newfoundland labrador hydro
a nalcor energy company

Hydro Place. 500 Columbus Drive.
P.O. Box 12400. St. John's. NL
Canada A1B 4K7
t. 709.737.1400 f. 709.737.1800
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August 2, 2019

Minister of Municipal Affairs and Environment
PO Box 8700
St. John's, NL
A1B 4J6
Attention: Director of Environmental Assessment

Newfoundland and Labrador Hydro would like to take this opportunity to submit project registration for a Flood Control Berm at the Springdale Terminal Station pursuant to the Environmental Assessment Regulations, 2003. Attached are 10 bound copies and 1 digital copy of the registration documents.

If you have any questions or concerns you may contact me at (709) 737-1938.

Regards,

Chad Evans
Environmental Services

Attachment
cc Rod Healey
Troy Butler

Registration Pursuant To The

Environmental Assessment Regulations 2003

under the

Environmental Protection Act
(O.C. 2003-220)

For The Proposed

Flood Control Berm at the Springdale Terminal Station

August 2019

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1.0 Name of Undertaking

Flood Control Berm at the Springdale Terminal Station

1.1 Proponent

Newfoundland and Labrador Hydro
A Nalcor Energy Company
500 Columbus Drive
P.O. Box 12400
St. John's, NL
A1B 4K7

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Vice President, Engineering Services
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1.2 Principal Contact Person

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2.0 Project Rationale

Newfoundland and Labrador Hydro (Hydro), a Nalcor Energy Company, is the major supplier of electrical power and energy in the Province of Newfoundland and Labrador. On the Island of Newfoundland Hydro owns and operates hydroelectric generating plants at Bay d'Espoir (604 MW), Cat Arm (127 MW), Hinds lake (75 MW), Upper Salmon (84 MW), Granite canal (40 MW) and Paradise River (8 MW). In addition, it operates an oil fired generating station (490 MW) at Holyrood and 4 Gas Turbines (250 MW) at Hardwoods, Stephenville and Happy Valley-Goose Bay. Hydro operates 24 diesel plants (57.5 MW) within the province. In Labrador, Hydro is the majority owner of the Churchill Falls Hydroelectric Generating Facility (5,400 MW). Hydro maintains and operates approximately 4,400 km of transmission lines and 3,500 km of distribution lines to support its generation facilities.

The Springdale Terminal Station (SPL TS) is located on the 138 kV transmission system between Stony Brook and Howley. The station supplies power to NL Power customers in the Springdale area and is located just west of where Davis Brook passes under Beachside Road (Route 392).

Davis Brook (a tributary to the Indian River) flows in a southerly direction and flooding occurs at the terminal station via overland flow across Route 392 and pooling downstream of the site. Significant flooding events have occurred in April 2006 and again in April 2015. On both of these occasions, water levels exceeded the door threshold elevation and entered the control building. During the 2015 flood event, water levels were high enough to infiltrate a control cabinet and damage a protective relay. The damage caused a trip of TL223 and resulted in an outage to NL Power customers. Figure 2-1 shows the terminal station under flood conditions.

Figure 2-1: Flood Conditions at Springdale Terminal Station

The proposed undertaking is required to prevent the flooding of the terminal station, ensuring a safe work environment and reliable operation for customers.

3.0 Project Alternatives

Hydro commissioned Stantec Consulting Limited (Stantec) to complete several hydrological models of the area to investigate different options which could mitigate the flooding observed at the site. In 2017, an initial model was completed in HEC-RAS (Hydrologic Engineering Centre’s River Analysis System) using available topographic data and varying failure conditions such as partial culver blockage at Davis Brook and Route 392.

This initial study investigated the following options and identified what was deemed the most cost effective for further analysis:

- Route 392 Culvert Replacement
- Upstream Detention with Berms
- Perimeter Site Ditching
- Berm Around the Site
- Realign Lower Little Bay Road
- Underground/Above Ground Detention
- Redirecting Runoff to Indian Brook
- Redirecting Portion of Watershed

The 2017 study identified upstream retention berms, culvert replacement and redirecting runoff as the most favorable options to mitigate the flood conditions. This report is included as Appendix A attached to this document.

<u>2017 Upstream Berms</u>

Approximately 400 m of retention berms were added to the hydraulic model upstream of Route 392 which prevented the flooding in the station from water moving across Route 392. The addition of these berms led to flooding of the station via pooling from Davis Brook downstream of the roadway. An additional berm was added along the east side of the site and west side of Little Bay Road. Modelling showed this option effectively prevented flooding at the site and reduced flooding at downstream residences.

