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Northrup Group

Hydraulics and Hydrology Report – The Crossing Saint John, New Brunswick

March 6, 2008

Ref. No. B07434

Draft

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Ref. No. B07434

March 6, 2008

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Mr. Troy Northrup
Northrup Group
Ashburn Place
479 Rothesay Avenue
PO Box 1289
Saint John, NB
E2L 4G7

Dear Mr. Northrup:

Re: Hydraulics and Hydrology Report – The Crossing
Draft Report

Please find enclosed a copy of the draft Hydraulics and Hydrology Report for the proposed development of 'The Crossing' in Saint John, New Brunswick. This report outlines the results of the hydrological study of the possible flood levels at the proposed Crossing site, and the potential effects of development on the Marsh Creek watershed.

If you require additional information, please contact the undersigned at your earliest convenience.

Yours truly,

TERRAIN GROUP INC.

Ronald A. Hiltz, P.Eng., CDP

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Terrain Group Inc.
1 Spectacle Lake Drive
Dartmouth, Nova Scotia
Canada B3B 1X7

tel. 902.835.9955
fax 902.835.1645

www.terraingroup.com

1 Introduction and Scope of Work

1.1 Introduction

"The Crossing" is a 46,500 square metre commercial development proposed for a 41 hectare site located between Ashburn Road and Highway #1 in East Saint John. The Crossing site is strategically positioned at a major intersection of traffic accessing and exiting the City of Saint John, putting it in an ideal position to serve tourists and the greater Saint John community. Retail stores, restaurants, food stores, strip mall buildings, a sports and leisure community center, warehouses, office spaces, hotels, cinema, and gas stations are all envisioned for The Crossing.

The proposed site of The Crossing development is located within the Marsh Creek watershed. The Marsh Creek watershed includes a total drainage area of 4,125 hectares consisting of steep bedrock slopes draining into a large marsh basin. Prior to human intervention, the basin was a salt marsh flooded during high tide by the Bay of Fundy. Today, the tides are kept out of the marsh basin by the Courtney Bay Causeway. The Marsh Creek watershed drains to a forebay holding area behind the causeway where it is released at low tide into Courtney Bay through 5 parallel culverts. The culverts are equipped with flap gates to prevent tidal waters from entering the watershed during high tide. Much of the Marsh Creek watershed, including most commercial developments on Rothesay Avenue, McAllister Drive, and the proposed Crossing development, is located within a former tidal area referred to as The Great Salt Marsh, and is therefore located below the ordinary high water mark (ohwm) relative to high tide.

The marsh basin is flat with poor drainage resulting in frequent flooding. Flooding events are compounded by the fact that the watershed can only drain during low tide. The watershed has been the focus of several studies since the early 1970s to identify measures to mitigate freshwater flooding. In the summer of 2007, Terrain Group undertook the creation of a hydraulic and hydrologic model of the Marsh Creek watershed on behalf of the City of Saint John. The purpose of the project was to evaluate the extent of flooding that could be expected during a major storm event, evaluate the effectiveness of previous mitigative work, and to suggest further mitigative measures to reduce flooding.

1.2 Scope of Work

Terrain Group was retained by the developer to provide stormwater master planning for The Crossing as well as evaluate the storage potential of the a 20 hectare parcel of land, located between the CN rail yard and Marsh Creek, which could be considered for potential wetland compensation. The hydraulic and hydrologic model created for the City of Saint John as part of the Marsh Creek Watershed Analysis project was used to determine anticipated flow rates, stormwater storage capacity, and flood elevations anticipated on The Crossing site. The same computer model was then modified to create various scenarios needed to evaluate the effects of development on the rest of the Marsh Creek watershed with and without wetland storage compensation in the Lower Marsh Creek Parcel.

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2 Existing Conditions

The Marsh Creek watershed comprises approximately 4,125 Ha of land in East Saint John, New Brunswick. The landforms found within the watershed are highly variable in nature and range from rocky hills to an extremely flat marsh basin. Marsh Creek is the principle drainage route within the Marsh Creek watershed collecting runoff from several tributary streams. Marsh Creek drains to the Marsh Creek forebay located directly behind the Courtney Bay Causeway. Water is stored in the forebay until the tide elevation in Courtney Bay is below the water elevation in the forebay. Seawater from Courtney Bay is prevented from entering the Marsh Creek watershed by flap gates installed on the 5 culvert outlets.

The Crossing is located within the Little Marsh Creek Sub-Watershed with Little Marsh Creek flowing through The Crossing site. A sketch showing the location of The Crossing site has been included in Appendix A. Lawlor Lake, located near the Brookville Quarry, is the source of Little Marsh Creek. The section of the creek which passes through The proposed Crossing site is very flat resulting in low stream velocities and marsh like conditions. It is located within the boundaries of the former Great Salt Marsh tidal area. Portions of the site are identified on the New Brunswick Wetlands Inventory Map as being environmentally sensitive. If the site was filled to an elevation above the 1:100 Year 24-hour flood elevation, approximately 17,000 m^3 of storage would be eliminated.

A former CN property located on the eastern side of Marsh Creek below the Strescon facility and to the north of the CN trestle located near the intersection of Rothesay Avenue and Russell Street has been identified as property which could be provided as wetland compensation for the development of The Crossing site. See Appendix A for a drawing showing the location of the former CN property. Complete excavation of these lands, referred to as the Lower Marsh Creek Parcel, to create a manmade wetland involves the removal of approximately 356,000 m^3 of soil. This would result in the creation of approximately 20 hectares of manmade wetland and would create approximately 400,000 m^3 of storage. The complete excavation of this parcel of land would require a significant amount of earth works; a more practical approach would be to excavate only the volume of earth equivalent to the required ratio for compensation for lost wetland on The Crossing parcel.

