drive Barrier Landform System Improvements (Design Drawings, HGS Ltd., 2007)) • Shoreline Management Plan, (N.K. Becker and Associates, 1986) • Riverside Drive East Flood Relief Study (BTS Consulting Engineers, 1998) • East Riverside Flood Protection Map (City of Windsor, 1986)

Comments and Observations N/A

2.3 *State the Time Horizon for the Assessment*

a. State the period over which the infrastructure must operate.	Indefinite time period – Developed areas protected by the dike system are below current Lake St. Clair water levels. The dike system must provide protection from overland flooding for as long as the area is occupied. Interior drainage is provided by storm sewers, retention ponds and pumping stations. These must operate indefinitely.
b. State the design life of the infrastructure components.	Dike - Design life for landform barrier / dike system has not been clearly established. Earth berms can last indefinitely with proper maintenance. Storm sewer system - Design life for system components generally varies between 50 – 100 years. This is a major system with staged upgrades and modifications occurring on an ongoing basis. Refer to Sewer Master Plan for phasing of planned upgrades.
c. Document the maintenance and/refurbishment schedule for the infrastructure as it may apply to the useful service life of the infrastructure.	No maintenance or inspection schedule has yet been established for the dike system. The City's Operations Department has confirmed that maintenance and repair of the dike system would be carried out on an as-needed basis if problems are reported. Storm sewers are currently inspected and cleaned on an as-needed basis. The City's Operations Department indicates that a new inspection schedule is under development. Refer to the Sewer Master Plan for the planned refurbishment / upgrade schedule for the storm sewer system.

d. State the useful service life remaining in the infrastructure components.	Dike – varies with individual geographical segments • West of Little River – large portion of landform barrier is on private property and may be subject to possible unapproved alterations affecting the useful service life. • East of Little River – useful service life varies with continued development in the area. • Windsor-Tecumseh boundary – landform barrier is inaccessible for detailed evaluation or monitoring due to location on private property. • Useful life of berm varies with each property it crosses and the potential for unapproved alterations. Sewer system – Refer to Sewer Master Plan for useful service life of individual components.
Comments and Observations N/A	

2.4 *State the Geography*

Add rows as necessary.

a. List the major features of the local geography that may influence the microclimate of the infrastructure or impose peripheral risk. i. Specifically identify hills, valleys, river systems, lakes, ocean frontage that may moderate the climate parameters considered in the evaluation. ii. Only select those geographical features that, in the practitioner's professional judgment, are relevant to this assessment.
Geographically, the City of Windsor is centrally located within the Great Lakes Basin, situated along the south shore of Lake St. Clair and the Detroit River. Lake levels in Lake St. Clair are affected by lake levels and outflows from Lakes Huron, Michigan and Superior upstream. East Riverside is generally flat, low-lying terrain with the majority of the study area below the current lake level elevation. East of Little River, the dike system being assessed east of Little River is subject to wind / wave

action from Lake St. Clair. Parts of the existing storm sewer system in this area are located north of the existing dike and are therefore exposed to the effects of overland flooding due to wind / wave action. The dike segment west of Little River is subject to wave action from the Detroit River, where the maximum wave heights generated are from shipping traffic. Portions of this section of dike are located north of Riverside Drive, closer to the shoreline, and may have a greater risk of erosion due to wave action. The inland dike system along the Windsor-Tecumseh boundary is a secondary boundary limiting overland flow between municipal boundaries and is not subject to wave action. The sewer system is this area does not have cross connections under the landform barrier / dike.
b. Provide references.
ERCA flood plain mapping LiDAR (12 April 2019) provided by the City of Windsor City of Windsor GIS information
Comments and Observations Generally speaking, the geography of the study area is fairly uniform, consisting of flat, low-lying lands protected from overland flooding by the dike system along Riverside Drive. Because the dike condition varies considerably west and east of Little River, the risk on either side of Little River will be assessed separately.

2.5 *State Specific Jurisdictional Considerations*

a. As applicable, itemize:		b. Provide references.
▪ Jurisdictions that have direct control/influence on the infrastructure;	• City of Windsor • ERCA (approvals process for new developments)	Conservation Authority Act, R.S.O. 1990 c.C.27
▪ Sections of laws and bylaws that are relevant to the infrastructure;	City of Windsor Zoning bylaw – definition of freeboard as 0.3m increase in elevation	City of Windsor By-Law 8600; Ontario Regulation 158/06
▪ Sections of regulations	Ontario Regulation 158/06 – as it defines	Ontario

that are relevant to the infrastructure;	a flood plain or wetland as a regulated area. Also defines freeboard and regulates development in floodplains	Regulation 158/06
▪ Standards that are relevant to the design, operation and maintenance of the infrastructure;	Dike system – the City of Windsor does not currently have any specific policies or bylaws relating to dike maintenance. Sewer system • City of Windsor Development Manual • City of Windsor Standard Specifications and Drawings	City of Windsor Development manual, May 2015
▪ Guidelines that are relevant to the design, operation and maintenance of the infrastructure; and	N/A	
▪ Infrastructure owner/operator administrative processes and policies as they apply to the infrastructure.	N/A	

Comments and Observations

The City of Windsor does not currently have language in their bylaws to regulate the maintenance of earth berms designed for flood control located on private property - other than for the earth berms located along Little River (and along other municipal drains, subject to the Drainage Act).

2.6 *State Other Potential Changes that May Affect the Infrastructure*

a. Identify and document other factors that can affect the design, operation, and maintenance of the infrastructure:	
i. Document changes in use pattern that increase/decrease the capacity of the infrastructure.	Increased development in and around the dike: • changes to height and / or alignment of the berm • alteration of materials / configuration of berm Sewer system: • Changes to drainage cross-connectivity • Drainage system changes as per recommendations of Sewer Master Plan
ii. Document operation and maintenance practices that increase/decrease the capacity or useful life of the infrastructure.	Dike system: • Lack of regular inspection schedule – alterations to system potentially not identified until critical failure • Lack of routine maintenance – this could potentially affect the dike capacity resulting from settlement Sewer system: • City has a regular CCTV inspection and cleaning schedule in place • Inventory / inspection schedule for mechanical / flow control components (i.e. sluice gates, backflow prevention devices) is not available - this could lead to failure of components or failure to activate flow control devices in an emergency event.
iii. Document changes in management policy that affect the load pattern on the infrastructure.	Dike system – N/A Sewer System: • Subject to outcome of Sewer Master Plan
iv. Document changes in laws, regulations and standards that affect the load pattern on the infrastructure.	N/A
<u>Comments and Observations</u> N/A	

2.7 *Identify Relevant Climate Parameters*

Add rows as necessary.

a. List the relevant climate parameters associated with the design, development, and management of the infrastructure. i. Use the ***Climate Parameter List*** provided in **Appendix A** as a guideline. ii. Additional guidance can be found in: ▪ The ***PIEVC Data Integrity and Availability Review*** and/or ▪ ***Environment Canada's National Climate Data Archive*** (http://climate.weatheroffice.ec.gc.ca/Welcome_e.html).	b. State the climate information source(s). Sources may include, but are not limited to: ▪ National Building Code of Canada Appendix Tables ▪ Intensity Duration Frequency (IDF) curves, ▪ Flood plain mapping, ▪ Heat units, ▪ Water elevation ▪ Etc.
Instantaneous water levels (on Lake St. Clair)	Canadian water level monitoring stations (Environment and Climate Change Canada (ECCC)) • Tecumseh, (station decommissioned in 1993) • Belle River, Station #11965 (operational) US water level monitoring stations (National Oceanic and Atmospheric Administration (NOAA)) • Windmill Point, Station ID 9044049 • St. Clair Shores, Station ID 9034052
High winds	Environment Canada Climate data
High intensity / long duration rainfall	Environment Canada weather data

	Technical Report – A Comparison of Future IDF Curves for Southern Ontario, TRCA & ERCA, July 2015
Comments and Observations N/A	

2.8 *Identify Infrastructure Threshold Values*

Add rows as necessary.

a. For each climate parameter selected, identify a threshold value above which, or below which, the infrastructure performance will be affected.

   i. Threshold values may be based on:

   - Codes;
   - Standards;
   - Engineering Guidelines;
   - Operating or Maintenance Procedures;
   - Professional Judgement; and/or
   - Other, as appropriate.

   ii. As appropriate, a number of different thresholds may be identified for a specific climate parameter based on varying degrees of infrastructure response arising from parameter values changing over a broader range.

   - In such cases, each parameter-threshold pair would be treated as a separate event within the context of the assessment.

Threshold Value	b. Clearly document the source of the threshold value.	c. Provide justification for the threshold value selected.
Instantaneous Lake St. Clair water elevation = 176.0m	Current observed lake level elevation – data obtained from Windmill Point (monitoring on 6 minute intervals) and Belle River (hourly monitoring) water level monitoring stations.	West of Little River – Observed sandbagging required to minimize water flow onto Riverside Drive corridor causing backflow conditions and draining into sewer system. Observed overtopping of low level berm in area of Lauzon Road (berm required emergency topping up of elevation to maintain integrity). East of Little River – Observed sandbagging required to minimize water flow onto Riverside Drive corridor near Sandpoint Beach. Windsor-Tecumseh boundary – no observed affects. This threshold value does not apply to this segment.
Current predicted Lake St. Clair high-water elevation = 176.5m	1:100-Year Instantaneous Water Elevations for Lake St. Clair. (RWDI report dated April 2019 – see Appendix C)	Current high-water elevation determined using statistical analysis presented in RWDI report. Elevation is used as the minimum design criteria for reinstatement of the berm. (Note: this elevation does not include freeboard)
Future predicted high-water level elevation = 176.8m	1:100-Year Instantaneous Water Elevations) for Lake St. Clair), RWDI report dated 2019	Future high-water elevation (for 2050) determined using statistical analysis and climate change model projects presented in the RWDI report. Elevation is used as the future design criteria for berm height. (Note: this elevation does not include freeboard)

Wind-driven waves • Lake St. Clair – 1.5m • Detroit River – 0.75m	• City of Windsor Shoreline Management Plan, N.K. Becker & Associates., 1986 • Design wave analyses using U.S. Army Corps of Engineers methodology	A design wave for Lake St. Clair of 5ft and a design wave for the Detroit River is between 2-2.5ft. Specific critical wave heights cannot be quantified independent of other climate parameters.
Rainfall • No specific threshold	Professional Judgement	Refer to Sewer Master Plan for threshold values for rainfall and runoff (referencing updated IDF curves). Specific threshold values cannot be quantified independent of other climate parameters.
Comments and Observations Wind-driven waves and rainfall are secondary parameters that may affect the impact of the primary parameter (i.e., Lake St. Clair water levels) on the diking system.		

2.9 *Identify Potential Cumulative or Synergistic Effects*

Add rows as necessary.

a. Review the selected climate parameters and threshold values and evaluate the potential cumulative impact of combining or sequencing weather events and/or climate trends to assess the possibility of these combined events yielding a higher impact compound event.

b. Include relevant cumulative or synergistic events on the list of climate parameters carried forward for risk assessment.

   i. The practitioner must exercise professional judgment in establishing conceivable combined or synergistic events to avoid assessing multiple, improbable, combinations.

Cumulative and/or Synergistic Event	Threshold Value	Justification
High lake level elevations combined with wind-driven waves	N/A	Analysis of instantaneous high-water elevations already accounts for lake set-up. In areas where the dike is close to the water's edge, waves could affect the capacity of the dike. This effect, however, is not readily quantifiable.
High lake level elevations combined with heavy rainfall	N/A	High lake level elevations causing backflow conditions and additional volume flow into the sewers affect the capacity of the storm sewer system to accommodate run-off from rainfall events. This effect is a qualitative.

Comments and Observations

High water levels in the lake could potentially affect the runoff parameters for any gravity outfalls to Lake St. Clair. Secondary flooding could occur with the implementation of flow control devices designed to prevent backflow from the lake. (i.e. Catch basins on the south side of landform barrier being interrupted with a sluice gate in high lake water conditions would not be able to drain). The St. Paul Pumping Station is located north of the current (and proposed reinstated) berm. High water level elevations have the potential to compromise this pumping station.

2.10 State Climate Baseline

Add rows as necessary.

a. List historical extreme weather events:

   i. Identify the frequency of the events
   ii. Identify the duration of the events
   iii. Identify the date(s) of the events
   iv. Identify the magnitude/intensity of the events

b. If data is not available:

   i. Based on professional judgement, infill missing data using reasonable assumptions
   ii. Provide written justification/substantiation for the assumptions.

c. List the values that are chosen.

d. Provide references.

Historic Extreme Weather Event	Value	Reference
1973 flooding of East Riverside (shoreline erosion and inland flooding) – resulting from high lake elevations and wind-driven waves	N/A	Shoreline Management Plan, (N.K. Becker & Associates, 1986)
1986 flooding of East Riverside (shoreline erosion and inland flooding) - resulting from high lake elevations and wind-driven waves	N/A	Shoreline Management Plan, (N.K. Becker & Associates, 1986)
1998 flooding of East Riverside (shoreline erosion and flooding of Riverside Drive) - resulting from high lake elevations and wind-driven waves	N/A	Riverside Drive East Flood Relief Study, (BTS Consulting Engineers, 1998)

Comments and Observations

N/A

2.11 *State the Changing Climate Assumptions*

Add rows as necessary.

a. Assess the relevancy and applicability of observed global, regional or site-specific changing climate trends with respect to the infrastructure.

i. Document how these trends influence the infrastructure.

Trend	**Influence**
Increased variability in Great Lakes water levels due to changes in precipitation patterns and seasonal evaporation.	Projected increases in instantaneous peak water levels on Lake St. Clair affect the design elevation / height of the dikes in East Riverside. With higher instantaneous lake levels, higher berms and flood walls are required to protect inland areas from potential flooding.

Comments and Observations

N/A

b. Where appropriate, identify incremental changes to the **Climate Baseline** conditions based on the trends identified in (a) above.

Incremental Change	**Influence**
Increasing 1:100-year instantaneous water level of Lake St. Clair • Current – 176.5m • 2030 – 176.6m • 2050 – 176.8m	The design elevation for the top of the dike system (berms, walls, etc.) will need to be increased to match or exceed the 1:100-year instantaneous water level on Lake St. Clair, in order to maintain surface flood protection for the low-lying areas inland.

Comments and Observations

Projected lake level elevations established from the RWDI study, April 2019 (see Appendix C).

c. Where appropriate, identify incremental changes to the **Climate Baseline** conditions based on sensitivity analysis.
    i. Increase or decrease Climate Baseline conditions by percentages selected based on the practitioner's professional judgement.
    ii. Provide written justification/substantiation for the assumptions and incremental values used in the sensitivity analysis.

Incremental Change	**Justification**
N/A	

Comments and Observations

No sensitivity analysis was deemed necessary

d. Where appropriate, use surrogate information from other geographic areas to respond to identified data gaps and uncertainties.
    i. Document the source of the infill data.
    ii. Provide written justification/substantiation for using the infill data.

Incremental Change	**Justification**
N/A	

Comments and Observations

Infill data was not deemed to be necessary for the purposes of this study.

e. Where appropriate, arbitrarily define changing climate assumptions or predictions.
    i. Provide written justification/substantiation for using the assumptions.

Incremental Change	**Justification**
N/A	

Comments and Observations

N/A

f. Where appropriate, employ regional climate change models to project changing climate effects in the region of the infrastructure.

ii. Review the basis and basic assumptions of the model(s).
iii. Provide written justification/substantiation for using the model in the evaluation.

Incremental Change	**Justification**
The RWDI report of 2019 provides incremental changes to projected instantaneous high-water levels on Lake St. Clair.	RWDI used two different climate models with 2 method variations for each model. • CGCM3, AE and CGCM3, Delta (Coupled Global Climate Model) • GFLD, AE and GFLD, Delta (Geophysical Fluid Dynamics Laboratory Develop) Analysis of historical data using CGCM3, AE provided the highest instantaneous water levels for Lake St. Clair. This model also projected the current water levels that have been observed in Lake St. Clair. It is of note that the projections of the additional three models used do not indicate as much of an increase in lake levels, but also predicted current lake levels that are lower than is currently being observed.

Comments and Observations

The 3 projections indicating lower water levels on Lake St. Clair could still be valid. The 1:100-year instantaneous peak water level analyses should be revisited in the future to validate which climate change model(s) are most appropriate.

Establish Changing climate Probability Scores

a. From **Figure 3**, choose Method A or Method B to define probability scores. i. Record in project documentation the Method that was used. ii. Use the same method for all probabilities used in the evaluation.	**Method** **Enter Either A or B** A
b. Choose the changing climate probability scoring approach. Either: i. Assign scores for the probability of climate parameters changing over the time horizon of the assessment such that the infrastructure threshold is triggered. ▪ If this approach is selected, go to **Task 2.12.c**	**Method** **Enter Either Yes or No** No
OR: i. Assign scores for the probability of climate parameters triggering infrastructure thresholds in the baseline climate and assign scores for the probability that climate parameters will trigger the infrastructure thresholds in the future climate. Changing climate impacts are assessed from the difference between the two scores. ▪ If this approach is selected, go to **Task 2.12.d**	**Method** **Enter Either Yes or No** Yes

c. Scoring Changing climate Probability

Add rows as necessary.

		Will the Interaction Change Over Time Horizon of Assessment?	More-Same-Less?	Projected Change in Magnitude?	Projected Change in Frequency	Robustness of Forecast?	Professional Judgment	Probability Score
		Y/N	+ 0 -	H M L	H M L	H M L	Comments	0-7
		☟	☟	☟	☟	☟	P =ƒ (A,B,C,D, & E)	
Climate Parameter	**Infrastructure Indicator**	A	B	C	D	E	☞	P
							Not Selected	

ALTERNATIVELY

d. Scoring Probability for Both Baseline and Future Climates

For the Baseline Climate

Add rows as necessary.

		Thresholds Triggered?	Magnitude of Event	Frequency of Event	Robustness of Forecast	Professional Judgment	Probability Score
		Y N	H M L	H M L	H M L	Comments	0-7
			☟	☟	☟	P =ƒ (A,B,C,D, & E)	
Climate Parameter	Infrastructure Indicator	B	C	D	E	☞	P

See completed table in Appendix D

For the Future Climate

Add rows as necessary.