<u>2017 Upgrade Route 392 Culverts</u>

The hydraulic modelling was modified to simulate the replacement of existing culvert arrangement in Route 392 at Davis Brook. Current configuration includes a series of 6 culverts for a total end area of 14.94 m2 to pass water. A bottomless box culvert with end area of 26.69 m2 was evaluated in the hydraulic model. It was also noted that this option would require the elevation of Route 392 to be raised approximately 2 metres to accommodate the structure.

The analysis revealed that despite the increase in end area to pass water, the culvert upgrade was ineffective in reducing the flooding at the station. The flat nature of the riverbed and terrain causes water to naturally pool and flood at the site. To confirm this, the model was again run with the culverts and road way removed, allowing Davis Brook to flow unimpeded. Since similar flood predictions were observed in the model, it was deemed ineffective to upgrade the culverts as a means to mitigate flooding at the site.

2017 Diversion of Flow to Indian Brook

This mitigation option would include approximately 720 m of new ditching along the northwest side of Route 392 which would divert water from Davis Brook into Indian Brook to the southwest of the terminal station. This strategy would prevent overland flow across Route 392 and into the terminal station under flood conditions. As the water would be diverted, there would be less pooling and flooding downstream. Hydraulic modelling of this scenario shows that the ditching would be effective in mitigating the flooding observed at the terminal station and would reduce the amount of flooding observed at residential properties downstream of the station.

In 2018, Stantec completed additional work on the project with the goal to refine the model inputs to increase level of accuracy, and develop realistic opinions of probable cost for options that were previously identified. A new topographic survey was completed to refine the elevation data used as input to the hydraulic modelling. Only the retention berms and diversion ditch options were carried forward as it was determined replacement of culverts in Route 392 at Davis Brook was not a viable option. This report is included as Appendix B attached to this document.

2018 Berm Analysis

Based on site observations and new model data, the 2018 study refined the placement of the berms and reduced the total number of berms required to achieve the desired model outcome. The following summary was produced for this option:

Advantages	No interference with existing infrastructure
	Operation and Maintenance are reasonable
	Potential source of berm construction material nearby
Disadvantage	Requires modification of roadway
	Multiple permitting agencies
	Environmental Assessment required
	Potentially increase flood levels downstream of station
	Excavation in boggy areas and significant dewatering
	Increased head upstream of Route 392
	Impedance to site dewatering should flooding of the terminal station occur
	High cost in relation to approved budget

2018 Diversion Ditch Analysis

Topographic survey results showed that there is little elevation difference along the proposed ditch and 0.2% would be the maximum achievable slope of the diversion way without significantly altering the grades of accessways off Route 392. This option was not able to be validated by the hydraulic model as a viable means to mitigate flooding at the terminal station.

The following summary was produced for this option:

Advantages	Does not interfere with existing infrastructure
	Operation and maintenance are reasonable
	Lowest cost option
Disadvantages	Does not alleviate flooding at the terminal station
	Requires modification of roadway
	Multiple permitting agencies

In 2019, a third option was added to the study which included evaluation of a perimeter berm which had not been carried forward in 2017. This option also included relocation of the main access point to the terminal station. The hydraulic analysis showed that the perimeter berm, new access and associated culverts were effective at preventing floodwater from entering the terminal station. Analysis also showed an improvement in flood conditions at downstream properties however flood conditions are still expected to occur there. This report is included as Appendix C attached to this document.

The opinion of probable cost for this option was significantly lower than the offsite berms which had been previously investigated proving this option as the best value to be carried forward for construction. Figure 3.1 shows the modelled output for the area with the perimeter berm in place for a 1 in 100 year flood.

Figure 3.1: Hydraulic Modelling of the Perimeter Berm Option

4.0 Project Objectives

The objective of the proposed undertaking is to prevent flood conditions at the NL Hydro Springdale Terminal Station. Historical flooding has seen water undulate the control building and short electrical systems resulting in power outages.

To facilitate this objective, an earthen perimeter berm will be constructed around the site, along with new site access and several culverts outside the site to allow for drainage of water away from the outside of the berm. Section 5 describes these project components in more detail.

5.0 Project Description

The Springdale Terminal Station is located on the Northwest edge of the town of Springdale. The property is bound by Route 392 to the north, followed by residential and forested lands. Little Bay Road lies east of the station, followed by Davis Brook which is a tributary to Indian River. Areas to the south and west of the site are largely undeveloped.