Lands owned by the City of Saint John located on the western side of Marsh Creek, east of Highway 1, and south of Strescon have also been identified as a potential stormwater storage site. These lands are currently protected from flooding by man-made berms along the west bank of Marsh Creek. Breaches could be created in these berms creating approximately 125,000 m^3 of storage, during a 1:100 year, 24-hour storm, contained within the lands owned by the City located between Marsh Creek and Highway 1.

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3 Hydrotechnical Study

Terrain has prepared a hydrologic and hydraulic model of the Marsh Creek watershed system in Saint John, New Brunswick. This section of the report deals with the hydrological and hydraulic modeling work that has been completed to examine the effect on the Marsh Creek watershed of developing "The Crossing", located near Ashburn Road. The model was also used to evaluate the effect on the watershed of creating storage downstream of Ashburn Road.

Hydrology is the study of rate and volume of runoff that occurs from the surface of the land resulting from rainfall and snowmelt events. Factors that influence this runoff include land use, topographic slope, vegetative cover, area of permeable and impermeable surface, moisture content of the soil, and precipitation intensity. Open channel hydraulics is the study of the behaviour of water in channels, pipes, and conduits and the factors that influence it, such as channel size and geometry, channel embankment vegetation and condition, and slope of the channel or conduit. This section of the report examines the hydrology of the watershed system and the hydraulics of the stream system to determine the most applicable stormwater management approach for the development of The Crossing.

3.1 Marsh Creek Watershed System

The watershed area draining to the forebay behind the Courtney Bay Causeway, and subsequently to Courtney Bay totals approximately 4,125 hectares (10,200 acres) and includes approximately 18 individual lakes and ponds. The Upper Glen Falls Reservoir, located near the end of Glen Road, is an earthen dam structure constructed in the 1970s to provide flood mitigation in the Marsh Creek watershed. A floodway located adjacent to the Golden Grove Road also serves to mitigate flooding. The land uses in the Marsh Creek watershed vary greatly and include: high-density residential; low-density residential; commercial; industrial; and, heavily forested land. In considering the hydrology for the overall watershed system, it was necessary to subdivide the watershed into sub-watersheds where different land uses prevail, and into sub-watersheds that are tributary to lakes and significant hydraulic obstacles in the channel system.

The various land uses in a watershed can produce very different runoff characteristics for a given rainstorm. Therefore, specific runoff coefficients have been applied for the various sub-watersheds depending on the land use that exists now or that may exist in the future. In this project, we have used the widely accepted United States Soil Conservation Service (US-SCS) method for calculating runoff from the sub-watersheds. Specific curve numbers (CN) have been used to describe the degree of imperviousness of each sub-watershed. The CN coefficients used span the range from a low of 47 for the forested land, to a high of 98 for the proposed fully developed site of The Crossing.

3.2 Hydrological Analysis

Terrain Group has prepared a computer-based hydrologic and hydraulic model of the Marsh Creek watershed system to estimate the peak stormwater flow to the forebay located behind the Courtney Bay Causeway. Figure 3-1 illustrates, in schematic form, the various hydrologic and hydraulic features of the Marsh Creek watershed System that have been included in the model.

Stormwater flow in the watershed system has been modeled using a computer-based software product known as the "HydroCad Stormwater Modeling System", Version 8. HydroCad is a computer-aided design program for modeling the hydrology of stormwater runoff. The hydrologic component in HydroCad is based largely on hydrologic techniques developed by the US-SCS, combined with other recognized

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hydrologic calculation procedures. For a given rainfall event, these subroutines are used to generate runoff hydrographs at critical locations throughout the watershed system. This model allows the designer to verify that a given drainage conveyance system is adequate to accommodate the area under consideration, and to predict where flooding or soil erosion is likely to occur.

Terrain Group has divided the Marsh Creek watershed into a system of sub-watersheds. The various land uses within each of the sub-watersheds were then identified to approximate infiltration and runoff rates and volumes. Particular geometry, volumetric information and outlet geometry for major lakes, reservoirs, floodways and major hydraulic obstructions (bridges, culverts, etc.) were also input into the model to permit the calculation of the amount of storage available for a given unit of depth at each pond, lake, reservoir, floodway or obstruction and the resulting outflow rate from that node during a runoff event.

The model also required rainfall data for the Saint John area. Rainfall data selected for all analysis was the 1 in 100 year design storm for Saint John, which is based on analysis of historic storms by the Atmospheric Environment Service (AES). Total depth of the selected storm is 163 mm (6.4") for 24 hours. Base flows were introduced at the boundaries of the model to account for the fact that water is flowing in the Marsh Creek system prior to the arrival of a storm event. The base flows are the portion of stream flow which is not a direct result of rainfall runoff. Groundwater infiltration into the streams and lakes accounts for most of the base flow in the system. The model was allowed to run for a 12-hour period prior to the introduction of the storm to allow the base flows introduced at the boundaries of the model to balance throughout the model. Rainfall was distributed using a Chicago Storm distribution throughout the 24-hour storm event. The model was then run to determine the runoff hydrograph from each sub-watershed into and out of each node within the system. The model also generated estimates of the corresponding peak water levels experienced within each of the nodes, the peak volume of storage, and the times that these events occurred.

Of particular interest for this project is the peak flow rate from each of the various ponds and lakes. Peak flows from various critical points in the Marsh Creek system were exported to a hydraulic modeling software program to determine flood levels.

3.3 Hydraulic Analysis

Flood levels in the Marsh Creek watershed system have been modeled using a computer based software product known as the "U.S. Army Corps of Engineers River Analysis System, Version 4.0 Beta" (HEC-RAS). HEC-RAS is an integrated package of hydraulic analysis programs developed by the Hydrologic Engineering Center for the U.S. Army Corps of Engineers. Released in November 2006, the current version of HEC-RAS, Version 4.0 Beta, supports steady and unsteady flow water surface profile calculations, sediment transport/mobile bed computations, and water temperature analysis.