		Thresholds Triggered?	Magnitude of Event	Frequency of Event	Robustness of Forecast	Professional Judgment	Probability Score
		Y N	H M L	H M L	H M L	Comments	0-7
		☟	☟	☟	☟	P = ƒ (A,B,C,D, & E)	
Climate Parameter	Infrastructure Indicator	B	C	D	E	☞	P

See completed table in Appendix D

e. As appropriate, the practitioner may select an alternative probability scoring methodology.

   i. If the practitioner selects an alternative scoring methodology they are directed to substantiate and document this choice in the project report.
   ii. Whatever method is used, it must be used consistently throughout the probability scoring process.

Methodology	**Substantiation**

Figure 3: Probability Score Definitions

The practitioner is directed to express a professional opinion regarding the probability that a climate event that triggers an infrastructure threshold will occur. This should not be confused with the consequences of that climate event. The practitioner is asked to score the probability of the event in this step and assess the severity and/or consequences in the next step of the protocol.

Score	Probability	
	Method A	Method B
0	Negligible Not Applicable	< 0.1 % < 1 in 1,000
1	Highly Unlikely Improbable	1 % 1 in 100
2	Remotely Possible	5 % 1 in 20
3	Possible Occasional	10 % 1 in 10
4	Somewhat Likely Normal	20 % 1 in 5
5	Likely Frequent	40 % 1 in 2.5
6	Probable Very Frequent	70 % 1 in 1.4
7	Highly Probable Approaching Certainty	> 99 % > 1 in 1.01

2.12 Assess Data Sufficiency

Review the data set developed in **Sections 2.1 through 2.12**.

a. For data selected for the evaluation, assess and comment on:

▪ Data gaps;	No data gaps have been identified with lake elevation data.
▪ Data quality;	Historic data for lake level elevations was available from several regional sources ranging from collection on 6 min. intervals to hourly instantaneous high-water levels. Data quality is considered good.
▪ Data accuracy;	All data sources used the same baseline datum (IGLD 1985) – see RWDI report.
▪ The applicability of trends;	Climate change projection models used in RWDI analysis incorporated applicable trends.
▪ Reliability of selected climate model(s);	Projected lake level elevations were made using historical data and statistical models that take climate change into consideration. Analysis (by RWDI) was performed with several models – only one model indicated significantly increasing lake elevations.
▪ Reliability of changing climate assumptions or scenarios; and	Time frame for lake level projections has been limited to the year 2050 since climate projections become less reliable with greater time frames.
▪ Other factors.	

<u>Comments and Observations</u>

N/A

b. Clarify and summarize the priority of the documentation referenced in the evaluation.

i. Present these in a tabulated prioritized form

Document	Priority
Shoreline Management Plan, (N.K. Becker & Associates, 1986)	2
City of Windsor: East Riverside Flood Risk Assessment – 1:100-Year Instantaneous Water Elevation (RWDI, 2019)	1
Riverside Drive East Flood Relief Study, (BTS Consulting Engineers, 1998)	5
City of Windsor Sewer Atlas	4
LiDAR elevation data	3
Comments and Observations	

c. Document where there is insufficient information currently available to proceed with a particular portion of the assessment.

Insufficient Information	i. Where there is insufficient information currently available, identify a process to develop or infill that data.	ii. Where data cannot be developed, identify the data gap as a finding in Step 5 of the Protocol – Recommendations.

Date:	June 2019
Prepared by:	Jennifer Nicholls & David Killen, Landmark Engineers Inc.

PIEVC Engineering Protocol

For

Infrastructure Vulnerability Assessment and Adaptation to a Changing Climate

Worksheet Step 3

Risk Assessment

Revision 1.1

For further information about this ***Engineering Protocol*** or the ***National Engineering Vulnerability Assessment*** **Project** please contact Engineers Canada.

David Lapp, P.Eng.
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Engineers Canada

300 – 55 Metcalfe Street
Ottawa, Ontario, K1P 6L5 Canada

Instructions

This worksheet is designed to allow practitioners to document that they have actively considered and evaluated each step of the Protocol. The worksheet also provides a document were practitioner considerations regarding each task of the Protocol are recorded.

Complete Every Field

To ensure complete coverage of the Protocol steps, when completed, the practitioner should have entered a response in every field of this worksheet.

Document Tasks That Do Not Apply

Where a particular task is not relevant to the current assessment:

- Enter **N/A** in the relevant field of this worksheet and
- Provide rational for the decision in the comments field of the task.

Document Tasks That Are Omitted

Where a practitioner has chosen to omit a particular step of the Protocol:

- Enter **OMITTED** in the relevant field; and
- Provide rational for the decision in the comments field of the task.

Companion Excel Workbook Supports This Step of the Protocol

Practitioners may use the accompanying ***Excel Worksheet 3*** to formally document the results of their analysis.

Practitioners Executing Assessment of Baseline and Future Climates Must Repeat Steps

The accompanying Excel Worksheet 3 provides templates for three cases:

- Changing Climate – Changing Climate risk determined in one step;

- Baseline Climate – The climate risk associated with the current climate; and
- Future Climate – The climate risk associated with the projected future climate.

Practitioners should select the relevant spreadsheet(s) from those provide and delete those that they do not plan to use.

Protocol for Changing Climate Infrastructure Vulnerability Assessment

Practitioners are strongly cautioned to avoid the following common pitfalls in executing a vulnerability assessment based on the Protocol.

i. ***Skipping Protocol tasks***.

Although it is acceptable to select to not execute a particular task, the practitioner should nonetheless evaluate the question posed by that task and document the basis for the decision.

ii. Using previous case study reports as a template for the analysis.

Although previous studies provide an excellent reference, the application of the Protocol is highly specific to infrastructure. Applying previous case studies as a template can often lead the practitioner to miss key factors that contribute to the overall risk profile of the infrastructure.

iii. Using the worksheets without reference to the Protocol.

Although the worksheets parallel the Protocol, they do not provide supplementary context that may be necessary to correctly address the specified Protocol task.

3 Step 3 – Risk Assessment

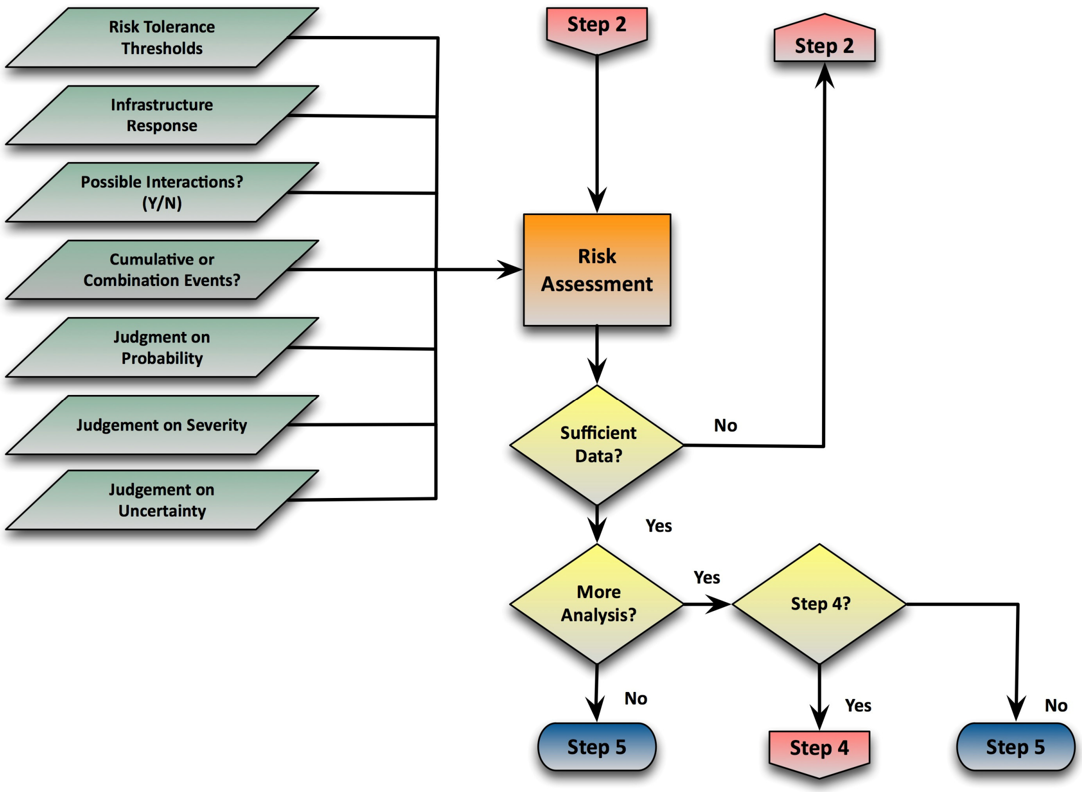
In this section the practitioner will identify the infrastructure's response to weather events and climate trends. The Protocol directs the practitioner to develop:

- A list of relevant weather events and climate trends; and
- A list of relevant infrastructure components.

Using a spreadsheet, the practitioner is directed to examine interactions between infrastructure and climatic events that, potentially, could lead to vulnerability. Pairings between infrastructure components and climate events are called interactions.

The process flowchart for Step 3 of the Protocol is presented in **Figure 4**.

Figure 4: Step 3 – Risk Assessment Process Flowchart



3.1 *Prepare Step 3 Worksheet*

	Enter ***Yes*** or ***No***	
a. Use this ***Worksheet***; or		No
b. Prepare practitioner specific documentation. i. Practitioner specific documentation ***MUST*** detail each task outlined in this step of the Protocol.	Yes	
<u>Comments and Observations</u>		

3.2 *Establish the Infrastructure Owner's Risk Tolerance Thresholds*

	Check Complete
a. Review the reference set of risk tolerance threshold values with the infrastructure owner. i. The reference threshold values are presented in **Figure 5**.	✓
b. Ensure that the owner understands the implications of these thresholds.	✓
c. Ensure that the owner agrees to the use of these thresholds in the risk assessment.	✓
Comments and Observations In the risk assessment workshop, a consensus was reached with City of Windsor staff to divide the Medium risk tolerance category equally into two sub-categories. These two sub-categories were named "Medium-High", and "Medium-Low"	

d. If, in discussion with the owner different thresholds are established, document these thresholds and use the infrastructure owner's threshold values in subsequent steps of the Protocol.

	Owner Established Risk Ranges (If Different than Figure 23)
High	> 36
Medium-High	24 - 36
Medium-Low	12 - 23
Low	< 12
Comments and Observations	N/A

Figure 5: Reference Risk Tolerance Thresholds

Risk Range	Threshold	Response
< 12	Low Risk	▪ No action necessary
12 – 36	Medium Risk	▪ Action may be required ▪ Engineering analysis may be required
> 36	High Risk	▪ Action required

e. Define "Special Case" risk interactions.

i. Notionally, these are interactions with risk scores of "7".

- Very High Severity – Very Low Probability
- Very Low Severity – Very High Probability

ii. The infrastructure, the owner may identify broader categories of Special Case risks.

- In this category, the owner may wish to consider events with severity and/or probability scores of "6" and "7", yielding risk scores in the range up to "14".
- In such a case the practitioner MUST clarify with the owner that this decision could result in an increase in the overall scope of the assessment with associated costs and schedule implications.

iii. The infrastructure owner may determine that only one category of Special Case is relevant in the current study. This would be one of:

- Very High Severity – Very Low Probability
- Very Low Severity – Very High Probability

iv. The infrastructure owner may determine that Special Cases risks are not relevant in the current assessment.

Special Case Risk Value (or Range)	**Rationale**
<u>Comments and Observations</u> No special case risk values were identified	

	Check Complete
f. Obtain consensus with the infrastructure owner regarding the threshold values and special case definitions to be used in the risk assessment.	✓
<u>Comments and Observations</u>	

3.3 *Prepare for Risk Assessment Workshop*

	Check Complete
a. Ensure availability and skill sets of proposed workshop attendees.	✓
b. Ensure that all pre-defined information is entered into Worksheet 3, or the practitioner's alternative working papers.	✓
<u>Comments and Observations</u> Workshop attendees included representation from the City's Engineering Department, Operations Department, and Pollution Control Department. Invitations were also extended to the Essex Region Conservation Authority, but scheduling conflicts prevented their attendance.	

c. At this point in the process the practitioner may elect to:	**Check Selected Methodology**
i. Perform a **consultant risk assessment** including all of the tasks identified below; or	
ii. Perform a **facilitated risk assessment** where participants at the workshop complete perform the risk assessment.	✓

<u>Comments and Observations</u>

A preliminary consultant risk assessment was performed prior to the facilitated risk assessment. This allowed the consultants to trouble shoot the process and develop support materials to conduct the facilitated risk assessment.

The risk scoring obtained in the consultant risk assessment was later included with the workshop results to include the consultants as participants in the facilitated risk assessment.

	Check Complete
d. Confirm this decision with the infrastructure owner. i. In a **consultant risk assessment**, the workshop would be deferred to later in the process and would be used to review and confirm the consultant's findings. ii. In a **facilitated risk assessment**, the tasks outlined below are mandatory elements of the workshop. iii. The practitioner must work with the infrastructure owner to ensure that appropriate time is allocated to the workshop depending upon the choice of risk assessment execution strategy.	✓

Comments and Observations N/A	

3.4 *Conduct a Risk Assessment Workshop*

In a consultant risk assessment process skip this step and proceed to Step 3.5.

	Check Complete
a. Conduct a workshop with the infrastructure operations, management and engineering staff and other relevant individuals.	✓
b. At the workshop confirm preliminary information identified by the practitioner in Step 2 and conduct risk assessment with workshop participants.	✓
c. Finalize the risk assessment worksheet, or practitioner's alternative working papers, based on the input from workshop participants.	✓
Comments and Observations The completed working papers prepared by Landmark for the workshop are included in Appendix D of the main report.	

3.5 *Confirm Climate Parameters*

	Check Complete
a. Review climate parameters selected for the risk assessment. i. Confirm that parameter list reflects the combined experience and professional judgment of the team.	✓

b. Eliminate from further assessment, items deemed to be irrelevant or outside of the scope of the risk assessment.	✓
c. Add into the risk assessment additional parameters deemed relevant by the team.	✓
Comments and Observations N/A	

3.6 *Confirm Infrastructure Threshold Values*

	Check Complete
a. Review infrastructure threshold values selected for the risk assessment. i. Confirm that the threshold values reflect the combined experience and professional judgment of the team.	✓
b. As appropriate, adjust threshold values based on workshop feedback.	N/A
Comments and Observations Threshold values were accepted by the workshop participants. No changes were made.	

3.7 *Confirm Probability Scores*

	Check Complete
a. Review climate parameter probability scores selected for the risk assessment. i. Confirm that the probability scores reflect the combined experience and professional judgment of the team.	✓

b. As appropriate, adjust climate parameter probability scores based on workshop feedback.	✓
Comments and Observations Each workshop participant individually determined probability scoring with the group discussing the results. Since scoring was from all participants was similar and reflected the consensus of the group, an average probability score was used for each parameter.	

3.8 *Confirm Potential Cumulative or Synergistic Events*

	Check Complete
a. Review cumulative or synergistic events selected for the risk assessment. i. Confirm that the cumulative or synergistic events reflect the combined experience and professional judgment of the team.	✓
b. As appropriate, adjust cumulative or synergistic events based on workshop feedback.	✓
Comments and Observations Cumulative or synergistic events were not adjusted during the workshop. The group discussed and decided to only assess the most relevant climate parameters and synergistic effects.	

3.9 *Identify Relevant Infrastructure Responses*

	Check Complete
a. For each infrastructure component selected, identify in Excel Worksheet 3, or the practitioner's alternative working papers, relevant infrastructure responses to weather events or climate trends. i. Infrastructure responses are the generally anticipated effects arising from the climate and other change parameters interacting with the infrastructure components. Their selection is evaluation specific. ii. **Appendix B** provides some infrastructure responses to consider. iii. Apply only those responses that are within scope of the current vulnerability assessment iv. Eliminate from consideration, all responses that are not relevant or outside of the scope of the current vulnerability assessment. v. The infrastructure responses should reflect the team's understanding of how each infrastructure component reacts to climate-imposed stress. vi. Infrastructure responses may include, but are not limited to: ▪ Structural responses related to integrity, serviceability and functionality; ▪ Management responses related to operations, maintenance, emergency response, policies and procedures; and/or ▪ Economic and public health and safety impacts.	✓
b. Use the identified infrastructure responses as a basis for the team's **Yes/No Analysis** and severity scoring exercise.	✓
Comments and Observations An Excel worksheet was generated based on the PIEVC worksheet provided.	

An assessment of the current conditions was added to the worksheet as it was identified early in the process that there existed a risk to the infrastructure assessed with the current day conditions.	

3.10 *Complete Yes/No Analysis*

	Check Complete
a. Assess whether each identified climate-infrastructure interaction could conceivable occur.	✓
b. In Worksheet 3, or the practitioner's alternative working papers, mark each conceivable interaction with "Yes".	✓
c. In Worksheet 3, or the practitioner's alternative working papers, mark each inconceivable interaction with "No".	✓
d. Where the team cannot decide if the interaction is possible, in Worksheet 3, or the practitioner's alternative working papers, mark each questionable interaction with "Yes".	✓
e. Eliminate from further assessment all interactions tagged "No".	✓
f. Carry forward for further assessment all interactions tagged "Yes".	✓
Comments and Observations N/A	

3.11 *Establish Interaction Severity*

a. Review **Figure 6** and select either Method D or Method E to express severity score definitions on a scale of 0 to 7.	**Method** **Enter Either D or E**

i. 0 means no negative consequences in the event that the interaction occurs; and ii. 7 means a significant failure will result if the interaction occurs.	D

	If Alternative Scoring Method Selected Enter Yes
b. As appropriate, the practitioner may select an alternative severity scoring method.	

c. Document the selected method.

i. The selected method must be used consistently in the risk assessment process.