Figure 5.1 below identifies the location of the terminal station in relation to the town of Springdale, Davis Brook and adjacent properties.

Figure 5-1: Aerial Images of Site and Surrounding Area

Hydro intends to construct an earthen perimeter berm and relocate terminal station vehicle access. Hydraulic modelling has shown that a berm with design parameters as indicated in Table 5.1 would provide effective mitigation measure for the terminal station with no adverse effect on nearby properties. Also included in the scope of this project would be

- The relocation or raising of two (2) transmission anchor guy wires associated with existing infrastructure at the site;
- The installation of two (2) an additional culverts. The additional culverts will be located under the new access road to the station and the other under Little Bay

Road. These will ensure that access road does not create a damming effect and runoff can freely drain to Davis Brook

Table 5.1: Conceptual Design Parameters for Proposed Perimeter Berm

Aspect	Design
Total Berm Length	270 metres
Berm Top Width	1.0 metres
Berm Bottom Width	4.0 to 6.0 metres
Berm Top Elevation	22.43 to 23.18 metres
Berm Height	1.0 metres
Berm Side Slopes	2:1
Riprap Erosion protection on the outward facing side or reinforced geofabric	

It is also anticipated that the construction of the berm will require adjustments to site grading to allow water to drain from the site. The cost estimate has included swales, elevation adjustments and a sump/pump to remove water if required.

Figure 5.2 shows the conceptual design and location of the berm around the perimeter of the station.

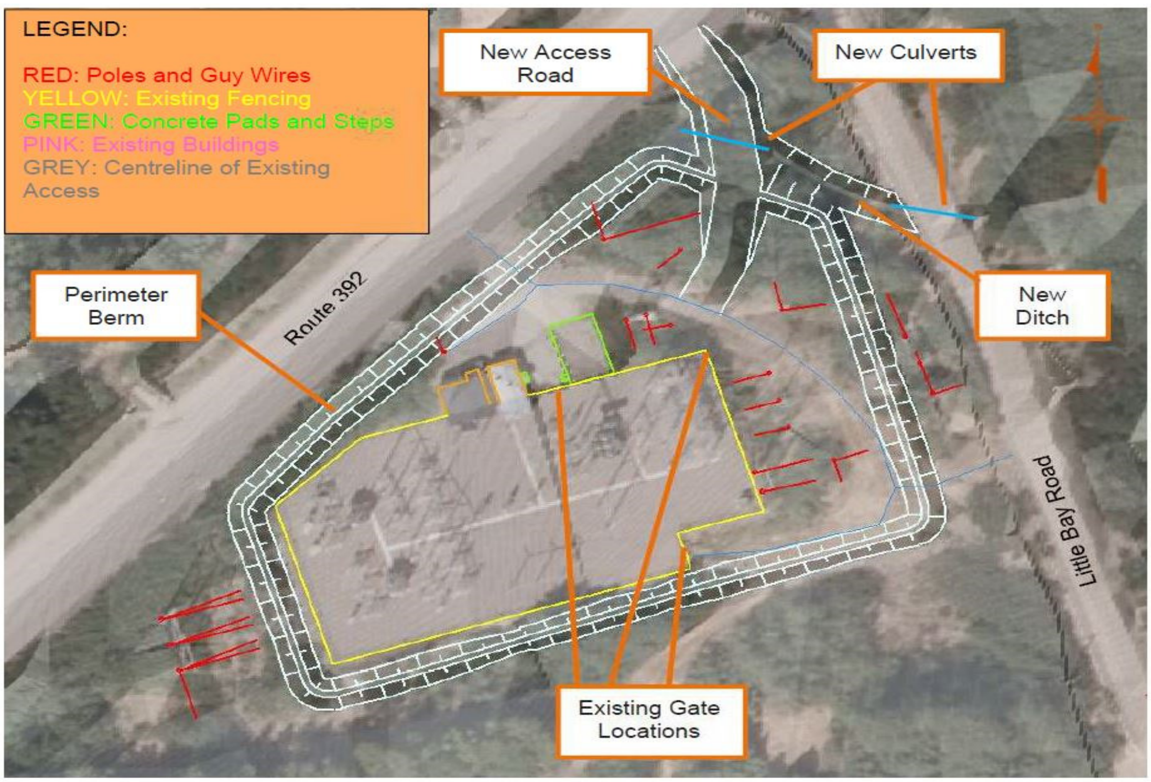

Figure 5-2: Proposed Perimeter Berm, Access Road and Existing Infrastructure

6.0 Project Key Environmental Aspects

The key environmental aspects of this Project include; work within 200 metres of scheduled Salmon waters, adjacent properties, terminal station drainage, construction noise and public consultation. These key environmental aspects are discussed below.