The Marsh Creek watershed model is a steady flow water surface profile based on peak flows from the HydroCAD model previously discussed. The HEC-RAS computational model is based on the one-dimensional energy equation. Energy losses from friction, expressed as Manning's 'n' coefficient; channel contraction/expansion; and various obstructions, such as bridges, culverts and dams are considered in the computations. The momentum equation is used in situations where the water surface profile changes rapidly, such as hydraulic jumps.

The stormwater models prepared during this project include both the hydrology of the sub-watersheds and the hydraulics of the brook and stream channels that carry the flows through the Marsh Creek system.

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Given that the discharge point from the Marsh Creek system is into Courtney Bay through a cluster of 5 parallel culverts under the causeway, the HydroCAD model takes into account that the Marsh Creek system cannot drain when the tide in Courtney Bay rises above the water stored in the forebay. The culverts are equipped with flap gates to prevent water from entering the forebay from Courtney Bay during high tide.

3.4 Hydraulic Models Considered

Four distinct development conditions have been examined:

1. Scenario 1: The Existing Condition;
2. Scenario 2: The Crossing Site Fully Developed and No New Storage Provided Downstream;
3. Scenario 3: The Crossing Site Fully Developed and The Lower Marsh Creek Parcel Excavated to Provide a Wetland; and
4. Scenario 4: The Crossing Site Fully Developed and The Lower Marsh Creek Parcel Excavated to Provide a Wetland and the Berms on the West Side of Marsh Creek Breached to Provide Storage on City Lands.

Scenarios that consider The Crossing site to be fully developed assume that the Little Marsh Creek cross-section has been upgraded to the cross-section proposed by Terrain. A diagram of the proposed cross-section has been included in Appendix B.

Each of these cases is discussed in the following sections of the report.

Scenario 1 - The Existing Condition

The hydraulic performance and flood limits of the existing Marsh Creek Watershed been modeled for comparison and calibration purposes.

Scenario 2 – The Crossing Site Fully Developed and No New Storage Provided Downstream

This scenario represents the full development of The Crossing Site, approximately 41 hectares of currently undeveloped lands. As part of this development scenario, the cross-section of Little Marsh Creek has been upgraded to improve hydraulic performance where it flows through the site (Appendix B). Full development of The Crossing will eliminate 17,000 m^3 of storage. This scenario does not include any downstream improvements.

Scenario 3 - The Crossing Site Fully Developed and The Lower Marsh Creek Parcel Excavated to Provide a Wetland

This scenario includes the full development of The Crossing site and the upgrades to the Little Marsh Creek cross-section mentioned in Scenario 2. This scenario also includes the development of the Lower Marsh Creek Parcel into a man-made wetland used for storage during storm events (Appendix A). For the purpose of the model, the entire Lower Marsh Creek Parcel is assumed to be excavated to the approximate ordinary high water level in Marsh Creek with 3:1 slopes to existing ground surrounding the parcel. This excavation would require the removal and disposal of approximately 356,000 m^3 of soils.

According to the existing conditions model, a 1:100 Year, 24-hour duration storm will result in the storage of approximately 175,000 m^3 of water on the Lower Marsh Creek Parcel. The corresponding flood level is 3.5 m above mean seal level (amsl). Following excavation of the parcel as described above, during the same 1:100 Year, 24-hour duration storm, flood water levels are reduced to approximately 3.27m amsl. The resulting volume of water stored on the excavated Lower Marsh Creek Parcel is

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371,000 m³ representing a net increase of 196,000 m³ of storage due to the excavation. This scenario, where the entire Lower Marsh Creek Parcel is excavated, was modelled for the purpose of demonstrating the maximum, theoretical effect that could be realized on the watershed by creating downstream storage in this area. In actual practise it is not practical to excavate the entire parcel due to factors such as; land elevation for development of a walking trail/park lands, cost of the excavation and disposal of excavated materials. Additionally, as these a portion of lands were formally used for industrial purposes, there is potential that some of the soils on the Lower Marsh Creek Parcel could be "impacted soil" requiring special treatment and disposal. In practise, it may be more practical to provide a volume of storage on this parcel which is equivalent to the required ratio for compensation required for lost wetland on the main parcel.

Scenario 4 - The Crossing Site Fully Developed and The Lower Marsh Creek Parcel Excavated to Provide a Wetland and the Berms on the West Side of Marsh Creek Breached to Provide Storage on City Lands

This final scenario includes the full development of The Crossing site; the upgrades to the Little Marsh Creek cross-section; and the development of the Lower Marsh Creek Parcel into a manmade wetland as discussed in Scenario 3. Scenario 4 also includes the breaching of the berms located on the west side of Marsh Creek so that the City Lands located east of Highway 1, and south of the Strescon lands will be used for storage during significant rainfall events. During a 1:100 Year, 24-hour storm, removal of the berms will provide 125,000 m³ of new storage in addition to the 175,000 m³ provided by the Lower Marsh Creek Parcel. The total new storage created by Scenario 4 is 300,000 m³.

3.5 Model Calibration

Given the complex nature of this watershed, it is necessary to compare the model output to observed flow rates and water levels to confirm the validity of the model. During the spring, summer and fall of 2007, Terrain Group maintained a series of 14 Solinst Leveloggers throughout the Marsh Creek watershed in conjunction with a weather station located at the City of Saint John Operations Building at 175 Rothesay Avenue. At four locations, leveloggers where placed on the upstream and the downstream side of hydraulic structures, such as culverts, so that the flow could be determined based on the headloss measured between the two leveloggers. The remaining leveloggers were placed throughout the watershed to monitor water levels.