Methodology	Rational

	Check Complete
d. Using the selected methodology, establish a severity score for each interaction tagged "Yes".	✓
Comments and Observations N/A	

Figure 6: Severity Score Definitions

The practitioner is directed to express a professional opinion regarding the severity of an event. This should not be confused with the probability of that event. The practitioner is asked to assess the probability of the event in the previous step and assess the severity and/or consequences in this step of the protocol.

Score	Severity of Consequences and Effects	
	Method D	Method E
0	No Effect	Negligible Not Applicable
1	Measurable	Very Low Some Measurable Change
2	Minor	Low Slight Loss of Serviceability
3	Moderate	Moderate Loss of Serviceability
4	Major	Major Loss of Serviceability Some Loss of Capacity
5	Serious	Loss of Capacity Some Loss of Function
6	Hazardous	Major Loss of Function
7	Catastrophic	Extreme Loss of Asset

3.12 *Calculate Risk Scores*

	Check Complete
a. For each interaction tagged "Yes", calculate the risk represented by the interaction using the following equation: R = P × S Where: R = Risk P = Probability of the climate event or change in the climate event S = Severity of the interaction	✓
b. Record the calculated risk scores in Worksheet 3, or the practitioner's alternative working papers.	✓
<u>Comments and Observations</u> N/A	

3.13 *Conduct a Risk Assessment Workshop (Consultant Option)*

In a facilitated process skip this step and proceed to Step 3.14.

	Check Complete
a. Conduct a workshop with the infrastructure operations, management and engineering staff and other relevant individuals.	✓
b. Review and confirm results of the practitioner risk assessment based on completion of **Steps 3.5 through 3.12**.	✓
c. Finalize the risk assessment worksheet, or practitioner's	

alternative working papers, based on the input from workshop participants.	
Comments and Observations	

3.14 *Assess Data Sufficiency*

Add rows as necessary.

a. Document where there is insufficient information currently available to proceed with an element of the assessment.		
Insufficient Information	i. Where there is insufficient information currently available, identify a process to develop or infill that data.	ii. Where data cannot be developed, identify the data gap as a finding in Step 5 of the Protocol – Recommendations.
N/A		

3.15 *Confirm the Infrastructure Owner's Risk Tolerance Thresholds*

	Check Complete
a. At completion of the risk assessment, review the results with the infrastructure owner and confirm that the preliminary set of risk tolerance thresholds established in **Step 3.2** are still relevant within the context of the preliminary risk profile established in **Step 3.12**. i. As appropriate, the practitioner may adjust risk tolerance thresholds based on these discussions.	✓

Comments and Observations Risk tolerance thresholds were not adjusted	

3.16 *Document Risk Profile*

	Check Complete
a. Group interactions into four categories, based on the infrastructure owner's approved risk tolerance thresholds. i. High Risk ii. Medium Risk iii. Low Risk iv. Special Cases	✓
b. Identify patterns of weather events, climate trends or other factors that contribute to higher risk scores.	✓
c. Document the root causes and other factors that contribute to higher risk, as determined above.	✓
d. Review the risk profile with the infrastructure owner to ensure agreement with, and understanding of, factors leading to higher risk scores.	✓
Comments and Observations Four risk tolerance categories were used.	

3.17 *Review Special Cases*

	Check Complete
a. Prepare a listing of Special Case interactions, as defined in **Task 11.3.2.g**. i. If the infrastructure owner has determined that Special Cases are not relevant in the current assessment, skip this step.	
b. Group Special Case risks into two categories: ii. Interactions with **Very High Severity - Very Low Probability**. iii. Interactions with **Very High Probability - Very Low Severity**.	
c. Review **Very High Severity – Very Low Probability** interactions with infrastructure owner and determine: i. Has the infrastructure owner previously identified this scenario? ii. Does the infrastructure owner have procedures, guidelines or protocols in place to address such a scenario? iii. If there are no procedures, guidelines or protocols in place, does the practitioner, in consultation with the infrastructure owner, deem that action is necessary to address this scenario? iv. If the practitioner deems that procedures, guidelines or protocols are necessary, identify this conclusion as a finding in Step 5. v. If the practitioner deems that the interaction warrants no further action at this time, identify this conclusion as a finding in Step 5.	
d. Review **Very High Probability – Very Low Severity** interactions with infrastructure owner and determine: i. Has the infrastructure owner previously identified this scenario? ii. Does the infrastructure owner have procedures, guidelines or protocols in place to address such a scenario? iii. If there are no procedures, guidelines or protocols in place, does the practitioner, in consultation with the infrastructure owner,	

deem that action is necessary to address this scenario? iv. If the practitioner deems that procedures, guidelines or protocols are necessary, identify this conclusion as a finding in Step 5. v. If the practitioner deems that the interaction warrants no further action at this time, identify this conclusion as a finding in Step 5.	
Comments and Observations	

3.18 *Identify Next Steps*

	Check Complete
a. Discard from further evaluation: i. Low risk interactions. ii. Medium risk interactions that do not contribute to an overall pattern of risk. iii. Medium risk interactions where the practitioner is confident with the reliability of the score as determined by the data sufficiency review. iv. Special Case risk interactions that have already been addressed through recommendations or deemed to require no further action at this time.	✓
b. Provide a written summary of interactions that are not considered for further evaluation and document their risk scores.	✓
c. For high-risk interactions, go immediately to Step 5 and assess appropriate recommendations to address the identified vulnerability.	✓

d. Identify interactions for Step 4 analysis, as appropriate. These would normally include: i. Medium risk items that contribute to a pattern of higher risk. ii. Medium risk items that could shift to higher risk based on minor increases in probability or severity. iii. High-risk items that contribute to a pattern of vulnerability including medium and high-risk interactions. iv. Special Case interactions requiring better definition that can be resolved within the budget and schedule of the current assessment. v. Other interactions deemed appropriate as approved by the infrastructure owner.	✓
e. Carry forward into Step 4, items identified above. f. Identify matters that require additional study or evaluation outside of the current vulnerability assessment. These would normally include: i. Interactions requiring additional data that cannot be acquired within the schedule of the current risk assessment. ii. Evaluating climatic events that specifically contribute to heightened infrastructure risk where the practitioner and/or infrastructure owner determine that a better understanding of the factors that contribute to the event can help resolve identified risks. iii. Areas where identified patterns of risk could be resolved through the development or amendment of codes, standards, guidelines, procedures, etc. iv. Special Case interactions requiring better definition that cannot be resolved within the budget and/or schedule of the current assessment. v. Other issues deemed appropriate by the practitioner.	✓
g. Document the additional work identified above as recommendations in Step 5.	✓

Comments and Observations	

Date:	August 2019
Prepared by:	Jennifer Nicholls & David Killen, Landmark Engineers Inc.

PIEVC Engineering Protocol

For

Infrastructure Vulnerability Assessment and Adaptation to a Changing Climate

Worksheet Step 4

Engineering Analysis

Revision 1.1

For further information about this ***Engineering Protocol*** or the ***National Engineering Vulnerability Assessment*** **Project** please contact Engineers Canada.

David Lapp, P.Eng.
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Instructions

This worksheet is designed to allow practitioners to document that they have actively considered and evaluated each step of the Protocol. The worksheet also provides a document were practitioner considerations regarding each task of the Protocol are recorded.

Complete Every Field

To ensure complete coverage of the Protocol steps, when completed, the practitioner should have entered a response in every field of this worksheet.

Document Tasks That Do Not Apply

Where a particular task is not relevant to the current assessment:

- Enter **N/A** in the relevant field of this worksheet and
- Provide rational for the decision in the comments field of the task.

Document Tasks That Are Omitted

Where a practitioner has chosen to omit a particular step of the Protocol:

- Enter **OMITTED** in the relevant field; and
- Provide rational for the decision in the comments field of the task.

Companion Excel Workbook Supports This Step of the Protocol

Practitioners may use the accompanying ***Excel Worksheet 4*** to formally document the results of their analysis.

Protocol for Changing Climate Infrastructure Vulnerability Assessment

Practitioners are strongly cautioned to avoid the following common pitfalls in executing a vulnerability assessment based on the Protocol.

i. ***Skipping Protocol tasks***.

Although it is acceptable to select to not execute a particular task, the practitioner should nonetheless evaluate the question posed by that task and document the basis for the decision.

ii. ***Using previous case study reports as a template for the analysis.***

Although previous studies provide an excellent reference, the application of the Protocol is highly specific to infrastructure. Applying previous case studies as a template can often lead the practitioner to miss key factors that contribute to the overall risk profile of the infrastructure.

iii. ***Using the worksheets without reference to the Protocol.***

Although the worksheets parallel the Protocol, they do not provide supplementary context that may be necessary to correctly address the specified Protocol task.

4 Step 4 – Engineering Analysis

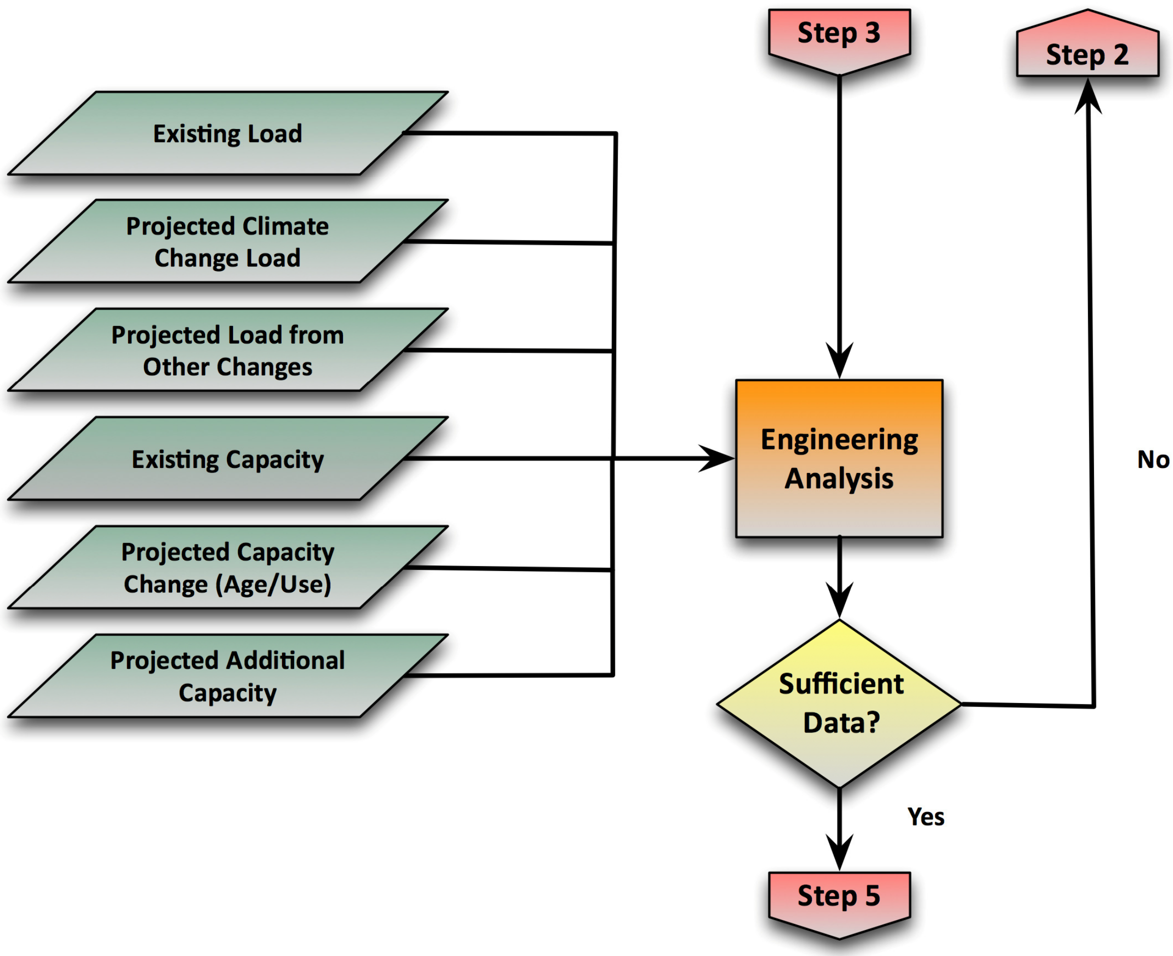
In this step the practitioner will assess the impact of projected changing climate loads placed on the infrastructure and its capacity. Vulnerability exists when infrastructure has insufficient capacity to withstand the projected or anticipated loads that may be placed on it. Resiliency exists when the infrastructure has sufficient capacity to withstand increasing loads resulting from changing climate.

Engineering Analysis requires the assessment of the various factors that affect load and capacity of the infrastructure. Based on this assessment, indicators or factors are determined in order to relatively rank the potential vulnerability of the infrastructure components to various climate effects.

Much of the data required for Engineering Analysis may not exist or may be very difficult to acquire. Engineering Analysis requires the application of multi-disciplinary professional judgement. Thus, even though numerical analysis is applied, the practitioner is cautioned to avoid the perception that the analysis is definitively quantitative or based on measured parameters. The results of the analysis yield a set of parameters that can be ranked relative to each other, based on the professional judgement of the practitioner. This can be used to rank the relative vulnerability or resiliency of the infrastructure.

The process flowchart for Step 4 of the Protocol is presented in **Figure 7**.

Figure 7: Step 4– Engineering Analysis Process Flowchart



4.1 *Prepare Step 4 Worksheet*

	Enter ***Yes*** or ***No***	
a. Use this ***Worksheet***; or		No
b. Prepare practitioner specific documentation. i. Practitioner specific documentation ***MUST*** detail each task outlined in this step of the Protocol.	N/A	

<u>Comments and Observations</u>

Load and capacity analyses are not applicable to the subject infrastructure. Practitioner specific engineering analyses will focus on conceptual design of dike improvements and sewer backflow prevention measures to mitigate identified risks.

In the following steps, the Practitioner may either record results in Excel Worksheet 4 or in their own working papers. In any event, the information stipulated by this Protocol should be duly recorded.

4.2 *Calculate the Existing Load (L_E)*

Calculate the existing load on the infrastructure components that the practitioner selected for Engineering Analysis.

	Check Complete
a. Determine the existing load on the infrastructure based on: ▪ Definitions; ▪ Direct measurements;	OMITTED

▪ Engineering calculations; or ▪ Assumptions based on professional judgement.	
b. Substantiate the rationale for the methodology used.	
<u>Comments and Observations</u>	

4.3 *Calculate Changing Climate Load (L_C)*

Calculate the projected changing climate load placed on the infrastructure components that the practitioner selected for engineering analysis.

	Check Complete
a. Determine the projected Changing Climate load on the infrastructure based on: ▪ Definitions; ▪ Direct measurements; ▪ Engineering calculations; or ▪ Assumptions based on professional judgement.	OMITTED
b. Substantiate the rationale for the methodology used.	
<u>Comments and Observations</u>	

4.4 *Calculate Other Change Loads (L_O)*

Calculate the projected Other Change load placed on the infrastructure components that the practitioner selected for engineering analysis.

	Check Complete
a. Determine the other projected loads on the infrastructure based on: ▪ Definitions; ▪ Direct measurements; ▪ Engineering calculations; or ▪ Assumptions based on professional judgement.	OMITTED
b. Substantiate the rationale for the methodology used.	
Comments and Observations	

4.5 *Calculate Total Load (L_T)*

	Check Complete
Calculate the total projected load on the infrastructure components that the practitioner selected for engineering analysis, using the equation: $\mathbf{L_T = L_E + L_C + L_O}$ Where: L_T = Total projected load on the infrastructure L_E = Existing load on the infrastructure L_C = Projected load on the infrastructure resulting from changing climate L_O = Projected load on the infrastructure resulting from other changes	OMITTED

Comments and Observations	

4.6 Calculate the Existing Capacity (C_E)

Calculate the existing capacity of the infrastructure components that the practitioner selected for engineering analysis.

	Check Complete
a. Determine the existing capacity of the infrastructure based on: ▪ Definitions; ▪ Direct measurements; ▪ Engineering calculations; or ▪ Assumptions based on professional judgement.	OMITTED
b. Substantiate the rationale for the methodology used.	
Comments and Observations	

4.7 Calculate the Projected Change in Existing Capacity ($C_{\Delta E}$)

Calculate the projected change (loss) in capacity arising from aging and normal wear and tear of the infrastructure components that the practitioner selected for engineering analysis.

	Check Complete
a. Determine the projected change, if any, to the capacity of the infrastructure over the time horizon of the evaluation; based on:	OMITTED

▪ Definitions; ▪ Direct measurements; ▪ Engineering calculations; or ▪ Assumptions based on professional judgement.	
b. Substantiate the rationale for the methodology used.	
Comments and Observations	

4.8 *Calculate Additional Capacity (C_A)*

Calculate other projected additional capacity of the infrastructure components that the practitioner selected for engineering analysis.