6.1 Scheduled Waters Within 200 metres of Project Site

Based on Section 28 in the Environmental Assessment Regulations, 2003 ": An undertaking that will occur within 200 metres of the high water mark of a river that is a scheduled salmon river under the Fisheries Act (Canada) shall be registered".
The Newfoundland and Labrador Anglers guide, issued by the Department of Fisheries and Oceans, identifies Indian River (including Davis Brook) as a scheduled Salmon River located in Zone 4 of the province. The Indian River originates upcountry in the Birchy Lake Watershed and flows in an easterly direction eventually discharging to salt water in the Town of Springdale. Davis Brook, located approximately 100 metres east of the Springdale Terminal station is a tributary of the Indian River system.

The works proposed by this undertaking will occur within this 200 metre buffer however do not require any in-water work or physical alteration of the water body. A site specific erosion and sedimentation control plan has been developed for the project to mitigate construction impacts and prevent silt laden runoff from entering Davis Brook. Please refer to Section 9.0 for details on erosion and sedimentation control.

6.2 Adjacent Properties

There are several developed properties which have been identified in the vicinity of the project location. These have been shown below in Figure 6-2. As previously discussed, the primary cause of flooding in this area is from overland flow across Route 392 and pooling of water downstream of the culverts at Route 392 and Davis Brook. The hydraulic modelling study has shown that the construction of the berm will not have the benefit of preventing flooding at adjacent properties. However, modelled results shows that the level of flood water will remain the same as current day or marginally improve through the work proposed by this undertaking.

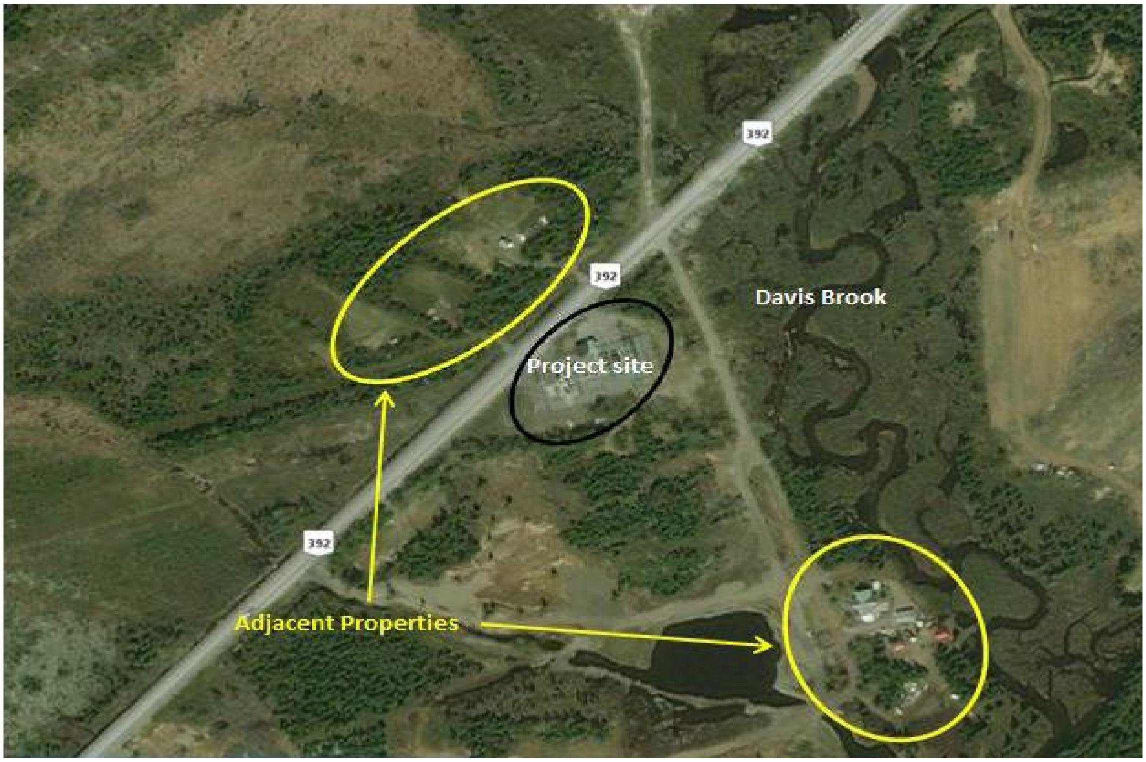

Figure 6-2: Properties Adjacent to Project Site

There may be short term inconvenience for these properties (and other roadway users) during the construction phase of the project. It is likely that there will be temporary lane closures on Route 392 during construction of the berm that runs adjacent to the roadway. A traffic management plan will be developed for the project prior to the start of work.