On November 3, 2007, the City of Saint John experienced rainfall as the remnants of hurricane Noel passed through the region. The result of the storm was 60.4 mm of rain measured at the 175 Rothesay Avenue weather station over a period of 16 hours. This storm was chosen for calibration as the most significant rainfall to occur during the spring, summer and fall of 2007. Calibration of the HydroCAD model was based on four locations within the watershed representing areas where significant flow is introduced to Marsh Creek and its tributaries. The calibration focused on three criteria; peak flow, overall fit of the hydrograph, and total volume of flow over 72 hours. Fit of the hydrograph was evaluated using an R^2 statistical analysis. R^2, or the coefficient of determination, is a value between 0 and 1 which represents the proportion of variation in the measured data that can be explained by the model. A value of 1 represents a perfect fit while 0 represents no correlation between measured values and the model. For example, an R^2 of 0.7 means that the model explains approximately 70% of the variation in the measured data. The remaining variation is due to other factors that were not included in the model.

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During calibration of the model, Terrain also looked at historical rainfall data from Environment Canada and at Flood Risk Mapping prepared by Proctor and Redfern Limited in 1979. The Proctor and Redfern Flood Risk Map is based on flooding evidence from a storm that occurred in 1975. On November 13/14 of 1975 approximately 169.9 mm of rain fell over a 24-hour period as measured by the rain gauge located at the Saint John airport. This storm compares closely with the statistical 1:100 Year, 24-hour rainfall of 163 mm and, thus, the November 1975 was considered by Terrain to be a 1:100 Year storm for calibration purposes.

The HEC-RAS model was calibrated by comparing the peak modelled water surface elevations to those peak elevations measured by the leveloggers during the November 3rd, 2007 storm. The HEC-RAS model was also evaluated by comparison of the modelled water elevations from the 1:100 year, 24-hour storm to the Flood Risk Mapping based on historical evidence from the November 13/14, 1975 storm.

Based on the measured flows, measured water levels and the historical flood mapping by Proctor and Redfern, and the flows and water levels estimated in the model, it is our opinion that this model creates a reasonably accurate representation of this watershed during extreme runoff events.

3.6 Analysis

Water elevations were evaluated for each scenario at three locations in the Marsh Creek watershed. These locations were chosen to represent distinct regions of the watershed. The first location is immediately upstream of the culvert under Highway #1 (LOC#1) at Foster Thurston. This location represents the areas prone to flooding on the Ashburn Creek and Little Marsh Creek tributaries. The second location is between Rothesay Avenue and Ashburn Road at the intersection of Marsh Creek with Little Marsh Creek (LOC#2). This location was chosen to provide an indication of the effects development would have on flooding in the upper reaches of Marsh Creek. The third location is just upstream of the CN trestle bridge located near the intersection of Rothesay Avenue and Russell Street (LOC#3). This location provides an indication of the effect that development would have below the proposed storage areas.

Table 3.1 – Peak Water Elevation at Various Locations
During a 1:100 Year, 24 Hour Duration Storm Event

	LOC#1	LOC#2	LOC#3
Scenario 1 – Existing Conditions	4.08m	3.97m	3.43m
Scenario 2 – Developed	4.08m	3.95m	3.40m
Scenario 3 – Developed w\ Lower Marsh Creek Parcel	4.04m	3.91m	3.20m
Scenario 4 – Developed w\ Lower Marsh Creek Parcel and City Lands Storage	4.02m	3.89m	3.12m

3.7 Results

The results obtained from the stormwater models indicate that development of The Crossing will not have a negative effect on flooding in the Marsh Creek watershed. The models predict that the water elevation experienced just upstream of the Highway #1 culvert will be the same following development of The Crossing as compared to the existing condition. While development of The Crossing will result in a greater peak discharge from the site than is currently experienced, the peak water elevation is unaffected because this additional water will be discharged before the bulk of water from the Little Marsh Creek Sub-Watershed reaches the marsh.

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In the models, development of The Crossing results in a decrease of between 2 and 3 centimetres in the peak flood elevations at the other two locations of interest. The models are not refined enough to predict water levels to within a couple of centimetres. However, the fact that these water levels are shown to have decreased slightly indicates that development of The Crossing will lead to a slight decrease in flood levels in the Marsh Creek watershed, or at least not exasperate the current flooding situation. Again, this appears to be due to the fact that the additional runoff from the developed Crossing site would be discharged well before the peak of the total system is experienced. This phenomena is associated with the development of land areas which are much smaller than the total watershed.

Development of storage by creation of a man-made wetland on the Lower Marsh Creek Parcel and by breaching the berms on the western bank of Marsh Creek at the City Lands will reduce flooding throughout the Marsh Creek watershed. The greatest reduction to the flood water elevation will be experienced in the reach of Marsh Creek below the proposed storage areas, that being between the CN trestle bridge and the Courtney Bay Forebay. In this area, the models predict that the peak flood elevation during a 1:100 year return period would be reduced by 31 centimetres or approximately 1 foot. In the other locations of interest, the models predict a reduction of approximately 6 centimetres in the peak flood water elevation. Development of downstream storage has a significant positive effect on water levels in the reaches of Marsh Creek that are not currently experiencing significant flood risk and has a minor positive effect or no negative impact on flood water elevations in the remainder of the Marsh Creek Watershed.

The development of The Crossing site will increase the total volume of stormwater runoff from the site due to replacement of permeable surfaces with hard, impermeable surfaces such as concrete and asphalt. However, the development will not substantially increase the peak water level in the former Great Salt Marsh tidal area due to the timing of the peak stormwater flow from the site compared to the flow from the rest of the watershed. The additional runoff developed on The Crossing site will have discharged to the forebay or to Courtney Bay before the bulk of the water from the rest of the watershed reaches the former Great Salt Marsh tidal area. Excavation of the Lower Marsh Creek Parcel and the City Lands will replace displaced storage volume.

The development of The Crossing has no negative impact on flooding in the Marsh Creek watershed whether the storage is constructed or not.