	Check Complete
a. Determine the projected additional capacity of the infrastructure over the time horizon of the evaluation; based on: ▪ Definitions; ▪ Direct measurements; ▪ Engineering calculations; or ▪ Assumptions based on professional judgement.	OMITTED
b. Substantiate the rationale for the methodology used.	
Comments and Observations	

4.9 *Calculate the Projected Total Capacity (C_T)*

	Check Complete
Calculate projected total capacity of the infrastructure components that the practitioner selected for engineering analysis, using the equation: $\mathbf{C_T = C_E - C_{\Delta E} + C_A}$ Where: C_T = Total projected capacity of the infrastructure C_E = Existing capacity of the infrastructure $C_{\Delta E}$ = Projected change in capacity of the infrastructure resulting from aging and normal wear and tear C_A = Projected additional capacity of the infrastructure	OMITTED
<u>Comments and Observations</u>	

4.10 *Calculate Vulnerability Ratio*

	Check Complete
Evaluate the vulnerability of the infrastructure components that the practitioner selected for engineering analysis, using the ratio: $V_R = \frac{L_T}{C_T}$ Where: V_R = Vulnerability Ratio L_T = Projected total load on the infrastructure C_T = Projected total capacity of the infrastructure	OMITTED

When $V_R > 1$, the infrastructure component is vulnerable **When $V_R < 1$, the infrastructure component has adaptive capacity**	
<u>Comments and Observations</u>	

4.11 *Calculate Capacity Deficit*

	Check Complete
Where vulnerability has been identified for the infrastructure components that the practitioner selected for engineering analysis, calculate the projected capacity deficit using the following equation: $\mathbf{C_D = L_T - C_T}$ $\mathbf{= L_T - (C_E + C_{\Delta E} + C_A)}$ Where: C_D = Projected capacity deficit of the infrastructure component L_T = Projected total load on the infrastructure component C_E = Existing capacity of the infrastructure component $C_{\Delta E}$ = Projected change in capacity of the infrastructure component resulting from aging and normal wear and tear C_A = Projected additional capacity of the infrastructure component	OMITTED
<u>Comments and Observations</u>	

engineerscanada
ingénieurscanada

4.12 *Assess Data Sufficiency*

Add rows as necessary.

a. Document where there is insufficient information currently available to proceed with an element of the assessment.		
Insufficient Information	i. Where there is insufficient information currently available, identify a process to develop or infill that data.	ii. Where data cannot be developed, identify the data gap as a finding in Step 5 of the Protocol – Recommendations.
N/A		

4.13 *Evaluate Need for Additional Work*

Add rows as necessary.

a. Identify matters that require additional study or evaluation outside of the current vulnerability assessment. These would normally include: i. Interactions requiring additional data that cannot be acquired within the schedule of the current risk assessment. ii. Evaluating climatic events that specifically contribute to heightened infrastructure risk where the practitioner and/or infrastructure owner determine that a better understanding of the factors that contribute to the event can help resolve identified risks. iii. Areas where identified patterns of risk could be resolved through the development or amendment of codes, standards, guidelines, procedures, etc. iv. Other issues deemed appropriate by the practitioner.

City of Windsor Sewer Master Plan – A hydraulic modeling study of the existing sewer systems and the development of recommended alternatives for improvements and capacity upgrades are being developed by Dillon Consulting. The dike and sewer improvements recommended through this risk assessment report should be reviewed and addressed as part of the final Sewer Master Plan.
Riverside Vista Improvements Ph 2A – Design for the reconstruction of Riverside Drive from Ford Blvd. to St. Rose Beach is currently being developed by Dillon Consulting. The dike improvements recommended through this risk assessment report should be reviewed and incorporated into the final design for the Riverside Vista project.
A separate study has been initiated by the City of Windsor to address the Little River corridor and the dike system separating this from the area of study for this flood risk assessment.
Comments and Observations

	Check Complete
b. Document the additional work identified above as recommendations in Step 5.	✓
Comments and Observations Continue analysis of existing storm sewer and pumping stations through the City's (ongoing) Sewer Master Plan study. Incorporate recommendations for dike improvements and backflow protection measures into environmental assessment for Sewer Master Plan and the Riverside Vista Improvements to allow for property acquisition. Confirm required top of berm elevation for areas west of St. Rose Beach in conjunction with Riverside Vista Ph2 (ongoing).	

4.14 *Identify Conclusions and Recommendations*

	Check Complete
a. Where the practitioner deems that they have sufficient, reliable, data to draw conclusions and make recommendations, proceed to Step 5.	✓
<u>Comments and Observations</u> N/A	

Date:	August 2019
Prepared by:	Jennifer Nicholls & David Killen, Landmark Engineers Inc.

PIEVC Engineering Protocol

For

Infrastructure Vulnerability Assessment and Adaptation to a Changing Climate

Worksheet Step 5

Recommendations and Conclusions

Revision 1.1

For further information about this ***Engineering Protocol*** or the ***National Engineering Vulnerability Assessment*** **Project** please contact Engineers Canada.

David Lapp, P.Eng.
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To ensure complete coverage of the Protocol steps, when completed, the practitioner should have entered a response in every field of this worksheet.

Document Tasks That Do Not Apply

Where a particular task is not relevant to the current assessment:

- Enter **N/A** in the relevant field of this worksheet and
- Provide rational for the decision in the comments field of the task.

Document Tasks That Are Omitted

Where a practitioner has chosen to omit a particular step of the Protocol:

- Enter **OMITTED** in the relevant field; and
- Provide rational for the decision in the comments field of the task.

Protocol for Changing Climate Infrastructure Vulnerability Assessment

Practitioners are strongly cautioned to avoid the following common pitfalls in executing a vulnerability assessment based on the Protocol.

i. ***Skipping Protocol tasks***.

Although it is acceptable to select to not execute a particular task, the practitioner should nonetheless evaluate the question posed by that task and document the basis for the decision.

ii. ***Using previous case study reports as a template for the analysis.***

Although previous studies provide an excellent reference, the application of the Protocol is highly specific to infrastructure. Applying previous case studies as a template can often lead the practitioner to miss key factors that contribute to the overall risk profile of the infrastructure.

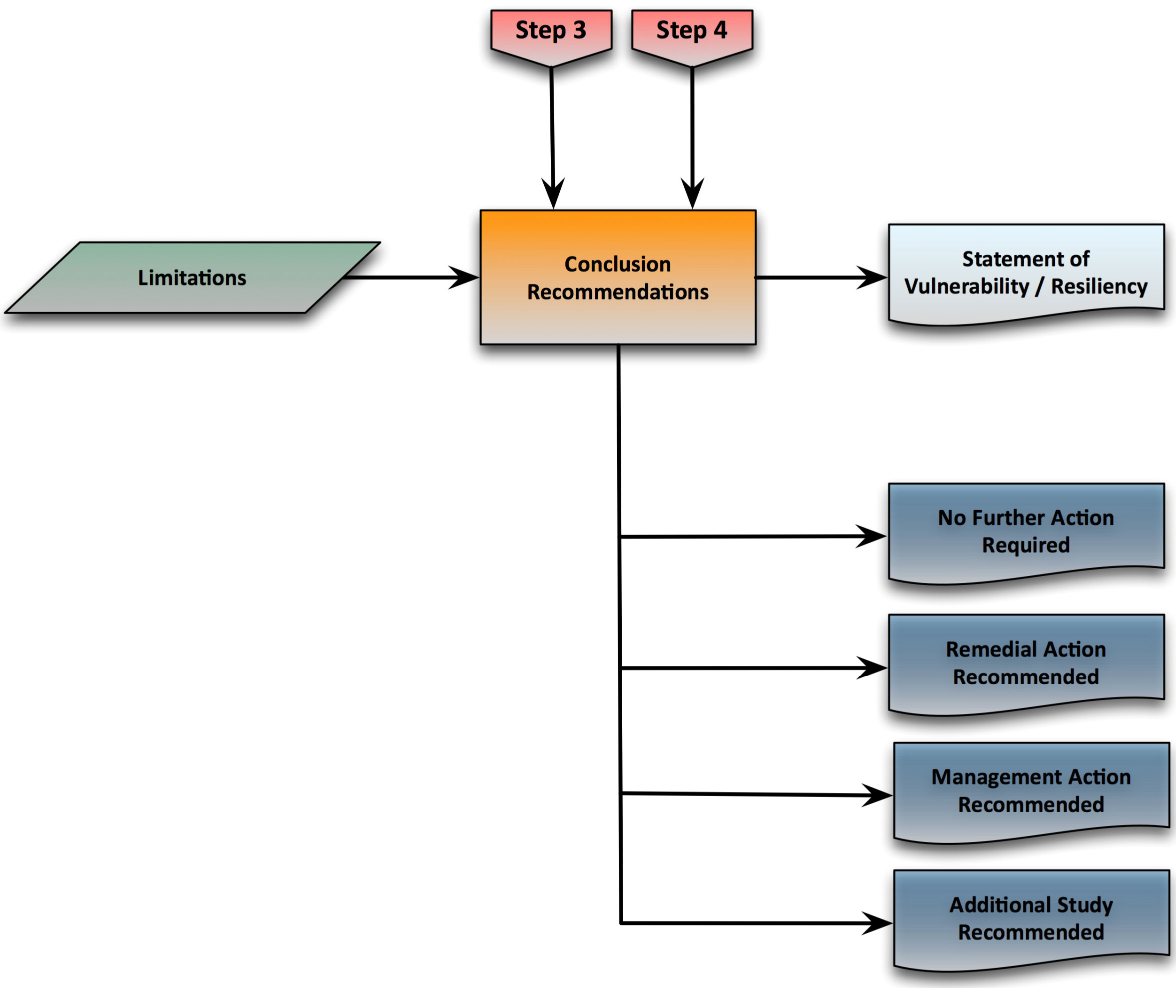
iii. ***Using the worksheets without reference to the Protocol.***

Although the worksheets parallel the Protocol, they do not provide supplementary context that may be necessary to correctly address the specified Protocol task.

5 Step 5 – Recommendations and Conclusions

The process flowchart for Step 5 of the Protocol is presented in **Figure 8**.

Figure 8: Step 5 – Recommendations Process Flowchart



5.1 *Prepare Step 5 Worksheet*

	Enter ***Yes*** or ***No***	
a. Use this ***Worksheet***; or	Yes	
b. Prepare practitioner specific documentation. i. Practitioner specific documentation ***MUST*** detail each task outlined in this step of the Protocol.		No
Comments and Observations		

5.2 *Declare Assumptions Regarding Available Information, Data Sources, Uncertainties and Relevant Limitations*

Add rows as necessary.

a. Comment on the limitations of the vulnerability assessment. These include limitations associated with: i. Major assumptions. ii. Available infrastructure information and sources. iii. Available changing climate information and sources. iv. Available other change information and sources. v. The use of generic or specific examples to represent populations. vi. Uncertainty and related concepts. vii. Other relevant limitations, if they exist.
Major assumptions: • Climate Change will cause increased instantaneous peak lake elevations • Wind-driven wave heights established in the 1986 *Shoreline Management Plan* study would not be affected by climate change
Available infrastructure information and sources: • City of Windsor sewer atlas was used for storm sewer mapping – with ongoing

reconstruction projects along Riverside Dive, the proposed storm sewer upgrades were assumed to have been implemented • LiDAR was the primary source of topographic information and was used to obtain current top of dike elevations. The most recent data available was from 2017. Ongoing construction through the area of study would affect the accuracy of this data for specific areas.
Available changing climate information and sources: • RWDI provided updated 1:100-year instantaneous peak water levels. Their analyses were based on 2 different climate models with 2 variations within each model. Of the 4 water level projections, only 1 model (CGCM#, AE) projected the current lake water levels currently being observed on Lake St. Clair. Projected future instantaneous peak water levels used for risk assessment with this study are from this same model.
The use of generic or specific examples to represent populations: • Conceptual designs have been developed for improvements to the existing dike and storm sewer systems based on generalized existing property conditions. Individual properties vary significantly and site-specific design solutions may be required in additional locations beyond what has been noted herein.
Uncertainty and related concepts: • The final findings and recommendations of the ongoing study for the Sewer Master Plan were not available at the time of this report. The recommendations for sewer improvements recommended in this risk assessment report should be reviewed to confirm any impacts on the hydraulic capacity of the storm sewer system.
Comments and Observations N/A

5.3 *State Conclusions*

Add rows as necessary.

a. Present specific conclusions arising from Steps 1 through 4. i. Report on infrastructure components that have been assessed to be vulnerable. ii. Summarize infrastructure components that have been assessed to have adaptive capacity.

Current Climate Conditions • Cross-connectivity of the storm sewer system under the dike poses an immediate risk for overland flooding. This risk exists in areas on both sides of Little River Future Climate Conditions: • East of Little River, the highest risk for inland flooding is via bypassing of the dike system • West of Little River, the highest risk for inland flooding is due to both bypassing of the dike system and overtopping of the existing dikes. The current and future highest-risk scenarios were associated with high severity scores for emergency flood mitigation and property damage.
Comments and Observations N/A

5.4 *State Recommendations*

Add rows as necessary.

a. Present specific recommendations arising from Steps 1 through 4. As appropriate, classify recommendations into the following categories: i. Remedial engineering actions; ii. Monitoring activities; or iii. Management actions.
Remedial Engineering Actions
Conceptual designs for modifications and improvements to the dike system and storm sewer connections under the dike have been developed and are presented in the main body of the risk assessment report. • A recommended first priority to mitigate risk is for the City to carry out functional and detailed design of backflow prevention measures on both sides of Little River and implement these as soon as possible. • A second priority identified is for the City to carry out functional and detailed design of the proposed dike improvements for the area west of Little River and implement these as soon as possible.

Monitoring Activities
It is recommended that the City continue to monitor lake elevation trends and use this data to re-evaluate projected instantaneous lake elevations to confirm the accuracy of the projections long-term.
It is recommended that the City develop and implement a policy requiring regular inspections of the diking system and any backflow protection measures that are implemented as a result of this study.
Management Actions
Comments and Observations

b. Report on data gaps and availability; requiring additional work or studies.
Refer to Worksheet #4, section 4.13 for additional ongoing studies
Comments and Observations

c. Identify matters that require further action.
N/A
Comments and Observations

5.5 *Prepare Statement of Vulnerability / Resiliency*

	Check Complete
a. Based on the limitations, conclusions and recommendations outlined above, prepare a Statement of Vulnerability / Resiliency.	✓
Comments and Observations Based on the data collected and the analyses carried out over the course of this risk assessment, it is our opinion that the existing flood protection system (i.e. dikes, berms and interconnected sewers) along Riverside Drive East is vulnerable to being bypassed via interconnectivity of the sewer system and through gaps in the dike west of Little River. This vulnerability extends to the possibility of overtopping of the existing dikes when increased high water levels on Lake St. Clair due to climate change are taken into account. The projections for high water levels used in this assessment extend to the year 2050, and should be periodically reevaluated as additional water level data becomes available.	

	Identify Vulnerability or Resiliency Mark Yes or No
b. For infrastructure that is deemed to be generally resilient the statement should include: i. A declaration that the infrastructure is generally resilient. ii. A declaration of the global limitations of the assessment. iii. A declaration of the time horizon of the assessment. iv. A declaration of climate trends or interactions that may	

contribute to the vulnerability of the infrastructure.	
c. For infrastructure that is deemed to be generally vulnerable the statement should include: i. A declaration that the infrastructure is generally vulnerable. ii. A declaration of the global limitations of the assessment. iii. A declaration of the time horizon of the assessment. iv. A declaration of climate trends or interactions that significantly contribute to the vulnerability of the infrastructure.	
Comments and Observations N/A	

	Check Complete
d. The practitioner may use a format of their own choosing to prepare the Statement but, as a minimum, it must: i. Make a declaration regarding the degree of vulnerability or resiliency of the infrastructure. ii. Make a declaration of the global limitations of the assessment. iii. Make a declaration of the time horizon of the assessment. iv. Make a declaration of climate trends or interactions that contribute, or may contribute, to the vulnerability of the infrastructure.	
Comments and Observations N/A	

Date:	August 2019
Prepared by:	Jennifer Nicholls & David Killen, Landmark Engineers Inc.

APPENDIX B

Technical Briefs

Technical Brief – TB1

Subject: East Riverside Flood Risk Assessment - Dike Inventory

Dike Inventory

For the purposes of this assessment, the dike system has been divided into three distinct segments:

- West of Little River;
- East of Little River; and,
- The inland dike along the Windsor-Tecumseh boundary.

These segments have been further subdivided into specific 'Areas' (as illustrated in Figures 7 & 8 of the main report) to assist in identifying specific features and environmental factors that may affect the dike's function. The segment west of Little River is comprised of Areas 1 – 5; the segment east of Littler River is comprised of Areas 6 – 9; and the dike along the Windsor-Tecumseh boundary is described in Area 10.

A) West of Little River (Areas 1-5)

West of Little River, the area south of the dike system is generally low-lying. Between the Little River Corridor and Watson Ave., the dike consists of an earth berm and is located on the south side of Riverside Drive. It is discontinuous, with interruptions for driveways and intersecting roads. Between Watson Ave. and Frank Ave., the location of the dike shifts to the north side of Riverside Drive and continues westerly as far as St. Rose Beach. The earth berm is located fairly close to the shoreline in Kiwanis Park, Bridges Bay Park, and the St. Rose Beach area; although the remaining areas west of Frank Ave. do not have a discernable berm.

Land use along this dike system is primarily residential, consisting of single-family dwellings, apartment complexes and public parks. Areas of commercial development are located in the area of Lauzon Rd. and immediately west of Little River. Apartment complexes are isolated to the section between Watson Ave. and Little River. The St. Paul Pumping station is located in the area of Kiwanis Park and is on the north side of the existing earth berm.

Cross-connectivity of the storm sewers across the dike system has been identified in several locations, with: two gravity outfalls in the area of St. Rose Beach; the sewer main connecting to the St. Paul Pumping Station; the location of the berm crossing from the south to the north side of Riverside Drive; and where the storm sewer main along Riverside Drive connects to the main along Riverdale Ave. One catch basin east of St. Clair Towers is directly connected under the dike to a gravity outfall discharging to the Detroit River creating cross-connectivity.