The scope of work also includes a new culvert be installed at Little Bay Road to the east of the site. Installation of this culvert will create a short term disruption of access for the property identified to the southeast of the terminal station.

6.3 Terminal Station Drainage

Following construction of the perimeter berm, changes to site grading may also necessitate the installation of a sump pit and pump. The purpose of this would be to remove any accumulated precipitation that may not naturally dissipate following large precipitation events or spring snow melt.

Should this be required, a site specific operating procedure will be developed and issued to local staff on requirements for draining water from the sump pit. The procedure will include roles and responsibilities as well measures to ensure all requirements for discharge contained in the *Environmental Control Water and Sewage Regulation, 2003* are met.

6.4 Construction Noise and Dust

Construction of project components will require the use of heavy equipment such as excavators, dump trucks, rollers and compaction equipment. Construction activity will be limited to daylight hours to minimize the noise disruption on adjacent properties. The site is located adjacent to a paved road so dust suppression may not be necessary. If required, standard and approved dust suppression methods will be employed.

6.5 Stakeholder Consultation

Consultation for this undertaking was achieved through engagement with key identified stakeholders. A project briefing package was developed for presentation to the Town of Springdale. This content was originally planned to be presented to town council during an in-person session however was independently reviewed by key town personnel due to scheduling challenges. Adjacent landowner was also provided with an information package outlining project components/rationale and were encouraged to provide feedback and concerns.

A response to the briefing package was received from the Public Works Superintendent with the Town of Springdale. These comments were in relation to the detail design of the berm structure, the HEC-RAS model generated via the hydrologic study and protection of critical areas, namely the TW Bridge that acts as a gateway to the community and the adjacent properties. NL Hydro provided an itemize response to the comments received. On July 30, 2019 the Town of Springdale acknowledged the feedback from NL Hydro to the comments previous submitted. The TW bridge infrastructure is outside of the hydraulic influence zone of the HEC-RAS model used for the assessment. The design criteria has been compared to storm water infrastructure design guidelines from the Department of Transportation and Works, and the City of St. John's, and is found to meet, or exceeds in most cases, these criteria.

The adjacent landowner (Perry Pelly, 431 Little Bay Road) was provided with a project fact sheet for review and comment. Based off of phone conservations, he has no objections to the undertaking. Our modelling has predicted no adverse impact to the Pelley property. A small decrease in water level is predicted from 0.36m (assuming 100 year flooding, no mitigation and no culvert blockage at Route 392) to 0.34 m under the same model conditions with the perimeter berm installed at the Hydro terminal station.

The project briefing package provided to the Town of Springdale, project fact sheet provided to the adjacent landowner and copies of correspondence from the Town of Springdale have been attached as Appendix D.

7.0 Occupations

Construction of the perimeter berm will be executed through the public tender process. Stantec will provide the engineered design and a contract will be issued and awarded for the construction phase of the project. The successful contractor will be responsible for engaging all of the construction trades directly. The construction workforce is expected to peak at approximately 10 people. It is anticipated that the contractor will utilize construction labor, heavy equipment operators and surveyors for completion of their work. NL Hydro will assign a construction management representative (CMR) to oversee the work on their behalf. Any necessary modifications to NL Hydro equipment and lines as a result of this project will be completed by internal forces using licensed electricians and powerline technicians.

Following construction, the site will be operated and maintained by existing staff from NL Hydro.

8.0 Project Schedule

It is anticipated that construction for the proposed undertaking will commence in June 2020 and take approximately six (6) weeks to complete. Table 8.1 below outlines milestone dates associated with the project.