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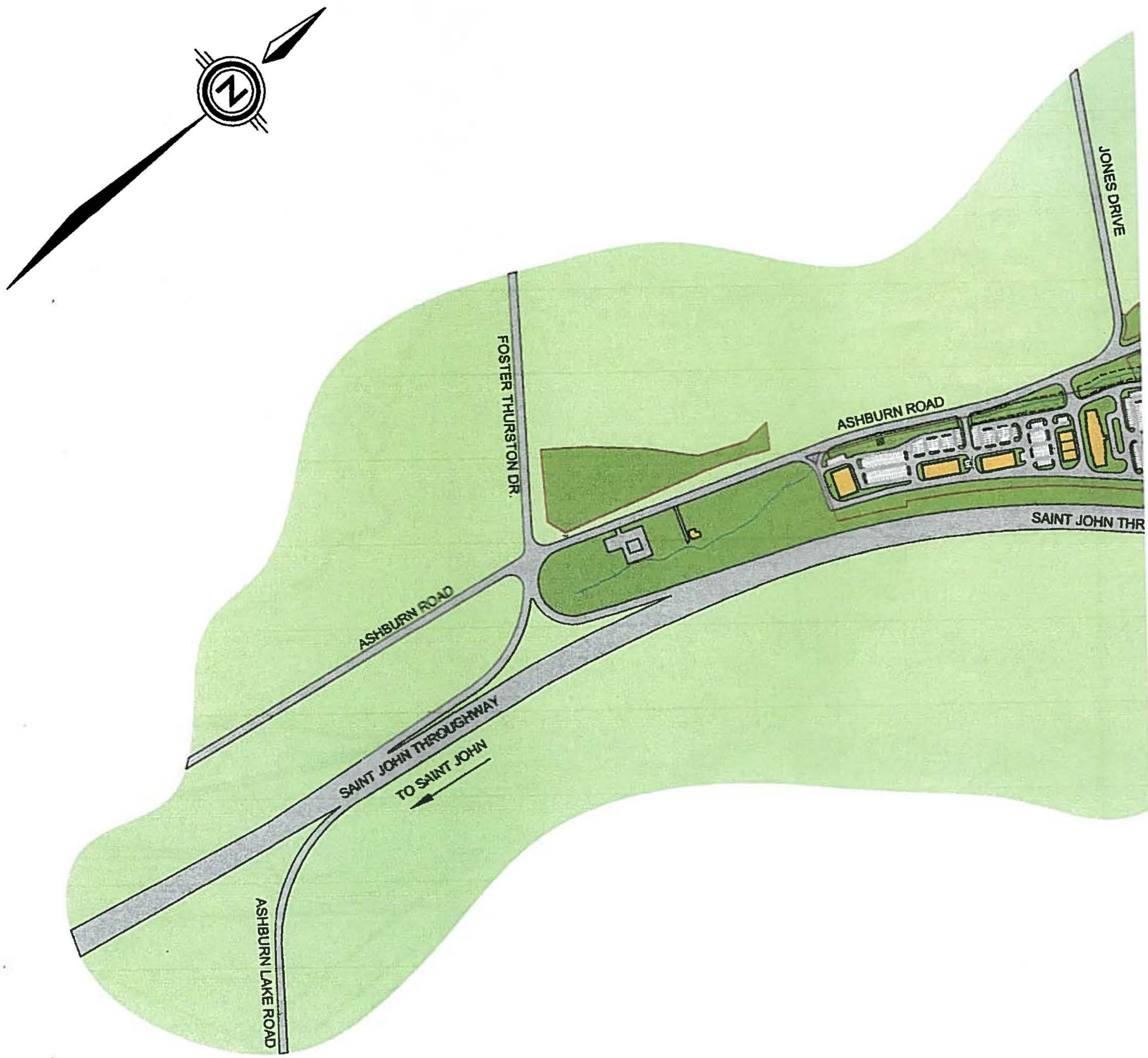
Appendix A
Sketch Showing
Location of The Crossing Site



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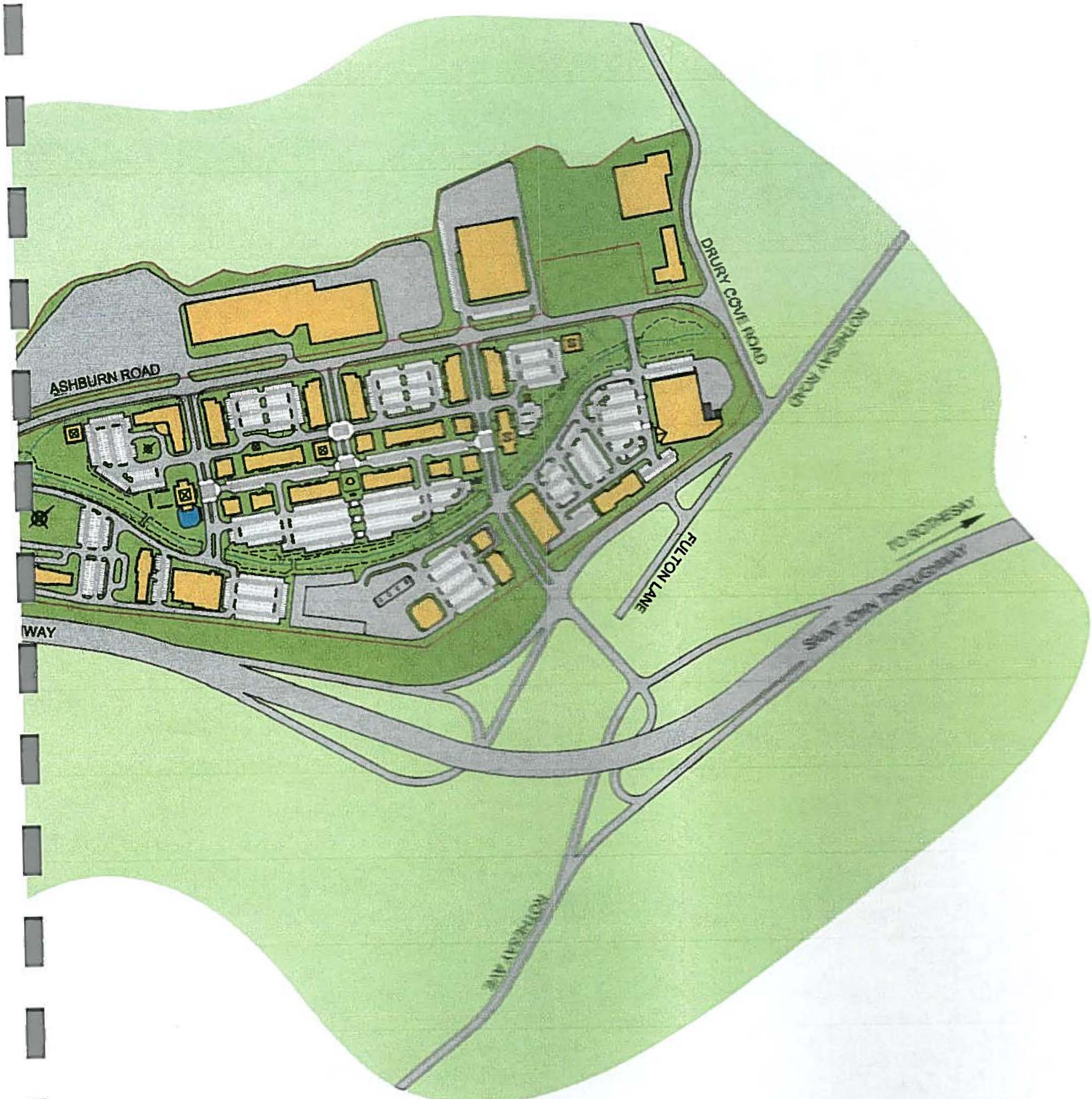
Terrain Group Inc.
1 Spectacle Lake Drive
Dartmouth, NS
B3B 1X7