A brief description of each Area within this segment is provided below:

a. *Area 1 – St. Rose Beach Area*

- Distance along Riverside Drive – 650m (approx.)
- Area is west of Little River and is generally low-lying with the berm location noted on the north side of Riverside Drive
- The St. Rose Beach area includes a storm sewer gravity outfall along the concrete pier within the park
- A second storm sewer gravity outfall is located approximately 50m west of St. Rose Beach
- In the park area, there is an earth berm with discontinuity at the pedestrian walkway crossing
- Residential single-family homes continue from either side of St. Rose Beach, and are located on both sides of Riverside Drive; at St. Rose Beach, residential single-family homes are on the south side of Riverside Drive
- On either side of St. Rose Beach, there is no discernable berm
- Refer to Figure 9 for graphical representation of ground elevations, approximate storm sewer locations and topographical features

b. *Area 2 – Bridges Bay Area*

- Distance along Riverside Drive – 600m (approx.)
- Area is west of Little River and is generally low-lying with the berm location noted on the north side of Riverside Drive
- St. Paul Pumping Station is located on the north side of Riverside Drive, north of the existing earth berm
- Continuous earth berms are located along the shoreline of Bridges Bay and Kiwanis Park areas
- Residential single-family homes continue west of Bridges Bay Park and are on both sides of Riverside Drive. A single residential home is located between Bridges Bay Park and Kiwanis Park north of Riverside
- With the exception of the park areas, there is no discernable berm
- Refer to Figure 10 for graphical representation of ground elevations, approximate storm sewer locations and topographical features

c. *Area 3 – Lauzon Area*

- Distance along Riverside Drive – 600m (approx.)
- Area is west of Little River and is generally low-lying
- West of Frank Ave., the berm is on the north side of Riverside Drive; East of Watson Ave, the berm is on the south side of Riverside Drive; between Frank Ave. and Watson Ave., the berm transitions from north side to the south side of Riverside Drive

- This area includes the eastern edge of Kiwanis Park, located on the north side of Riverside Drive with an existing earth berm
- East of Kiwanis Park, on the north side of Riverside Drive is one residential home followed by a large undeveloped commercial property. There is no discernable berm on either of these properties
- Two commercial strip plazas are on the south side of Riverside Drive with residential to the south and east of these
- Residential single-family homes on both sides of Riverside Drive east of Frank Ave.
- The storm sewers mains along Riverside Drive cross under the dike drain at proposed location for dike crossing Riverside Drive creating cross-connectivity; the storm sewer on Watson Ave. flows south and is connected to main on Riverside Drive creating cross-connectivity under the dike
- Refer to Figure 11 for graphical representation of ground elevations, approximate storm sewer locations and topographical features

d. Area 4 – Dieppe Street Area

- Distance along Riverside Drive – 600m (approx.)
- Area is west of Little River and is generally low-lying with the berm located on the south side of Riverside Drive
- Residential single-family homes are on both sides of Riverside Drive with apartment complexes and below-grade parking on the south side of Riverside Drive
- The earth berm is located on south side of Riverside Drive, but is discontinuous
- Storm sewer along Dieppe St. flows south and is connected to main on Riverside Drive creating cross-connectivity under the dike
- Catch basin, C1, located east of St. Clair Towers connects to storm sewer main with gravity flow discharging directly to the Detroit River
- Refer to Figure 12 for graphical representation of ground elevations, approximate storm sewer locations and topographical features

e. Area 5 – Riverdale Area

- Distance along Riverside Drive – 650m (approx.)
- This area is west of Little River and is generally low-lying with the berm on the south side of Riverside Drive. The east extents of this area is bounded dike system along the Little River corridor
- Apartment complexes and below-grade parking structures on both sides of Riverside Drive; small number of single-family homes on north side of Riverside Drive at west end of area
- Lakeview Park Marina, the Windsor Yacht Club and one commercial property are on the north side of Riverside Drive

- Earth berm is located on the south side of Riverside Drive, but is made discontinuous at driveway entrances except in the area of Westchester Condominiums
- Storm sewer along Riverside drive continues south on Riverdale with cross-connectivity under the dike
- Refer to Figure 13 for graphical representation of ground elevations, approximate storm sewer locations and topographical features

B) East of Little River (Areas 6-9)

East of Little River, the area south of the dike system is generally low-lying, with pockets of new development that are set at relatively higher elevations. The dike consists primarily of an earth berm located on the south side of Riverside Drive along the Ganatchio Trail. The berm is generally continuous, with minor deficiencies noted at driveway crossings and intersecting roads.

Land use along the dike system is primarily residential, with commercial developments north of Riverside in Area 6, and beach access at Sand Point Beach. Areas of surface parking are located north of the dike, but are south of Riverside Drive.

Cross-connectivity of storm sewers across the dike system has been identified with connecting storm sewers along Mountbatten Cres., Vanderbilt Cres., Sand Point Crt., at four locations between Florence Ave. and Clover St., and at Jarvis Ave. The East Marsh Pumping station is located in Area 8 with cross-connectivity under the dike via the main connecting the station to the storm sewers along Riverside Drive. There are also 21 catch basins on the south side of the dike that flow into the storm sewer on Riverside Drive creating cross-connectivity under the Ganatchio Trail berm.

A brief description of each Area within this segment is provided below:

f. *Area 6 – Lakeview Marina Area*

- Distance along Riverside Drive – 800m (approx.)
- This area is east of Little River with the berm located on the south side of Riverside Drive along the Ganatchio Trail. The west end of this area is bounded by the Little River dike system
- On the north side of the dike from west to east, property use includes: Lakeview Park Marina, surface parking areas, a commercial property, a small park, residential single-family homes, and an area of light industrial. On the south side of the dike are residential developments with low-lying area further south
- The earth berm dike is mainly continuous with some deficiencies
- Storm sewers, S8-S10 along Mountbatten Cres., Vanderbilt Cres., and Sand Point Ct., connect and flow into the storm sewer along Riverside Drive creating cross-connectivity under the dike
- Catch basins C2 – C7 are located on the south side of the dike connecting to the storm sewer along Riverside Drive creating cross-connectivity across the dike

- Refer to Figure 14 for graphical representation of ground elevations, approximate sewer locations and topographical features

g. *Area 7 – Sand Point Beach Area*

- Distance along Riverside Drive – 750m (approx.)
- This area is east of Little River with the berm located on the south side of Riverside Drive along the Ganatchio Trail
- On the north side of the dike is a parking area, Sand point beach, a small park and residential area; on the south side of the dike the area is generally low-lying with residential developments
- The existing earth berm is continuous with minor deficiencies
- Storm sewers, S11-S15 between Florence Ave. and Clover St. flow into the storm sewer along Riverside Drive creating cross-connectivity under the dike
- Catch basins C8-C11 are located on the south side of the dike connecting to the storm sewer along Riverside creating cross-connectivity under the dike
- Refer to Figure 15 for graphical representation of ground elevations, approximate sewer locations and topographical features.

h. *Area 8 – Greenpark Area*

- Distance along Riverside Drive – 700m (approx.)
- This area is east of Little River with the berm located on the south side of Riverside Drive along the Ganatchio Trail
- On the north side of the dike is single-family residential; on the south side of the dike is residential developments with the Sportsman Club at the west end of the area
- The area south of the dike is generally low-lying in the west with areas in the east at slightly higher elevations
- The existing earth berm is continuous with minor deficiencies
- Storm sewer, S16 connecting to East Marsh Pumping Station under the dike creates cross-connectivity under the dike
- Catch basins C12-C15 are located on the south side of the dike and are connected to the storm sewer along Riverside creating cross-connectivity under the dike
- Refer to Figure 16 for graphical representation of ground elevations, approximate sewer locations and topographical features.

i. *Area 9 – Rendezvous Area*

- Distance along Riverside Drive – 800m (approx.)
- This area is east of Little River with the berm located on the south side of Riverside Drive along the Ganatchio Trail
- Residential properties are on both sides of the dike with a small park area at the east end on the south side of the dike

- The area protected by the dike is low-lying with select areas at higher elevations
- The existing earth berm is continuous with minor deficiencies
- Storm sewers, S17 and S18 at Amalfi Crt. and Jarvis Ave. flow into the storm sewer along Riverside Drive creating cross-connectivity under the dike
- Storm sewer, S19 does not connect directly to the storm sewer along Riverside Drive, but is a gravity outfall to Lake St. Clair with connecting mains to the storm sewer along Little River Blvd and Blue Heron Lake
- Catch basins C16-C22 are located on the south side of the dike and are connected to the storm sewer along Riverside creating cross-connectivity under the dike
- Refer to Figure 17 for graphical representation of ground elevations, approximate sewer locations and topographical features.

C) Inland diking at City Limit (Area 10)

The dike system along the Windsor-Tecumseh boundary is an inland dike that limits overland flow between the City of Windsor and the Town of Tecumseh. It is located along the rear yards of properties on either side of the municipal boundary. It is not know if the City of Windsor has an easement along this dike, and thus the area was not accessible for visual review. Elevation data for this dike segment obtained via LiDAR indicate that the dike is continuous with minor deficiencies. There are no identified storm sewers or catch basins creating cross-connectivity under the dike.

A brief description of the Area of this segment is provided below:

j. Area 10 – City Limit (Inland)

- Distance along Windsor-Tecumseh boundary – 1000m (approx.)
- This area is east of Little River with the berm located inland along the rear yards of properties abutting the City of Windsor limits shared with the Town of Tecumseh
- Residential properties are on both sides of the earth berm. The Area was not accessible for visual review
- The dike is continuous with minor deficiencies
- There are no identified storm sewers or catch basins with cross-connectivity under the dike
- Refer to Figure 18 for graphical representation of ground elevations and topographical features.

Technical Brief – TB2

Subject: **East Riverside Flood Risk Assessment – Historical Flooding**

Historically, flooding in East Riverside has been a threat mainly due to the flat, low-lying topography of the area relative to the adjacent waterways. The history of overland flooding from Lake St. Clair and the Detroit River has been documented and studied in various shoreline studies and damage surveys over the years. Significant flooding events occurred in the early 1950s, and again in 1973, 1986, and 1998. The extent and severity of overland flooding events has varied with the water level on Lake St. Clair, the incidence of wind-driven waves and the condition of the inland dike systems. The Ganatchio Trail, a multi-use path that also functions as the primary dike for East Riverside (east of Little River), was initially constructed in the mid-1980s with modifications to the trail and dike implemented in 1995.

Current lake levels have set new instantaneous high-water elevations on Lake St. Clair. Despite the current lake elevations, storm events with large wind-driven waves out of the northeast have not yet occurred and overland flooding has been limited.

A general time-line of flooding events, dike construction and shoreline improvements is provided below:

1950s
- The *Shoreline Management Plan* (N.K. Becker & Associates, 1986) notes source documents from the Windsor Star indicating flooding in 1952 and 1954

1968
- Flooding was noted in the area of St. Rose Beach

1973
- Inland flooding occurred due to record high water levels on Lake St. Clair and strong on-shore winds on March 17th
- High instantaneous water elevation of 175.82m was recorded
- It was noted that water overtopped shoreline properties and spilled up to ½ mile inland along Jarvis Ave.

1983
- Completion of inland dike system and multi-use path, the Ganatchio Trail
- The original extents of the Ganatchio Trail were between Riverdale Ave. and the Windsor-Tecumseh boundary
- The path and dike were constructed using materials dredged from the Detroit River during the construction of the Lakeview Park Marina, and is located on what was formerly a rail corridor between Windsor and Tecumseh

1985
- High instantaneous water elevation of 175.81m was recorded

- N.K. Becker & Associates were contracted to create a Shoreline Management Plan for the area between Lauzon Rd. and the easterly limits of the City of Windsor

1986

- Historic high instantaneous water elevation of 175.96m occurred on March 31st
- N.K. Becker completed the Shoreline Management Plan recommending inland dikes and design elevations for these inland protections
- A system of inland land barriers was constructed, enclosing the northern half of the East Riverside Planning District

1995

- The Ganatchio Trail was widened to 15' and berms were reconstructed to protect inland areas from flooding

1998

- April 9th – Overland flooding occurred along Riverside Drive between Sand Point Beach and Greenpark Blvd., and in the area of the Riverside Sportsman Club due to high water levels and strong offshore winds

2019

- Essex Region Conservation Authority reported the Lake St. Clair monthly mean of 176.04m for the month of July 2019
- Sandbagging of vulnerable low-lying areas along the shoreline has occurred, and earth berms along the shoreline have been temporarily supplemented with additional material in several locations

Technical Brief – TB3

Subject: East Riverside Flood Risk Assessment – Areas Potentially Affected

Summary of Potentially Affected Areas

A) West of Little River

For the area of East Riverside west of Little River, inland flooding allowed to equalize to static water elevations of 176.0, 176.5 and 176.8m would affect 192ha, 275ha, and 334ha respectively. The areas affected for these flood levels are shown in Figures 5 and 6.

West of Little River, a flood elevation of 176.0m would affect approximately 1450 single residence land parcels and 40 apartment complexes. Commercial land parcels along Wyandotte St. E. and Lauzon Rd. would also be are affected. Within this area are two elementary schools, one secondary school, and three churches. At a static water elevation of 176.0m, water depths in this area would range from 0 - 1.5m.

With a flood elevation of 176.5m west of Little River, an additional 990 single residences and 14 apartment complexes would be affected. With overland flooding extending further inland, additional commercial land parcels along Wyandotte St. E. and Lauzon Rd. would be affected. One additional church would also be affected. At a static water elevation of 176.5m, water depths in the area would range from 0 – 2.0m.

West of Little River with flood water levels reaching a static elevation of 176.8m, an additional 690 individual residences and four apartment complexes would be affected. The geographical extent of overland flooding would extend mainly southward with this increased water elevation. At a static water elevation of 176.8m, water depths in the area would range from 0 – 2.3m.

A summary of the affected areas at each flood elevation is provided in the table below:

Affected Households / Land Parcels – West of Little River			
Static Water Elevation (m)	**Total Affected Area (ha)**	**No. of Land Parcels (incremental)**	**Prominent Landmarks (incremental)**
176.0	192	• 1445 single-family homes • 40 apartment buildings	Commercial Businesses: • Riverside Plaza • FreshCo. grocery store • Shoppers Drug Mart • Riverside Tavern • Tim Hortons • Lion's Head Tavern

Affected Households / Land Parcels – West of Little River (continued)			
			• Post office • Riverside Medical Center • Additional small businesses along Wyandotte St. E. and Lauzon Rd. Churches: • United Pentecostal Church • St. John Vianney Church • Anglican Church Schools: • St. John Vianney Catholic School • Riverside Secondary School • MS Hetherington Public School
176.5	275	• 988 single-family homes • 14 apartment buildings (quantities are in addition to quantities listed above)	Commercial Businesses: • Metro grocery store • Riverside Family Fitness • Foot Care Institute • WFCU Credit Union • Additional small businesses along Wyandotte St. E. and Lauzon Rd. Churches: • Riverside Baptist Church (noted landmarks are in addition to landmarks listed above)
176.8	334	• 687 single-family homes • 4 apartment complexes (quantities are in addition to quantities listed above)	Commercial Businesses: • Families First Funeral Home • Precision Plaza • Additional small businesses along Wyandotte St. E. and Lauzon Rd. (noted landmarks are in addition to landmarks listed above)

Note:
1) Properties north of Riverside Drive have not been included;
2) Additional areas may be affected with water storage along roadways;
3) Properties not included in overland flood mapping may still be vulnerable to basement flooding.

B) East of Little River

For the area east of Little River, static water elevations of 176.0, 176.5 and 176.8m would affect 174, 308, and 407 ha respectively. The areas affected for these flood levels is shown in Figures 5 and 6.

East of Little River, a flood elevation of 176.0m would affect approximately 350 single residence land parcels would be affected. Many homes would be unimpacted but the street would be flooded making it difficult to access the building. The only commercial development affected would be the Riverside Sportsman Club. At a static water elevation of 176.0m, water depths in this area would range from 0 - 1.0m.

With a flood elevation of 176.5m east of Little River, an additional 1160 single residences and 259 townhomes would be affected. At this water elevation, the Little River Water Pollution Control Plant and the small pumping stations located at stormwater retention ponds would be affected. At a static water elevation of 176.5m, water depths in the area would range from 0 – 1.5m.

If flood water levels reached a static elevation of 176.8m east of Little River, an additional 624 single residences and 350 townhomes would be affected. At a static water elevation of 176.8m, water depts in the area would range from 0 – 1.8m.

Properties outside of the overland flooding areas may be vulnerable to basement flooding via conveyance through the sewers. Emergency services facilities are outside of the flood areas, but access to the flooded areas for emergency response would be limited.

A summary of the affected areas at each flood elevation is provided in the table below:

Affected Households / Land Parcels – East of Little River			
Static Water Elevation (m)	**Total Affected Area (ha)**	**No. of Land Parcels (incremental)**	**Prominent Landmarks (incremental)**
176.0	174	• 350 single-family homes	Commercial Businesses: • Riverside Sportsman Club Churches: • Calvary Baptist Church
176.5	308	• 1160 single-family homes • 256 townhomes • (quantities are in addition to quantities listed above)	Infrastructure: • Little River Pollution Control Plant • Pumping stations for storm water retention ponds (Blue Heron Lake and North Neighborhood ponds)

Affected Households / Land Parcels – East of Little River (continued)			
			Churches: • Our Daily Bread Ministries (noted landmarks are in addition to landmarks listed above)
176.8	407	• 624 single-family homes • 350 townhomes (quantities are in addition to quantities listed above)	No additional landmarks affected

Note:

1) Properties north of Riverside Drive have not been included;
2) Additional areas may be affected with water storage along roadways;
3) Properties not included in overland flood mapping may still be vulnerable to basement flooding.

Technical Brief – TB4

Subject: **East Riverside Flood Risk Assessment – Risk Assessment Workshop**

Corresponding to Step 3 of the PIEVC Protocol, a Risk Assessment Workshop was conducted on 16 August 2019 at the offices of the City of Windsor.

Attendees:

- Anna Godo – City of Windsor, Engineering – Infrastructure & Geomatics
- Phong Nguy – City of Windsor, Manager of Contracts, Field Services & Maintenance
- Karina Richters – City of Windsor, Supervisor, Environmental Sustainability and Climate Change
- Roberta Harrison – City of Windsor, Maintenance Coordinator
- Dave Killen – Landmark Engineers, Senior Project Engineer
- Jennifer Nicholls – Landmark Engineers

Invitations to the Risk Assessment Workshop were extended to the Essex Region Conservation Authority, but scheduling conflicts did not allow for their attendance.

Background

Prior to the Risk Assessment Workshop, Landmark compiled background information summarizing:

- Purpose of the workshop
- Scope of the assessment (infrastructure to be assessed and its location)
- Time horizon
- Climate parameters and climate scenarios (including synergistic climate events)
- Threshold Values for Climate Parameters
- Probability scale factors
- Severity scale factors
- Risk Tolerance Thresholds

This background information was made available to the participants prior to the workshop and was reviewed and discussed for consensus as an introduction to the event. Copies of the materials provided to the workshop attendees are included in Appendix D.