Project Milestone	Anticipated Target Date
Submit EA Registration Document	2-Aug-19
Receive Official Environmental Release for Project	16-Sep-19
Complete Detailed Engineering	31-Dec-19
Award Contract for Construction	30-Apr-20
Start Construction of Perimeter Berm	1-Jun-20
Complete Construction of Perimeter Berm	10-Jul-20

Table 8.1: Target Dates for Project Milestones

9.0 Construction Mitigation

During Construction of the perimeter berm standard engineering, environmental and construction practices will be employed. A site specific erosion and sedimentation control plan has been developed for the undertaking and will be implemented prior to the start of any construction activity. During development of this plan, the most recent topographical survey was used to identify key locations around the site where runoff will likely travel and action is required to mitigate the potential off-site migration of silt laden water. The contractor will be responsible for monitoring and maintenance of erosion and sedimentation control equipment on an as required basis. The identified locations where silt fence will be installed are considered approximate and may need to be adjusted upon installation according to site conditions. As noted in Section 6.4, standard and approved dust suppression will be utilized if required. A copy of the erosion and sedimentation plan is included as Appendix E.

10.0 List of Potential Environmental Approvals

The proposed perimeter berm *Project* will require a number of provincial, federal and municipal approvals in relation to its construction and operations activities, which may include those listed in the Table 10.1 below.

Table 10.1: Springdale Terminal Station Flood Control Berm - List of Potential Environmental Approvals Required

Approval Potentially Required	Legislation / Regulation	Project Component / Activity Requiring Approval or Compliance	Department or Agency	Requirements
Release from the Environmental Assessment Process	Environmental Assessment Regulations, 2003 under the Environmental Protection Act	Project	Department of Environment and Conservation	Project within 200m of scheduled salmon river requires registration as an Undertaking.
Cutting Permit Operating Permit	*Forestry Act* and *Cutting of Timber Regulations*	Clearing land areas for the right-of-way, borrow pits, camp sites or laydown areas	Department of Natural Resources	A permit is required for the commercial or domestic cutting of timber on crown land.
Water Use Authorization	*Water Resources Act*	Dust Suppression	Water Resources Division, Department of Environment and Conservation	Water use authorization is required for all beneficial uses of water.
Policy Directives	*Water Resources Act*	Project activities	Water Resources Division, Department of Environment and Conservation	The Department has a number of potentially applicable policy directives in place, including those related to: Infilling Bodies of Water; Use of Creosote Treated Wood in Fresh Water; Treated Utility Poles in Water Supply Areas; Land and Water Developments in Protected Water Supply Areas; Development in Shore Water Zones; and Development in

Approval Potentially Required	Legislation / Regulation	Project Component / Activity Requiring Approval or Compliance	Department or Agency	Requirements
				Wetlands.
Preliminary Application to Develop Land	*Urban and Rural Planning Act, Protected Road Zoning Regulations*	Construction activity	Service NL	A development permit is required to build on and develop land, whether Crown or privately owned, within the building control lines of a Protected Road.
Quarry Permit	*Quarry Materials Act* and *Regulations*	Extracting borrow material	Mineral Lands Division, Department of Natural Resources	A permit is required to dig for, excavate, remove and dispose of any Crown quarry material.
Fuel Tank Registration - Storing and Handling Gasoline and Associated Products	*Environmental Protection Act,* and *Storage and Handling of Gasoline and Associated Products Regulations*	Storing and handling gasoline and associated products	Engineering Services Division, Service NL	Fuel Tank Registration required for storing and handling gasoline and associated products.
Permit for Storage, Handling, Use or Sale of Flammable and Combustible Liquids	*Fire Prevention Act,* and *Fire Prevention Flammable and Combustible Liquids Regulations*	Storing and handling flammable liquids	Engineering Services Division, Service NL	This permit is issued on behalf of the Office of the Fire Commissioner. Approval is based on information provided for the Certificate of Approval for Storing and Handling Gasoline and Associated Products.
Compliance Standard	*Dangerous Goods Transportation Act* and *Regulations*	Storing, handling and transporting fuel, oil and lubricants	Department of Transportation and Works	If the materials are transported, handled and stored fully in compliance with the regulations, a permit is not required. A Permit of Equivalent Level of Safety is required if a variance from the regulations is necessary. Transporting goods considered dangerous to public safety must comply with regulations.
Compliance Standard	*Fire Prevention Act,* and *Fire Prevention Regulations*	On-site structures (temporary or permanent)	Engineering Services Division,	All structures must comply with fire prevention standards.