tel. 902.835.9955
fax. 902.835.1645
www.terraingroup.com
info@terraingroup.com



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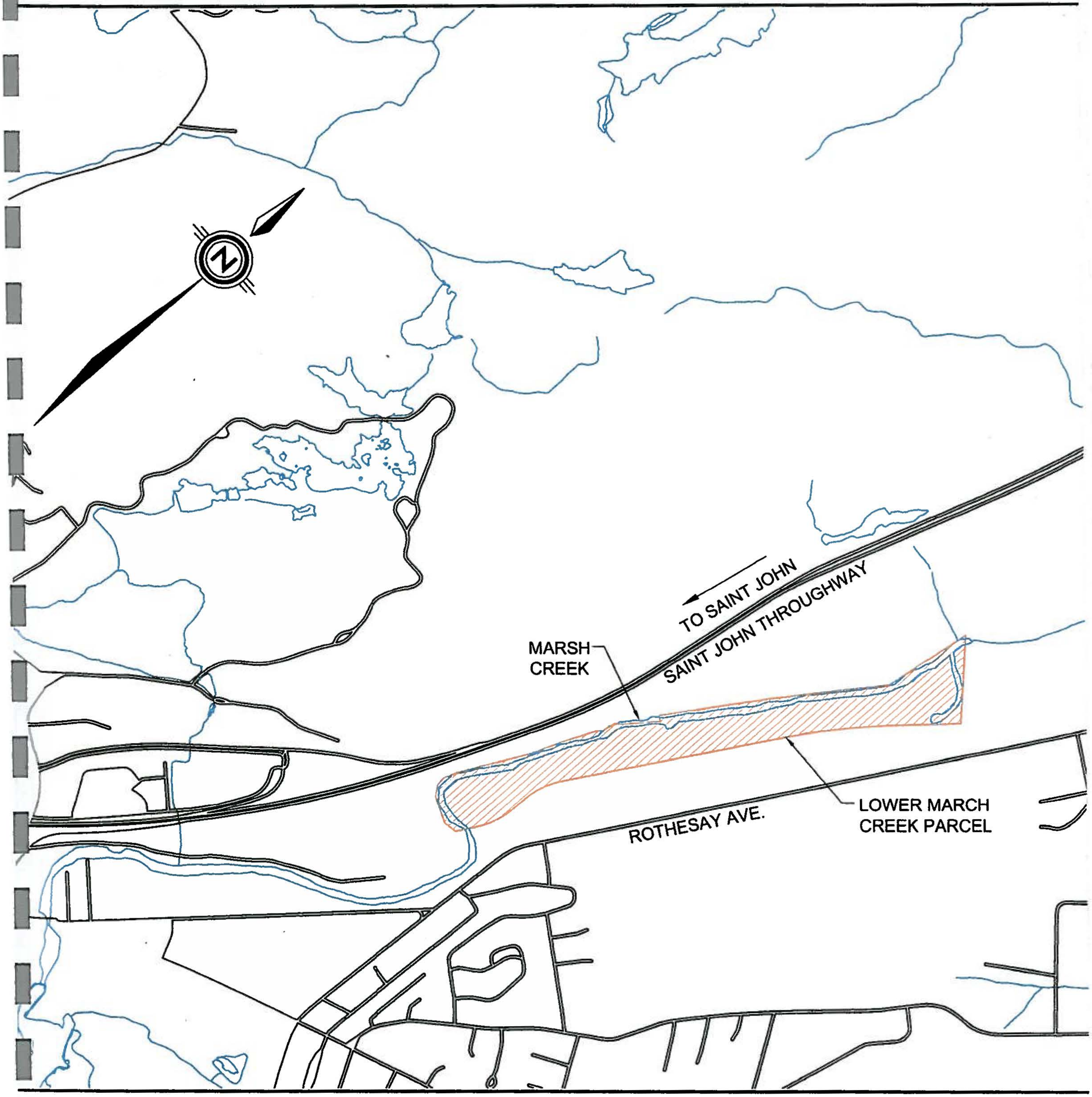