Discussion

Open discussions during the workshop:

- Modes of failure causing overland flooding
    - Two primary modes of failure were identified that could lead to overland flooding to inland areas in East Riverside: overtopping of the dike; or

short circuiting of the dike via cross-connectivity through the storm sewers under the dike.

- Selection of primary parameters
  - Landmark presented 3 climate parameters (e.g.; high instantaneous water elevations on Lake St. Clair, wind-driven waves on Lake St. Clair, and heavy rainfall) as the parameters having the greatest potential to affect the existing dike system and its ability to protect inland areas from overland flooding. It was discussed whether ice scour should be included as a primary climate parameter. It was noted that ice buildup on Lake St. Clair does have the potential to affect the shoreline protection along the waterfront. Erosion of the shoreline may lead to greater potential for water to wash up onto Riverside Drive and enter the storm sewers. It was reasoned that wind-driven waves were the greater cause of water washing up onto Riverside Drive and it was not necessary to include Ice scour as a parameter.
  - A consensus was reached on proceeding with the three primary parameters and the synergistic events suggested by Landmark. These parameters and climate scenarios are listed below:

No.	Primary Climate Parameters
C1	High Instantaneous Water Elevations
C2	Wind-Driven Waves
C3	Heavy Rainfall

No.	Synergistic Climate Events
S1	High Instantaneous Water Elevations (C1)
S2	Wind-Driven Waves (C2)
S3	High Instantaneous Water Elevations + Wind-Driven Waves (C1 + C2)
S4	High Instantaneous Water Elevations + Heavy Rainfall (C1 + C3)
S5	High Instantaneous Water Elevations + Wind-Driven Waves + Heavy Rainfall (C1 + C2 + C3)
Note: *Heavy rainfall included only as a synergistic climate event. It was determined that heavy rainfall alone is unlikely to affect the subject infrastructure.*	

- City of Windsor corporate risk assessments
  - In line with the City of Windsor Climate Change Adaptation Plan, the City has been internally conducting risk assessments on primary infrastructure. It was indicated that a risk assessment of some pumping stations had

already been completed. There was some concern expressed that the format of this risk assessment may not be consistent with the format that the City has been following to date. It was noted, however, that use of the PIEVC Protocol was a condition of funding for this project. It was agreed that the risk assessment should proceed according to PIEVC.

- Selection of Probability Scoring - Method A
  - The PIEVC Protocol allows for qualitative or quantitative scoring of probabilities, normalized to scores between 0 – 7. PIEVC Method A was selected for this risk assessment, but the qualitative descriptions were supplemented in two instances with statistical probabilities from Method B to provide some context and a relative baseline. Qualitative scoring was considered the best fit for the data available in this risk assessment. Statistical probabilities and threshold values were available for some of the climate parameters selected, but the probabilities being scored were taken as a measure of infrastructure response to a climate event (e.g.; the probability of a 1:100-year current instantaneous water elevations overtopping the dike west of Little River is greater than the probability of this occurring east of Little River due to the differing conditions of the dike in each area).
  - The selected scale for probability scores is provided below:

Scale	Probability Scale Factors: PIEVC Method A
0	Negligible / Not applicable
1	Improbable / Highly unlikely (Corresponds to 1:100-yr probability)
2	Remotely possible
3	Possible / Occasional (Corresponds to 1:10-year probability)
4	Somewhat likely / Normal
5	Likely / Frequent
6	Probable / Often
7	Highly Probable / Approaching Certainty

- Selection of Severity Scoring - Method D
  - The PIEVC Protocol presents 2 methods for scoring severity, both of which use descriptive qualifiers. Method D was selected for use with this risk assessment because the single-word descriptors best captured the effect climate events could have on the infrastructure and the inland areas protected by the infrastructure. The method not selected, Method E, qualified severity in terms of serviceability and loss of function and thus were not considered applicable.

- The selected scale for severity scores is provided below:

Scale	Severity of Consequences and Effects: PIEVC Method D
0	No Effect
1	Measurable
2	Minor
3	Moderate
4	Major
5	Serious
6	Hazardous
7	Catastrophic

- Performance measures are measures of the infrastructure's response to a climate event occurring. With this risk study, 3 performance measures were selected for evaluation:
  - Dike & Sewer Integrity;
  - Emergency Flood Mitigation, and;
  - Property Damage.

Risk Scoring

Upon reaching consensus regarding the parameters, scoring scales and performance measures, the workshop attendees assigned probability and severity scores for each climate event and each performance measure for both current and future conditions. The segments of the study area west and east of Little River were scored independently to reflect the differing dike conditions.

Each of the workshop attendees carried out their scoring independently, although some group discussions took place to help ensure that the basis / rationale for the scoring was generally consistent.

After the completion of the workshop, completed scoring sheets were compiled. Averages were taken of the individual scores to calculate composite risk rankings based on the performance measures. Each individual's scoring was weighted equally. A summary of the tabulated results from the risk assessment workshop is presented in Tables D1-D4, Appendix D.

Technical Brief – TB5

Subject: **East Riverside Flood Risk Assessment - Backflow Prevention Devices**

Backflow prevention generally consists of installing valves in existing infrastructure that close automatically (or manually) to stop floodwater from backing up or entering the storm system.

Types of Backflow Prevention Valves

There are many different types of backflow prevention valves that generally fall into the following categories:

- Slide Gate – gate that lowers vertically to close off flows
- Flap Gate – Hinged gate typically used for outfalls
- Duck Bill Check Valve – Self-sealing valve that is installed in a pipe or at an outfall
- Inline Backflow Device – Self-sealing valve installed in the pipe adjacent to a manhole

Slide Gates (Sluice Gates)

Slide Gates are generally used at outfalls but may also be incorporated into in-line manholes as well. When the gates are lowered, they close off the pipe and prevent water from flowing. These gates are usually deployed manually and some have capability to be operated by pneumatic actuators. It should be noted that these gates can be used as backflow prevention but can also be used to cut off the main flow when the direction of the floodwater is in the same direction as the main flow of the sewer.

Features:

- Gate is lowered to stop the flow of water through the sewer or into the sewer (if used at an outfall)
- Typically fabricated with stainless steel for optimum corrosion resistance
- Low maintenance
- Tight closure with tapered wedge seating

Cost:

- Cost depends on the size of the gate.
- Automation is provided as a separate cost.
- The cost does not include installation (supply only)
- Preliminary budget pricing used: $5,000 per gate and $9,000 for automation.

Image Source: Armtec

Flap Gates

Flap gates are typically installed at the end of an outfall but also may be installed within a manhole. They remain closed and allow flow to pass through in one direction during normal flow conditions. During a backflow condition, the water pressure from the opposite direction holds the gate closed so that no flow can enter.

Features:

- Typically fabricated with stainless steel for optimum corrosion resistance
- Create water tight connection for any circular pipe
- Long service life
- Low maintenance

Image Source: Hydro Gate

Image Source: CMP Group

Cost:

- Cost depends on the size of the gate.
- The cost does not include installation (supply only)
- Preliminary budget pricing used: $5,000 per gate.

Duck Bill Check Valve

A Duck bill check valve is a fully passive flow control device that does not require any power or manual assistance to operate. As pressure of flow increases, the lips open further to allow more flow. When there is backpressure or reverse flow, the lips squeeze together, preventing backflow.

Features:

- Seals around entrapped solids
- Can handle large obstructions without jamming

Image Source: Armtec

- No moving mechanical parts
- Does not require power or manual deployment
- Very minimal maintenance required
- Can be retrofitted into existing pipes
- Low pressure loss
- Cost effective

Cost:

- Cost depends on the size of the pipe
- The cost does not include installation (supply only)
- Preliminary budget pricing used: $5,000 per device.

In-Line Backflow Devices

In-line backflow devices can be installed within existing storm pipes to restrict backflow. The valves generally work on differential water pressure without manual intervention or electricity. Some examples of in-line devices are shown below.

Features:

- Very low head loss
- Available in sizes 75mm to 1950mm
- Manufactured from heavy duty elastomer (non-corrosive)
- Self-draining
- Seals around debris
- No moving mechanical parts
- Does not require power or manual deployment
- Very minimal maintenance required
- Can be retro fitted into existing pipes
- Cost effective

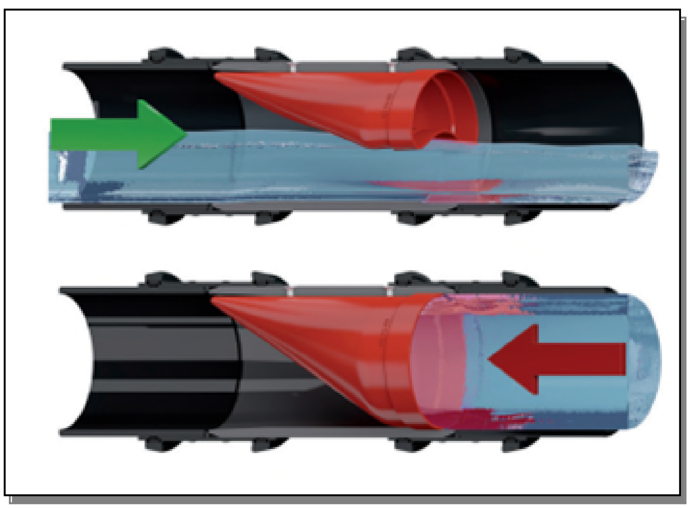


Image Source: Wapro

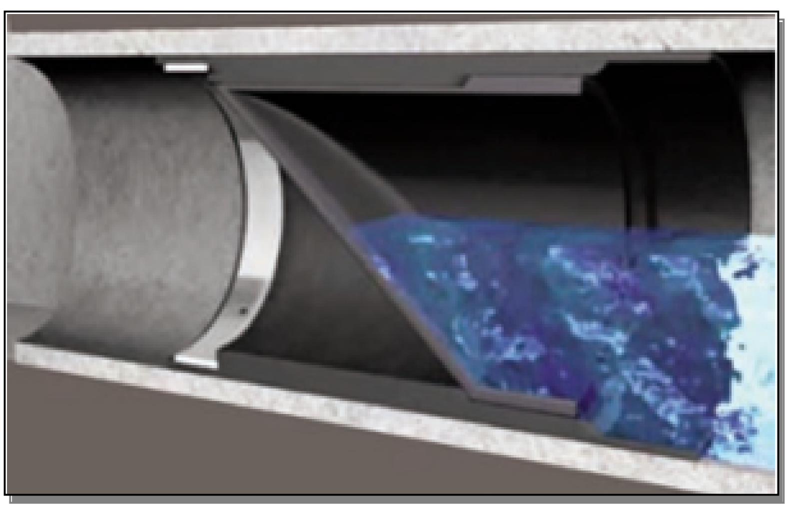


Image Source: Tideflex Technologies

Cost:

- Cost depends on the size of the pipe.
- The cost does not include installation (supply only)
- Preliminary budget pricing used: $5,000 per device.

Considerations

The following is a list of considerations that should be taken into consideration when selecting the appropriate device for each situation where backflow prevention is required:

- Maintenance Requirements;
- Reliability;
- Ability to operate valve manually during an event;
- Stormwater Management Requirements;
- Feasibility and Site Access;
- Cost;
- Flow Efficiency; and,
- Suitability.

Suppliers and Manufacturers

The following is a list of suppliers and manufacturers that produce the type of products that are needed to satisfy the requirements for this project. This is not to say that other manufacturers or suppliers could not (or should not) be considered in the future. This list is intended to provide examples of the type and quality of devices that would be recommended.

- Hydro Gate: https://www.hydrogate.com
- Armtec: https://armtec.com
- Fontaine Aquanox: http://www.iseaquanox.com
- Red Valve, Tideflex Technologies: https://www.redvalve.com/tideflex
- Waterman Industries: https://watermanusa.com

Technical Brief – TB6

Subject: **East Riverside Flood Risk Assessment - Flood Gates**

Flood gates are adjustable gates used to control water flow and protect vulnerable areas from flooding. They are typically used as flood barriers for:

- Underground garage parking entrances;
- Driveway and site entrances; and,
- Roadways where it is not feasible to raise the entire roadway to flood level.

Flood Gate Types

Flood gates can generally be divided into two categories: permanent structures or modular systems. Permanent structures are built into the ground when not in use. They can by deployed manually or automatically depending on the design and requirements.

Modular systems are generally erected when the threat of flooding occurs and are removed afterwards. The modular systems may require some hardware to be embedded into the concrete of the structure (or driveway or roadway) in order to allow for quick assembly. Some skill is required in order to ensure the systems are assembled correctly.

Although modular systems are effective, they would not be recommended for the following reasons:

- Cannot be controlled remotely or have an automatic deploy feature
- Require a space to store them when not in use
- May be difficult for homeowners to erect if they are not physically capable
- City would have little control over when and how the gates are deployed

Due to the potentially severe impacts of flooding in the East Riverside Area, it is recommended that permanent flood gates be installed where required.

Deployment Options

Flood gates can have the capability to automatically deploy or they can be manually deployed. Many of the automatic gates use the hydrostatic pressure of the flood waters to automatically raise the gates. This means that the gates may be raised even if there is no power.

Some of the advantages for the automatic gates are:

- Gates will raise automatically when needed depending on the water levels

- Gates will deploy even if homeowners are not home to manually raise the gates
- Gates will deploy even if homeowners are physically unable to manually operate the gate
- The City will have confidence that the gates will be properly deployed (no manual user error)
- Gates will deploy even if there is no power

Due to the number of gates required and their location on private property, we recommend that the type of gate chosen have the ability to automatically deploy rather than be manually deployed.

Flood Gate Features

Although flood gate designs can take on many different forms, they all typically have the following features:

- Recess into the pavement to provide unrestricted level access when not deployed
- Meet any width requirement and most height requirements
- Withstand loadings for cars and trucks
- Operated by manual deployment or automatic deployment
- Link to alarm systems (if desired)
- Many surface finishes available (non-slip epoxy coating, timber decking, clad with architectural finish such as stamped concrete)
- Withstand harsh environments
- Resist vandalism (no exposed components when closed)

Maintenance

Maintenance is recommended to be completed annually or half-yearly and includes the following:

- Test battery pack for performance and charge (where applicable)
- Operate the barrier and check for proper function
- Check alarm functions
- Check hydraulic system for component fatigue or leaks
- Check seals and replace if required
- Check surface finish for wear and refinish (paint) if required

Flood gates are typically designed to withstand harsh environments (including road salt). Components are typically fabricated from aluminum alloys and stainless steel, materials that will withstand the elements for many years. The majority of the flood gates researched indicate they should function for decades if not longer.

Cost

In order to estimate the cost of the gates, we have assumed two typical sizes of gates. One for driveways and one for roadways. The actual prices of each gate will depend on the widths and heights required for each location.

Driveway Gates: 6m wide by 1m high - $80,000
Roadway Gates: 15m wide by 2m high - $450,000

The budgetary costs provided above do not include installation or freight costs.

Suppliers or Manufacturers

The following is a list of suppliers and manufacturers that produce the types of gates that are needed to satisfy the requirements for this project. This is not to say that other manufacturers or gate suppliers could not (or should not) be considered in the future. This list is intended to provide examples of the type and quality of gates that would be recommended.

- Flood Break – https://floodbreak.com
- Flood Control International - http://www.floodcontrolinternational.com

Images

Image Source: Flood Break

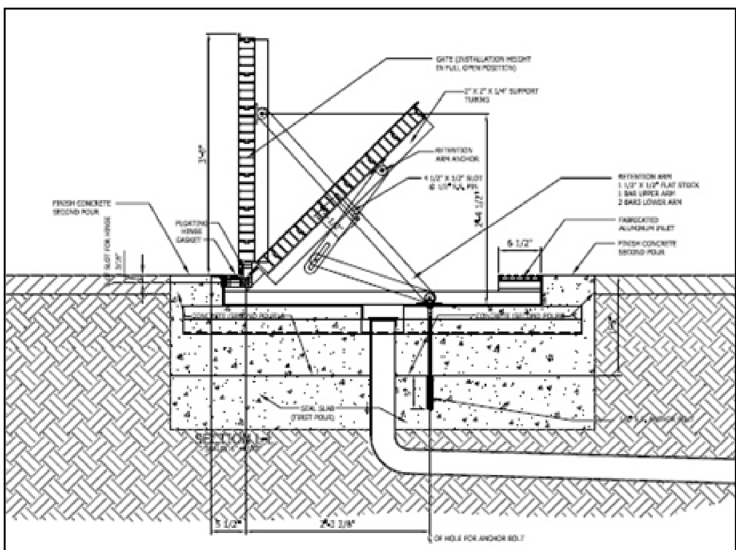


Image Source:
Flood Control International

Technical Brief - TB7

Subject: **East Riverside Flood Risk Assessment - Public Information Centre Summary**

A Public Information Centre (PIC) was held on Wednesday, June 26, 2019 from 4 -7pm at the WFCU Centre (8787 McHugh St.) in Windsor to present the initial findings of the East Riverside Flood Risk Assessment. A series of 22 display panels were prepared and made available for review by the public. The display panels depicted the current condition of the dike system, the potential impacts of lake flooding and the potential solutions that had been developed. Attendees were asked to sign in to record attendance and comment sheets were provided to obtain feedback.

During the 3-hour PIC, approx. 100 members of the public recoded their attendance. Only five comment sheets were received.

The following is a summary of the comment sheets received from the PIC:

- Why is there no 'by-law' to require homes north of Riverside Drive to install retaining walls for protection?
- ERCA and the City should work together to begin construction as soon as possible.
- Berms don't sound satisfactory – concrete walls should be used.
- The Buckingham area of East Riverside needs protection berms.
- Very informative.
- If 1973 flood happened today, the cost would be unimaginable due to the development since then.

Members of the Project Team were available throughout the PIC to discuss attendees' concerns and answer questions. The following is a summary of the types of questions and concerns that were raised by the public during discussions with the Project Team (not put into writing):

- How do the proposed solutions affect my property?
- I am north of Riverside Drive. How am I protected from lake flooding?
- I live south of Riverside Drive. How will these improvements protect my home?
- When will construction to the dike system begin?
- How does the dike system protect against basement flooding south of Riverside Drive during large rain events?
- What about the existing berms that were installed along the water in backyards along the Detroit River in the 1980s? Were those berms assessed?
- Many of the new homes on the north side of Riverside Drive no longer have berms in their back yard. Who is responsible to enforce the protection of these berms?