Approval Potentially Required	Legislation / Regulation	Project Component / Activity Requiring Approval or Compliance	Department or Agency	Requirements
			Service NL	
Compliance Standard	*Environmental Control Water and Sewage Regulation* under the *Water Resources Act*	Any waters discharged from the project	Pollution Prevention Division, Department of Environment and Conservation	A person discharging sewage and other materials into a body of water must comply with the standards, conditions and provisions prescribed in these regulations for the constituents, contents or description of the discharged materials.
Compliance Standard	*Occupational Health and Safety Act* and Regulations	Project-related occupations	Service NL	Outlines minimum requirements for workplace health and safety. Workers have the right to refuse dangerous work. Proponents must notify Minister of start of construction for any project greater than 30 days in duration.
Compliance Standard	*Workplace Hazardous Materials Information System Regulations*, *Occupational Health and Safety Act*	Handling and storage of hazardous materials	Operations Division, Service NL	Outlines procedures for handling hazardous materials and provides details on various hazardous materials.
Compliance Standard	*Fisheries Act*, Section 36(3), Deleterious Substances	Any run-off from the project site being discharged to receiving waters	Environment Canada Department of Fisheries and Oceans	Environment Canada is responsible for Section 36(3) of the *Fisheries Act*. However, DFO is responsible for matters dealing with sedimentation. Discharge must not be deleterious and must be acutely non-lethal.
Compliance Standard	*Migratory Birds Convention Act* and *Regulations*	Any activities which could result in the mortality of migratory birds and endangered species and any species under federal authority	Canadian Wildlife Service, Environment Canada	Prohibits disturbing, destroying or taking a nest, egg, nest shelter, eider duck shelter or duck box of a migratory bird, and possessing a live migratory bird,

Approval Potentially Required	Legislation / Regulation	Project Component / Activity Requiring Approval or Compliance	Department or Agency	Requirements
				carcass, skin, nest or egg, except when authorized by a permit. The Canadian Wildlife Service should be notified about the mortality of any migratory bird in the project area, including passerine (songbirds) and waterfowl species.
Compliance standards; permits may be required.	National Fire Code	On-site structures (temporary or permanent)	Service NL	Approval is required for fire prevention systems in all approved buildings.
Compliance standards; permits may be required.	National Building Code	On-site structures (temporary or permanent)	Service NL	Approval is required for all building plans.
Approval for Waste Disposal	*Urban and Rural Planning Act, 2000,* and Relevant Municipal Plan and Development Regulations	Waste disposal	Community Council	The use of a community waste disposal site in Newfoundland and Labrador by proponents/contractors to dispose of waste requires municipal approval. Restrictions may be in place as to what items can be disposed of a municipal disposal site.
Development or Building Permit		The perimeter berm will encroach the established distance from centerline of Route 392	Department of Transportation	A permit is required for any development or building within prescribed distances from roadways.

Appendix A

Flood Study: Springdale Terminal Station

(Stantec Consulting (May 16, 2017)

Appendix B

Engineering Flood Mitigation Analysis – Springdale Terminal Station

Stantec Consulting (November 1, 2018)

Appendix C

Memo: Engineering Flood Mitigation Analysis – Springdale Terminal Station

Stantec Consulting (February 12, 2019)

Appendix D

Consultation Documents

NL Hydro (July 2019)

Appendix E

Erosion and Sedimentation Control

Flood Study
Springdale Terminal Station

Final Report

Prepared for:
Newfoundland and Labrador Hydro
P.O. Box 12400
500 Columbus Drive
St. John's, NL A1B 4K7

Prepared by:
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May 16, 2017

Revision	Description	Author		Quality Check		Independent Review	
A	Draft	RLJ/DE	01/20/2017	AR	01/20/2017	SS/WW	01/20/2017
0	Final	RLJ/DE	04/10/2017	AR	04/10/2017	SS/WW	04/10/2017

PROVINCE OF NEWFOUNDLAND AND LABRADOR

pegnl ENGINEERING PERMIT J0291

STANTEC CONSULTING LTD.

05371

Signature or Member Number
(Member-in-Responsible Charge)

REGISTERED PROFESSIONAL ENGINEER
PEG Newfoundland and Labrador
PROFESSIONAL ENGINEERS AND GEOSCIENTISTS
DANIEL A. ERL
SIGNATURE
17.05.16
DATE
NEWFOUNDLAND & LABRADOR

Sign-off Sheet

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Prepared by Rachel Jones
(signature)

Rachel Jones

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(signature)

Dan Erl

Reviewed by
(signature)

Sheldon Smith

Approved by Wendy Warford
(signature)

Wendy Warford

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1.0 INTRODUCTION

Newfoundland and Labrador Hydro (Hydro) engaged Stantec in October 2016 to conduct a Flood Study at Springdale Terminal Station. Hydro has experienced flooding at this site in the past and have commissioned this study to investigate the cause and frequency of flooding. This report also outlines recommendations for potential flood mitigation measures.