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Terrain Group Inc.
Spectacle Lake Drive

tel. 902.835.9955
www.terraingroup.com
info@terraingroup.com

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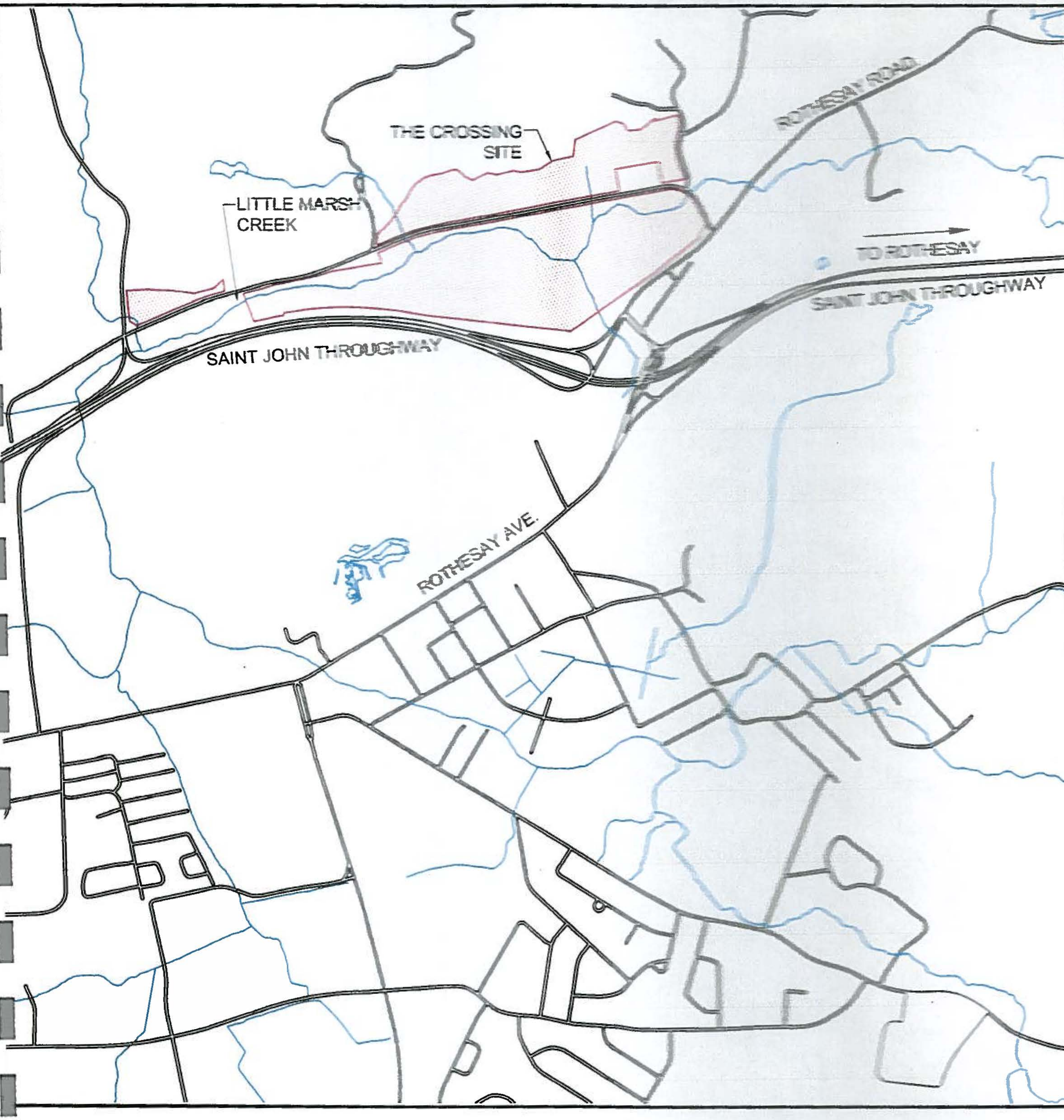
APPEND

SITE PLAN SHOWING LOWER



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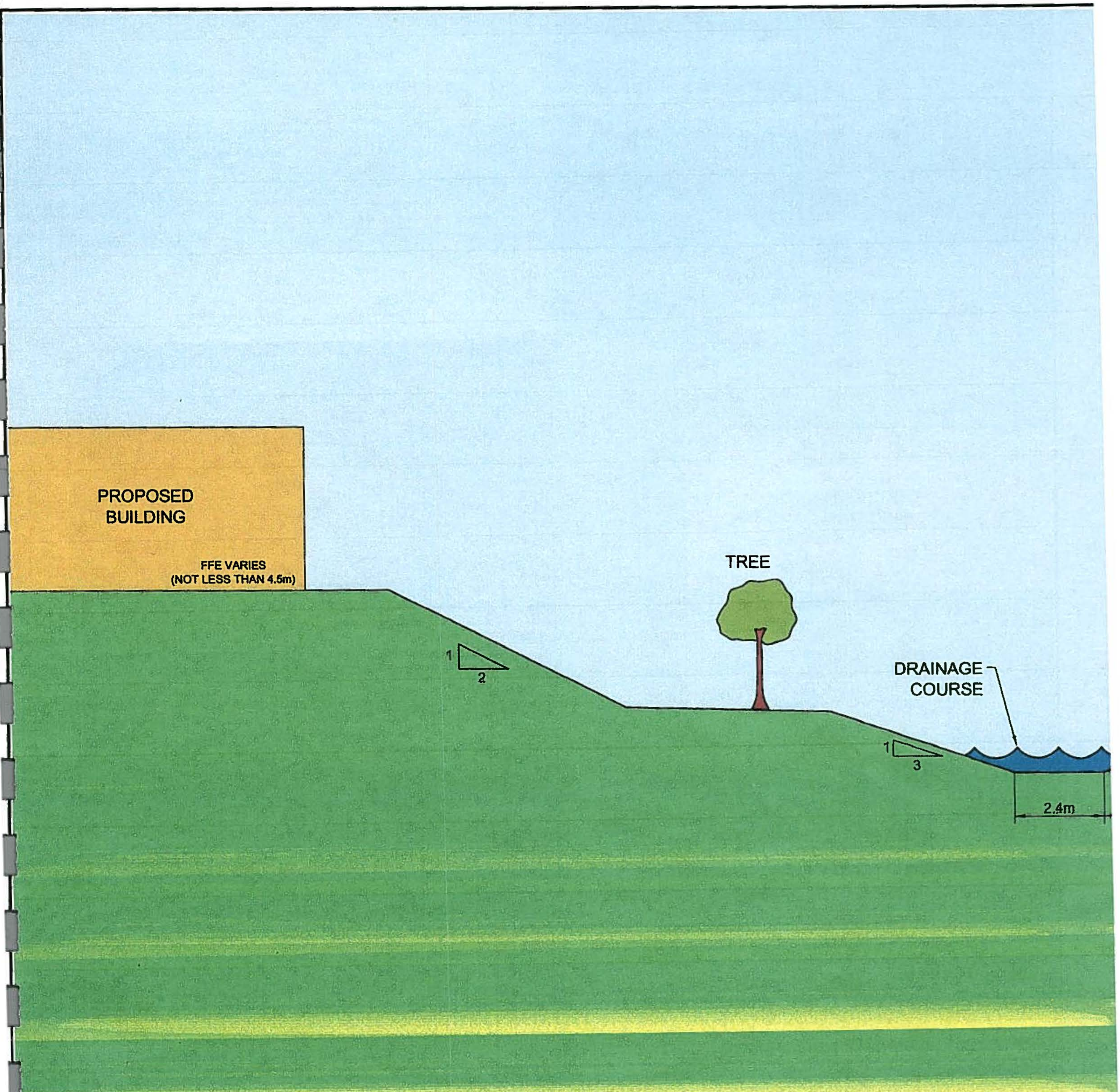
Appendix B
Proposed Cross Section