Although several of the issues raised were beyond the scope of this risk assessment, these concerns have been documented here to help inform City administration regarding the priorities of local residents.

Copies of the sign-in sheets and comment sheets received have been archived and are available upon request.

APPENDIX C

RWDI AIR Inc.

EAST RIVERSIDE FLOOD RISK ASSESSMENT – 1:100 – YEAR INSTANTANEOUS WATER ELEVATION

REPORT

LANDMARK ENGINEERS INC.

WINDSOR, ONTARIO

CITY OF WINDSOR:
EAST RIVERSIDE FLOOD RISK ASSESSMENT – 1:100-YEAR INSTANTANEOUS WATER ELEVATION

RWDI #1902374

April 4, 2019

SUBMITTED TO

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Appendix A: Study Area – Infrastructure to be Assessed

1 INTRODUCTION

RWDI have been retained to provide 1:100-year instantaneous water level elevation values for Lake St. Clair, with respect to the study area shown in **Appendix A**. This information is required by Landmark Engineers to complete a PIEVC Protocol assessment of the City of Windsor's flood protection infrastructure. The analysis will supplement the work described in the Shoreline Management Plan completed by N.K. Becker and Associates dated March 1986. As over 30 years have passed since that study, it is prudent to reflect any differences in the statistically determined 1:100-year instantaneous water level elevations with an expanded dataset. Available climate change projections have also been reviewed to provide 1:100-year instantaneous water level elevations for the 2030 and 2050 climates.

2 PAST CLIMATE AND FUTURE CLIMATE DATASETS

There are four water level monitoring stations on Lake St Clair near the study area that have been considered. These are listed in **Table 1**, along with the period of record, the data provider, the intervals of data available (hourly, monthly, etc.) and the distance from the station to the Riverside Drive and Little River in Windsor. All sources provide water elevations in above the International Great Lakes Datum (IGLD 1985).

Climate change datasets that contain monthly average water elevation projections for Lake St Clair are available from the Great Lakes Environmental Research Laboratory (GLERL). These datasets are based on the methodology described in Lofgren et al (2011). Two climate change models and two methods were used to create the climate change datasets, resulting in four different projections, that cover the 2058 – 2105 period.

Table 1: Historical stations used in analysis

Station	Distance to Riverside Drive & Little River	Interval and Period of Record	Data Source
Tecumseh	600 m E	Daily Maximum (1926-1993)	Environment and Climate Change Canada (ECCC)
Belle River	19 km ESE	Daily Maximum (1961-2017)	Environment and Climate Change Canada (ECCC)
Windmill Point	2 km N	6-min (1999-2018) Hourly (1970-2018) Monthly Average (1950-2018)	National Oceanic and Atmospheric Administration (NOAA)
St Clair Shores	15 km NNE	6-min (1996-2018) Hourly (1968-2018) Monthly Average (1968-2018)	National Oceanic and Atmospheric Administration (NOAA)

3 EXTREME VALUE ANALYSIS

A series of extreme value analyses have been applied to the available datasets using a Fisher-Tippet Type 1 distribution. A summary of these analyses is presented in **Figure 1** for the historical data and **Figure 2** for the climate change projections. The maximum daily, one hour and 6-minute values from single stations are representative of instantaneous water level elevations (i.e. including the set-up level). However, the monthly maximum mean values are averaged over a month and therefore do not include this set-up level. For this reason, the 0.34 m (1.1 ft.) wind set-up level from the Becker Shoreline Management Plan has been added to the monthly maximum mean values in **Figures 1** and **2**.

Figure 1: Extreme Value Analysis, Instantaneous Water Levels for Lake St Clair in Windsor, Historical Data

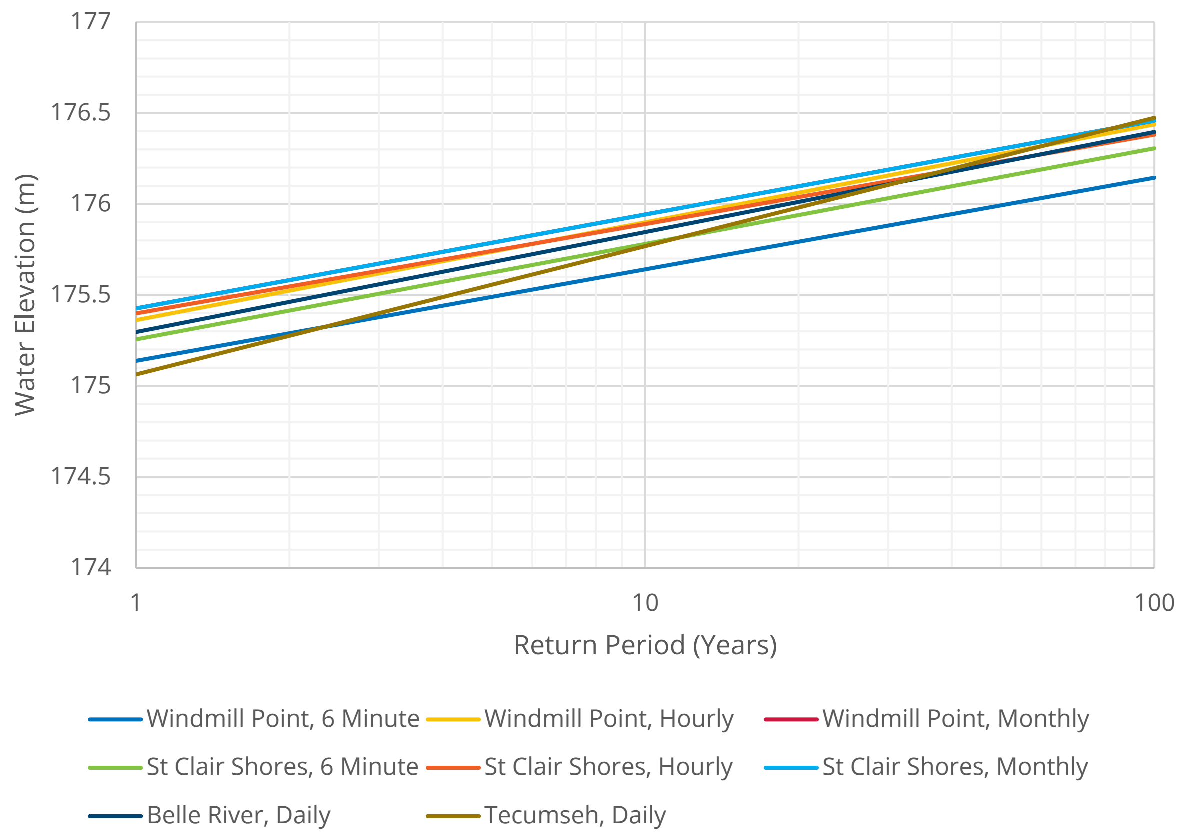
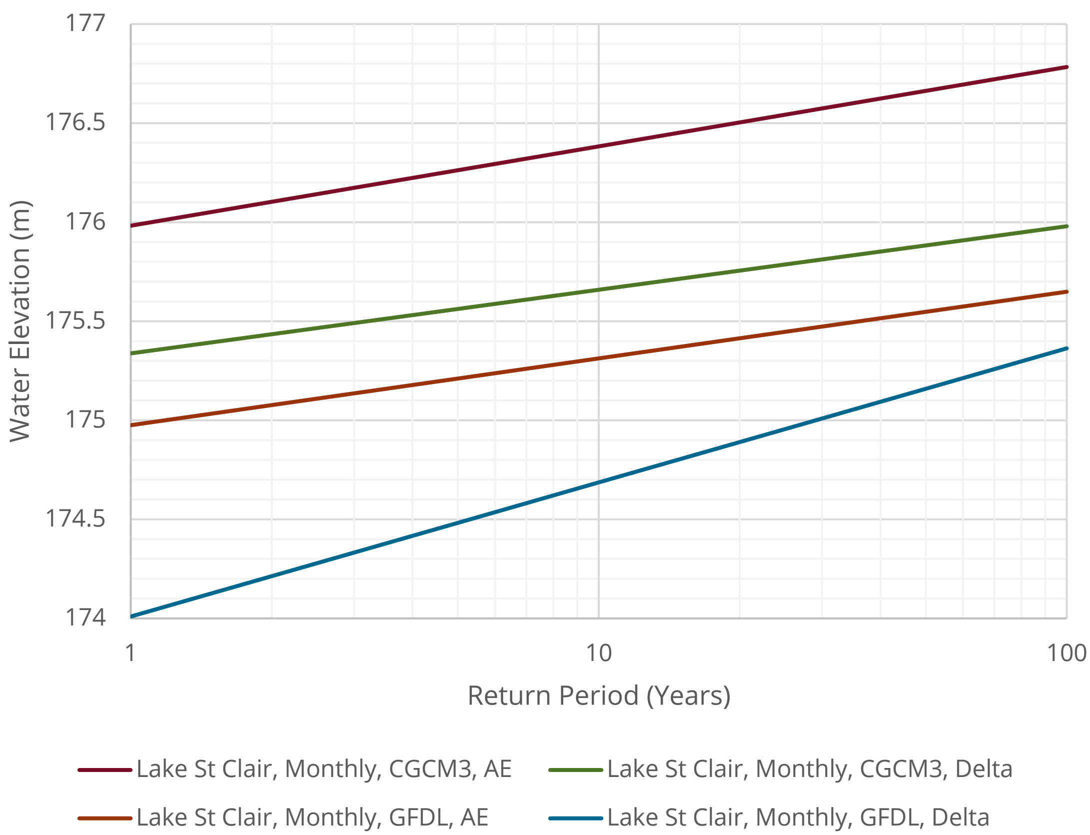


Figure 2: Extreme Value Analysis, Instantaneous Water Levels for Lake St Clair in Windsor, Future Climate Data



A summary of the 1:100-year values from the different datasets is provided in **Table 2**. From the historical datasets, the governing cases are from the Windmill Point, Monthly, St Clair Shores, Monthly and Tecumseh, Daily fits which all have 1:100 instantaneous water levels of 176.5 m.

Table 2: 1:100 Year Instantaneous Water Levels, Lake St Clair in Windsor, historical data D

Station and Dataset	1:100 Year Instantaneous Water Level (m, IGLD)
Historical Data	
Windmill Point, 6 Minute	176.1
Windmill Point, Hourly	176.4
Windmill Point, Monthly	176.5
St Clair Shores, 6 Minute	176.3
St Clair Shores, Hourly	176.4
St Clair Shores, Monthly	176.5
Belle River, Daily	176.4
Tecumseh, Daily	176.5
Future Climate Projections	
Lake St Clair, Monthly, CGCM3, AE	176.8
Lake St Clair, Monthly, CGCM3, Delta	176.0
Lake St Clair, Monthly, GFDL, AE	175.6
Lake St Clair, Monthly, GFDL, Delta	175.4

3.1 Future Climate Projections

While three out of four of the future climate projections are lower, the CGCM3, Alternate Energy (AE) method results in a 1:100 year is higher than the historical fits, with a 1:100-year instantaneous water level of 176.8 m. This represents the climate from 2058 – 2105. A linear interpolation between 2018 and 2058 yields 1:100-year instantaneous water levels of 176.6 m and 176.8 m for 2030 and 2050, respectively.

3.2 Limitations

It should be noted that the 1:100-year instantaneous water level elevation cannot include all possible anthropogenic impacts (i.e. caused by human interference) beyond those that are described by the historical climate and future climate scenarios. For example, changes to Great Lakes water management strategies (damming, water taking, etc.) could have a profound impact on the Lake St. Clair water levels. As the potential or impact of these changes are unknown, they cannot be included in any predicted values.

4 COMPARISON TO BECKER SHORELINE MANAGEMENT PLAN

The Becker Shoreline Management Plan predicted a 1:100-year instantaneous water level of 176.4 m (578.9 ft.). As only the Tecumseh station was considered in the Becker plan, a direct comparison can be made. The 1:100-year instantaneous water level from the RWDI analysis of the Tecumseh dataset is 176.5 m (579.0 ft.), which is very good agreement. Additional monitoring stations were considered in the RWDI analysis because Tecumseh monitoring station ceased operations in 1993, and the availability of stations with higher frequency measurement intervals, from monthly mean water levels in the Becker study to 6-minute water levels in the RWDI analysis.

4.1 Wave Heights

The recommendation of wave heights falls outside of the current scope, so similar to the water level setup height of 0.34 m (1.1 ft.), the wave heights of 2.5 ft. for the Detroit River shoreline and 5 ft. for the Lake St Clair shoreline line can be referenced from the Becker study.

5 CONCLUSION

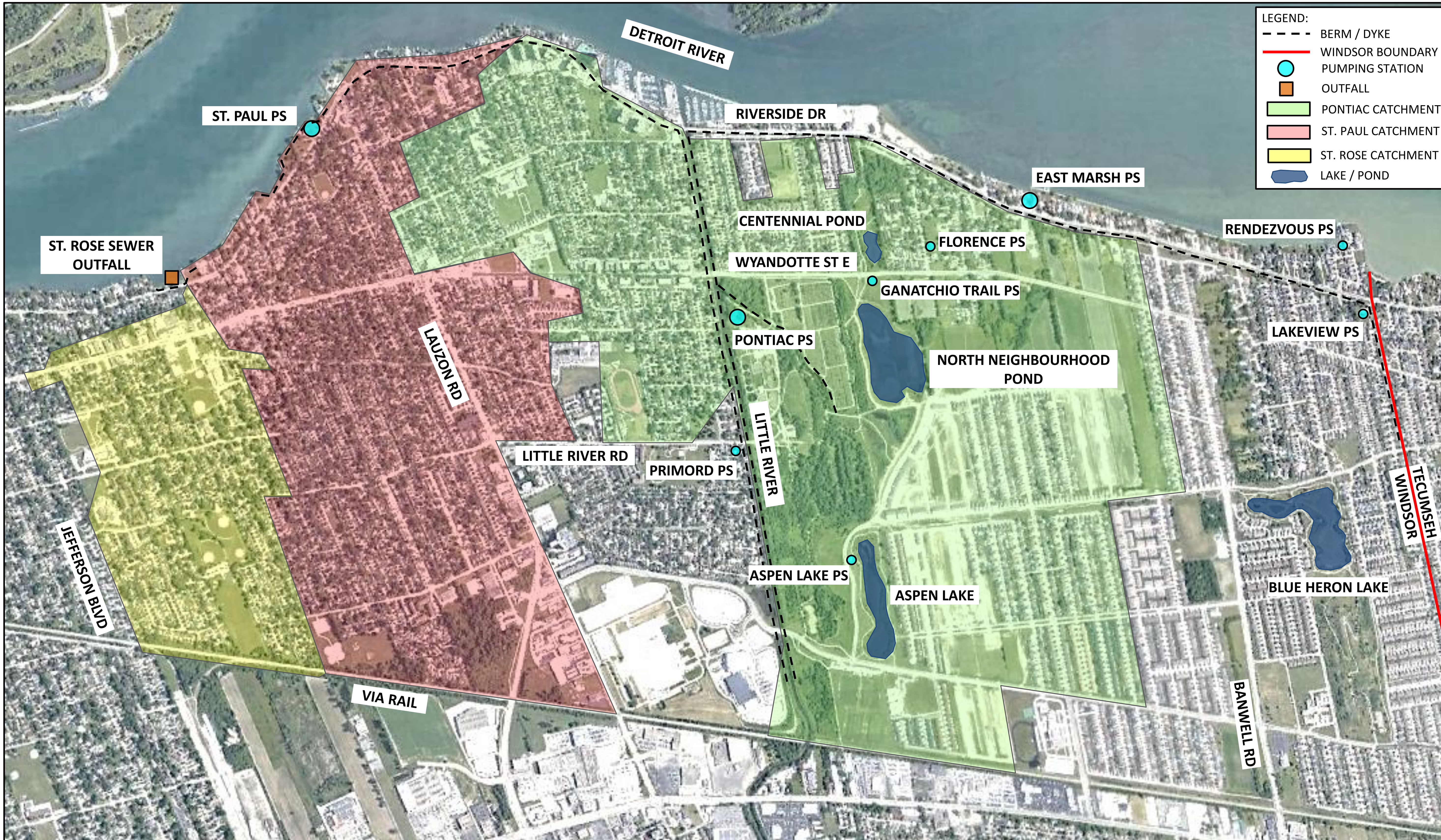
The 1:100-year instantaneous water levels have been determined for the current climate, as well as the 2030 and 2050 periods have been determined for the Lake St Clair shoreline in Windsor. The instantaneous water levels determined in this analysis are 176.5 m, 176.6 m and 176.8 m for 2018 (current climate), 2030 and 2050, respectively.

6 REFERENCES

Lofgren, B. M., Hunter, T. S., & Wilbarger, J. (2011). Effects of using air temperature as a proxy for potential evapotranspiration in climate change scenarios of Great Lakes basin hydrology. Journal of Great Lakes Research, 37(4), 744-752.

APPENDIX A

FIGURE 1A – STUDY AREA / INFRASTRUCTURE TO BE ASSESSED



Landmark Engineers Inc.

APPENDIX D

Risk Assessment Workshop

EAST RIVERSIDE FLOOD RISK ASSESSMENT
Risk Assessment Workshop – Backgrounder / FAQ

a) Why are we conducting this workshop?

In the fall of 2018, Landmark was retained by the City of Windsor to carry out a flood risk assessment for the areas protected from coastal flooding by the East Riverside dike system.

As a condition of the funding for the study, the City was required to follow the PIEVC Engineering Protocol that was authored by Engineers Canada. The PIEVC Protocol includes a step-by-step procedure for risk assessment. One of the key steps in the process is to carry out a risk assessment workshop involving a multi-disciplinary team with knowledge of the infrastructure being assessed and the effects of changing climate on that infrastructure.

In order to help fulfill the requirements of the PIEVC Protocol, you have been invited to participate.

b) What is the scope of the assessment?

The study involves an assessment of the existing dike system along Riverside Drive East and the Ganatchio Trail between St. Rose Beach and the boundary with the Town of Tecumseh.

The scope includes assessing the risk that the dikes will be overtopped as well as the risk of flood waters bypassing the dike system via interconnected sewers and catch basin leads that cross under the dike.

The scope of the study does NOT include:

- An assessment of the flood risk associated with heavy rainfall / insufficient sewer and / or pump station capacity. This is currently being studied as part of the City's ongoing Sewer Master Plan (SMP).
- An assessment of the flood risk associated with the potential for Little River to overtop its banks. We understand that the City recently commissioned a separate study to address this issue.

c) What is the intended format / procedure for this Workshop?

Using the procedures set out in the PIEVC Protocol, this workshop will generally follow these steps:

i) Confirm the scope of the assessment:

Review and confirm consensus with respect to the following:

- Infrastructure components – Dikes, Crossing / interconnected storm sewers
- Time Horizon – to 2050
- Climate Parameters

No.	Climate Parameters
C1	High Instantaneous Water Elevations
C2	Wind-Driven Waves
C3	Heavy Rainfall

Threshold Values for Climate Parameters:

Lake Levels:	176.0m	– Current lake level / highest recorded lake elevation – Water begins to flow onto Riverside Drive (field observations)
	176.5m	– Current 1:100-year lake level (RWDI study)
	176.8m	– Future 1:100-year lake level (RWDI study)
Wind-drive Waves:	5ft high on Lake St. Clair (N.K. Becker report) 2-2.5ft high on the Detroit River (N.K. Becker report)	
Rainfall:	Refer to IDF curves (SMP)	

Climate Scenarios to Consider:

No.	Synergistic Climate Events
S1	High Instantaneous Water Elevation (C1)
S2	Wind-Driven Waves (C2)
S3	High Instantaneous Water Elevation + Wind-Driven Waves (C1 + C2)
S4	High Instantaneous Water Elevation + Heavy Rainfall (C1 + C3)
S5	High Instantaneous Water Elevation + Wind-Driven Waves + Heavy Rainfall (C1 + C2 + C3)
Note: Heavy rainfall included only as a synergistic climate event	

ii) Assign probability scores to Climate Scenarios

The flood risks that are being assessed involve the probabilities that:

- The dike will be overtopped and/or
- The dike will be bypassed through the sewer system

This task involves assigning probabilities on a scale from 0 to 7 (see table) for each of the above, as a result of each of the listed climate scenarios – for both present and future conditions.

Determine probability for each climate scenario, considering east and west of Little River as separate areas, and sewer conveyance as a separate probability.

Scale	Probability Scale Factors: PIEVC Method A
0	Negligible / Not applicable
1	Improbable / Highly unlikely (Corresponds to 1:100-yr probability)
2	Remotely possible
3	Possible / Occasional (Corresponds to 1:10-year probability)
4	Somewhat likely / Normal
5	Likely / Frequent
6	Probable / Often
7	Highly Probable / Approaching Certainty

iii) Assign Severity scores to Performance Measures

Severity of an event occurring should not be confused with probability of an event. Referring to Climate Scenarios, this task involves assigning severity and/or consequences on a scale from 0 to 7 (see table) to performance measures.

Determine severity for each climate scenario, considering east and west of Little River, and sewer conveyance as a separate cases.

Scale	Severity of Consequences and Effects: PIEVC Method D
0	No Effect
1	Measurable
2	Minor
3	Moderate
4	Major
5	Serious
6	Hazardous
7	Catastrophic

Performance measures

- Dike & Sewer Integrity – a measure of degree that the dike and storm sewers integrity are compromised due to the occurrence of a climate scenario and / or a measure of any damage occurring to the dike or sewer resulting from the climate scenario.
- Emergency Flood Mitigation – a measure of emergency response required to mitigate effects of climate scenario, or respond to the occurrence of flooding due to specified climate scenario.
- Property Damage, Social Effects, Insurance Considerations – a measure of the damage that might occur to the protected infrastructure and people as a result of the specified climate scenario

iv) Determine Risk

Compile scores together for probability and severity and calculate risk.

RISK = PROBABILITY X SEVERITY

Assess and review results for any special cases

Risk Tolerance Thresholds:

Risk Range	Threshold	Response
< 12	Low Risk	No action necessary
12 - 23	Medium - Low Risk	Action may be required Engineering analysis may be required
24 - 36	Medium - High Risk	Action may be required Engineering analysis may be required
> 36	High Risk	Action Required

TABLE D1: RISK SCORING FOR FUTURE CONDITIONS

WEST OF LITTLE RIVER			CURRENT CONDITIONS			FUTURE CONDITIONS			
Performance Measure	Climate Parameter / Relevant Climate Event		Severity	Probability	Risk = Probability x Severity	Severity	Probability	Risk = Probability x Severity	Risk Ranking
PROPERTY DAMAGE	S5	Sewer Conveyance	6	5	30	7	6	42	High
EMERGENCY FLOOD MITIGATION	S5	Sewer Conveyance	5	5	25	6	6	36	Med-High
PROPERTY DAMAGE	S5	Dike Overtopping	6	4	24	7	5	35	
EMERGENCY FLOOD MITIGATION	S4	Sewer Conveyance	5	5	25	6	5	30	
PROPERTY DAMAGE	S4	Sewer Conveyance	5	5	25	6	5	30	
EMERGENCY FLOOD MITIGATION	S5	Dike Overtopping	5	4	20	6	5	30	
PROPERTY DAMAGE	S3	Dike Overtopping	4	4	16	6	5	30	
PROPERTY DAMAGE	S3	Sewer Conveyance	4	4	16	6	5	30	
EMERGENCY FLOOD MITIGATION	S3	Dike Overtopping	5	4	20	5	5	25	
EMERGENCY FLOOD MITIGATION	S3	Sewer Conveyance	5	4	20	5	5	25	
PROPERTY DAMAGE	S1	Dike Overtopping	4	3	12	5	5	25	
PROPERTY DAMAGE	S1	Sewer Conveyance	4	3	12	5	5	25	
EMERGENCY FLOOD MITIGATION	S4	Dike Overtopping	5	3	15	6	4	24	
PROPERTY DAMAGE	S4	Dike Overtopping	5	3	15	6	4	24	
DIKE & SEWER INTEGRITY	S5	Dike Overtopping	3	4	12	4	5	20	Med-Low
PROPERTY DAMAGE	S2	Dike Overtopping	4	3	12	5	4	20	
PROPERTY DAMAGE	S2	Sewer Conveyance	4	3	12	5	4	20	
EMERGENCY FLOOD MITIGATION	S1	Dike Overtopping	3	3	9	4	5	20	
EMERGENCY FLOOD MITIGATION	S1	Sewer Conveyance	3	3	9	4	5	20	
DIKE & SEWER INTEGRITY	S5	Sewer Conveyance	3	5	15	3	6	18	
DIKE & SEWER INTEGRITY	S4	Sewer Conveyance	2	5	10	3	5	15	
DIKE & SEWER INTEGRITY	S3	Dike Overtopping	2	4	8	3	5	15	
DIKE & SEWER INTEGRITY	S1	Dike Overtopping	2	3	6	3	5	15	
DIKE & SEWER INTEGRITY	S2	Dike Overtopping	2	3	6	3	4	12	
DIKE & SEWER INTEGRITY	S4	Dike Overtopping	2	3	6	3	4	12	
EMERGENCY FLOOD MITIGATION	S2	Dike Overtopping	2	3	6	3	4	12	
EMERGENCY FLOOD MITIGATION	S2	Sewer Conveyance	2	3	6	3	4	12	
DIKE & SEWER INTEGRITY	S3	Sewer Conveyance	2	4	8	2	5	10	Low
DIKE & SEWER INTEGRITY	S1	Sewer Conveyance	1	3	3	2	5	10	
DIKE & SEWER INTEGRITY	S2	Sewer Conveyance	1	3	3	2	4	8	

TABLE D2: RISK SCORING FOR FUTURE CONDITIONS
EAST OF LITTLE RIVER

Performance Measure	Climate Parameter / Relevant Climate Event		CURRENT CONDITIONS			FUTURE CONDITIONS			Risk Ranking
			Severity	Probability	Risk = Probability x Severity	Severity	Probability	Risk = Probability x Severity	
PROPERTY DAMAGE	S5	Sewer Conveyance	6	6	36	7	6	42	High
EMERGENCY FLOOD MITIGATION	S5	Sewer Conveyance	5	6	30	6	6	36	Med-High
PROPERTY DAMAGE	S5	Dike Overtopping	6	3	18	7	5	35	
PROPERTY DAMAGE	S4	Sewer Conveyance	5	5	25	6	5	30	
EMERGENCY FLOOD MITIGATION	S4	Sewer Conveyance	4	5	20	6	5	30	
PROPERTY DAMAGE	S3	Sewer Conveyance	5	4	20	6	5	30	
EMERGENCY FLOOD MITIGATION	S5	Dike Overtopping	5	3	15	6	5	30	
EMERGENCY FLOOD MITIGATION	S3	Sewer Conveyance	4	4	16	5	5	25	
PROPERTY DAMAGE	S1	Sewer Conveyance	4	4	16	5	5	25	
PROPERTY DAMAGE	S3	Dike Overtopping	5	4	20	6	4	24	
PROPERTY DAMAGE	S4	Dike Overtopping	5	3	15	6	4	24	
EMERGENCY FLOOD MITIGATION	S4	Dike Overtopping	4	3	12	6	4	24	
EMERGENCY FLOOD MITIGATION	S3	Dike Overtopping	4	4	16	5	4	20	Med-Low
PROPERTY DAMAGE	S2	Sewer Conveyance	4	4	16	5	4	20	
EMERGENCY FLOOD MITIGATION	S1	Sewer Conveyance	3	4	12	4	5	20	
DIKE & SEWER INTEGRITY	S5	Sewer Conveyance	2	6	12	3	6	18	
PROPERTY DAMAGE	S2	Dike Overtopping	4	3	12	5	3	15	
DIKE & SEWER INTEGRITY	S4	Sewer Conveyance	2	5	10	3	5	15	
DIKE & SEWER INTEGRITY	S5	Dike Overtopping	3	3	9	3	5	15	
PROPERTY DAMAGE	S1	Dike Overtopping	4	2	8	5	3	15	
DIKE & SEWER INTEGRITY	S3	Dike Overtopping	2	4	8	3	4	12	
EMERGENCY FLOOD MITIGATION	S2	Sewer Conveyance	2	4	8	3	4	12	
DIKE & SEWER INTEGRITY	S4	Dike Overtopping	2	3	6	3	4	12	
EMERGENCY FLOOD MITIGATION	S1	Dike Overtopping	3	2	6	4	3	12	
DIKE & SEWER INTEGRITY	S3	Sewer Conveyance	2	4	8	2	5	10	Low
DIKE & SEWER INTEGRITY	S1	Sewer Conveyance	1	4	4	2	5	10	
DIKE & SEWER INTEGRITY	S2	Dike Overtopping	2	3	6	3	3	9	
EMERGENCY FLOOD MITIGATION	S2	Dike Overtopping	2	3	6	3	3	9	
DIKE & SEWER INTEGRITY	S2	Sewer Conveyance	1	4	4	2	4	8	
DIKE & SEWER INTEGRITY	S1	Dike Overtopping	2	2	4	2	3	6	

TABLE D3: RISK SCORING FOR CURRENT CONDITIONS
WEST OF LITTLE RIVER

Performance Measure	Climate Parameter / Relevant Climate Event		CURRENT CONDITIONS			FUTURE CONDITIONS			Risk Ranking
			Severity	Probability	Risk = Probability x Severity	Severity	Probability	Risk = Probability x Severity	
PROPERTY DAMAGE	S5	Sewer Conveyance	6	5	30	7	6	42	Med-high
EMERGENCY FLOOD MITIGATION	S4	Sewer Conveyance	5	5	25	6	5	30	
EMERGENCY FLOOD MITIGATION	S5	Sewer Conveyance	5	5	25	6	6	36	
PROPERTY DAMAGE	S4	Sewer Conveyance	5	5	25	6	5	30	
PROPERTY DAMAGE	S5	Dike Overtopping	6	4	24	7	5	35	
EMERGENCY FLOOD MITIGATION	S3	Dike Overtopping	5	4	20	5	5	25	Med-Low
EMERGENCY FLOOD MITIGATION	S3	Sewer Conveyance	5	4	20	5	5	25	
EMERGENCY FLOOD MITIGATION	S5	Dike Overtopping	5	4	20	6	5	30	
PROPERTY DAMAGE	S3	Dike Overtopping	4	4	16	6	5	30	
PROPERTY DAMAGE	S3	Sewer Conveyance	4	4	16	6	5	30	
DIKE & SEWER INTEGRITY	S5	Sewer Conveyance	3	5	15	3	6	18	
EMERGENCY FLOOD MITIGATION	S4	Dike Overtopping	5	3	15	6	4	24	
PROPERTY DAMAGE	S4	Dike Overtopping	5	3	15	6	4	24	
DIKE & SEWER INTEGRITY	S5	Dike Overtopping	3	4	12	4	5	20	
PROPERTY DAMAGE	S1	Dike Overtopping	4	3	12	5	5	25	
PROPERTY DAMAGE	S1	Sewer Conveyance	4	3	12	5	5	25	
PROPERTY DAMAGE	S2	Dike Overtopping	4	3	12	5	4	20	
PROPERTY DAMAGE	S2	Sewer Conveyance	4	3	12	5	4	20	
DIKE & SEWER INTEGRITY	S4	Sewer Conveyance	2	5	10	3	5	15	Low
EMERGENCY FLOOD MITIGATION	S1	Dike Overtopping	3	3	9	4	5	20	
EMERGENCY FLOOD MITIGATION	S1	Sewer Conveyance	3	3	9	4	5	20	
DIKE & SEWER INTEGRITY	S3	Dike Overtopping	2	4	8	3	5	15	
DIKE & SEWER INTEGRITY	S3	Sewer Conveyance	2	4	8	2	5	10	
DIKE & SEWER INTEGRITY	S1	Dike Overtopping	2	3	6	3	5	15	
DIKE & SEWER INTEGRITY	S2	Dike Overtopping	2	3	6	3	4	12	
DIKE & SEWER INTEGRITY	S4	Dike Overtopping	2	3	6	3	4	12	
EMERGENCY FLOOD MITIGATION	S2	Dike Overtopping	2	3	6	3	4	12	
EMERGENCY FLOOD MITIGATION	S2	Sewer Conveyance	2	3	6	3	4	12	
DIKE & SEWER INTEGRITY	S1	Sewer Conveyance	1	3	3	2	5	10	
DIKE & SEWER INTEGRITY	S2	Sewer Conveyance	1	3	3	2	4	8	

TABLE D4: RISK SCORING FOR CURRENT CONDITIONS EAST OF LITTLE RIVER			CURRENT CONDITIONS			FUTURE CONDITIONS			
Performance Measure	Climate Parameter / Relevant Climate Event		Severity	Probability	Risk = Probability x Severity	Severity	Probability	Risk = Probability x Severity	Risk Ranking
PROPERTY DAMAGE	S5	Sewer Conveyance	6	6	36	7	6	42	Med-High
EMERGENCY FLOOD MITIGATION	S5	Sewer Conveyance	5	6	30	6	6	36	
PROPERTY DAMAGE	S4	Sewer Conveyance	5	5	25	6	5	30	
EMERGENCY FLOOD MITIGATION	S4	Sewer Conveyance	4	5	20	6	5	30	Med-Low
PROPERTY DAMAGE	S3	Dike Overtopping	5	4	20	6	4	24	
PROPERTY DAMAGE	S3	Sewer Conveyance	5	4	20	6	5	30	
PROPERTY DAMAGE	S5	Dike Overtopping	6	3	18	7	5	35	
EMERGENCY FLOOD MITIGATION	S3	Dike Overtopping	4	4	16	5	4	20	
EMERGENCY FLOOD MITIGATION	S3	Sewer Conveyance	4	4	16	5	5	25	
PROPERTY DAMAGE	S1	Sewer Conveyance	4	4	16	5	5	25	
PROPERTY DAMAGE	S2	Sewer Conveyance	4	4	16	5	4	20	
EMERGENCY FLOOD MITIGATION	S5	Dike Overtopping	5	3	15	6	5	30	
PROPERTY DAMAGE	S4	Dike Overtopping	5	3	15	6	4	24	
DIKE & SEWER INTEGRITY	S5	Sewer Conveyance	2	6	12	3	6	18	
EMERGENCY FLOOD MITIGATION	S1	Sewer Conveyance	3	4	12	4	5	20	
EMERGENCY FLOOD MITIGATION	S4	Dike Overtopping	4	3	12	6	4	24	
PROPERTY DAMAGE	S2	Dike Overtopping	4	3	12	5	3	15	
DIKE & SEWER INTEGRITY	S4	Sewer Conveyance	2	5	10	3	5	15	Low
DIKE & SEWER INTEGRITY	S5	Dike Overtopping	3	3	9	3	5	15	
DIKE & SEWER INTEGRITY	S3	Dike Overtopping	2	4	8	3	4	12	
DIKE & SEWER INTEGRITY	S3	Sewer Conveyance	2	4	8	2	5	10	
EMERGENCY FLOOD MITIGATION	S2	Sewer Conveyance	2	4	8	3	4	12	
PROPERTY DAMAGE	S1	Dike Overtopping	4	2	8	5	3	15	
DIKE & SEWER INTEGRITY	S2	Dike Overtopping	2	3	6	3	3	9	
DIKE & SEWER INTEGRITY	S4	Dike Overtopping	2	3	6	3	4	12	
EMERGENCY FLOOD MITIGATION	S1	Dike Overtopping	3	2	6	4	3	12	
EMERGENCY FLOOD MITIGATION	S2	Dike Overtopping	2	3	6	3	3	9	
DIKE & SEWER INTEGRITY	S1	Dike Overtopping	2	2	4	2	3	6	
DIKE & SEWER INTEGRITY	S1	Sewer Conveyance	1	4	4	2	5	10	
DIKE & SEWER INTEGRITY	S2	Sewer Conveyance	1	4	4	2	4	8	