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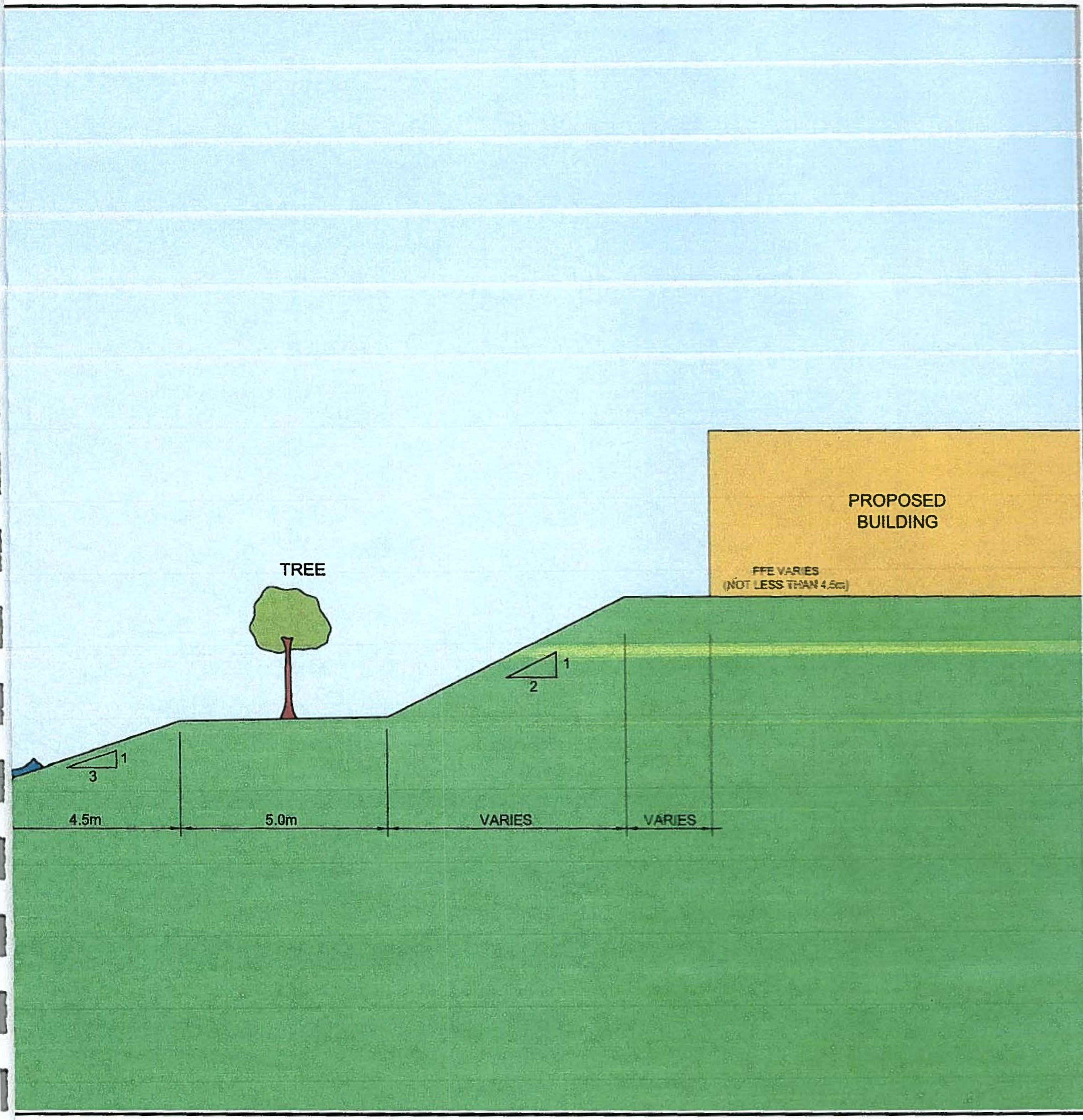

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DIX 'B'

SE CROSS SECTION

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