A Project Background is provided in Section 2, followed by discussion on study data (including site visit and survey activities) in Section 3. Hydrological and hydraulic analyses are detailed in Sections 4 and 5, respectively, followed by discussion of recommended flood mitigation strategies in Section 6. Finally, conclusions and recommendations are provided in Section 7.

2.0 PROJECT BACKGROUND

2.1 DESCRIPTION

Hydro has experienced repeated flooding at the Springdale Terminal Station located in Springdale, Newfoundland, as outlined in Figure 1. The terminal station is located near the north end of Little Bay Road, and approximately 150 m west of where Davis Brook passes under Beachside Road (Route 392) as shown in Figures 2 and 3, respectively.

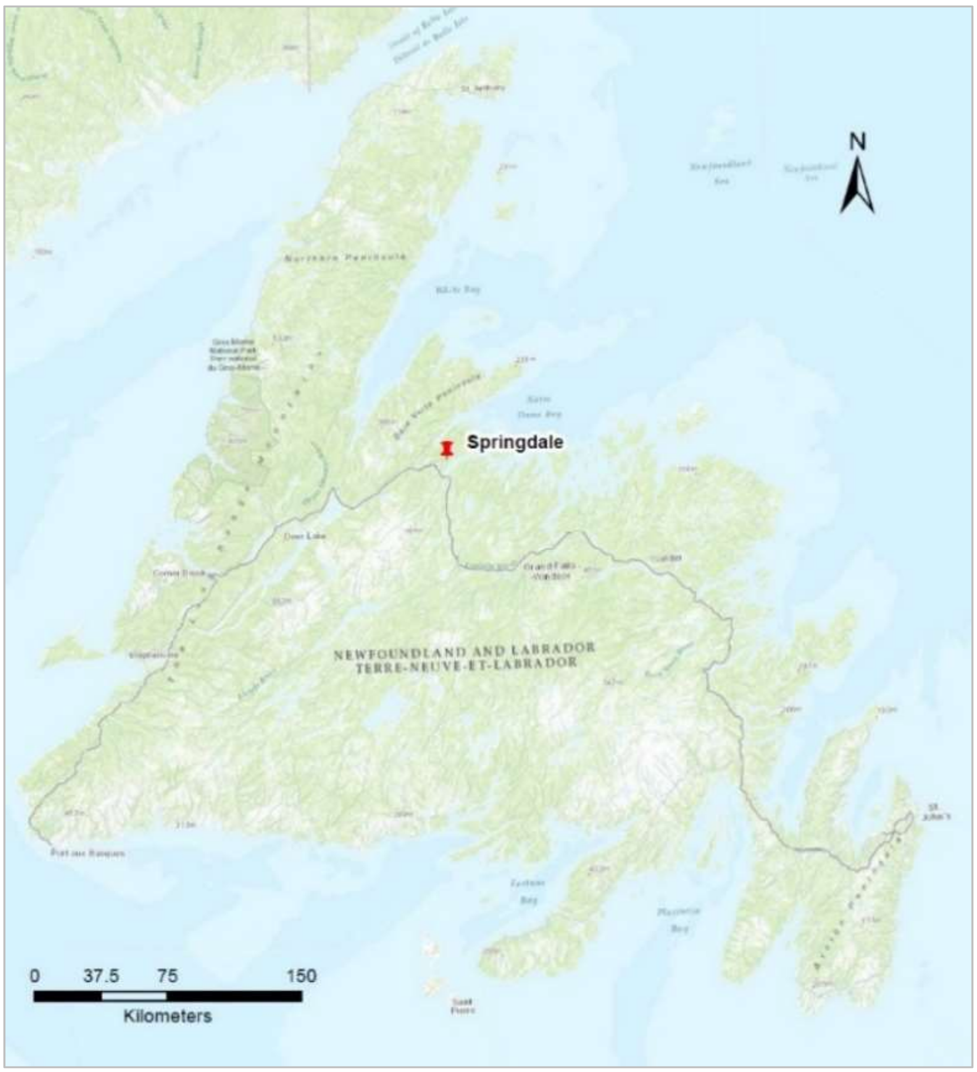


Figure 1 Location of Town of Springdale, NL

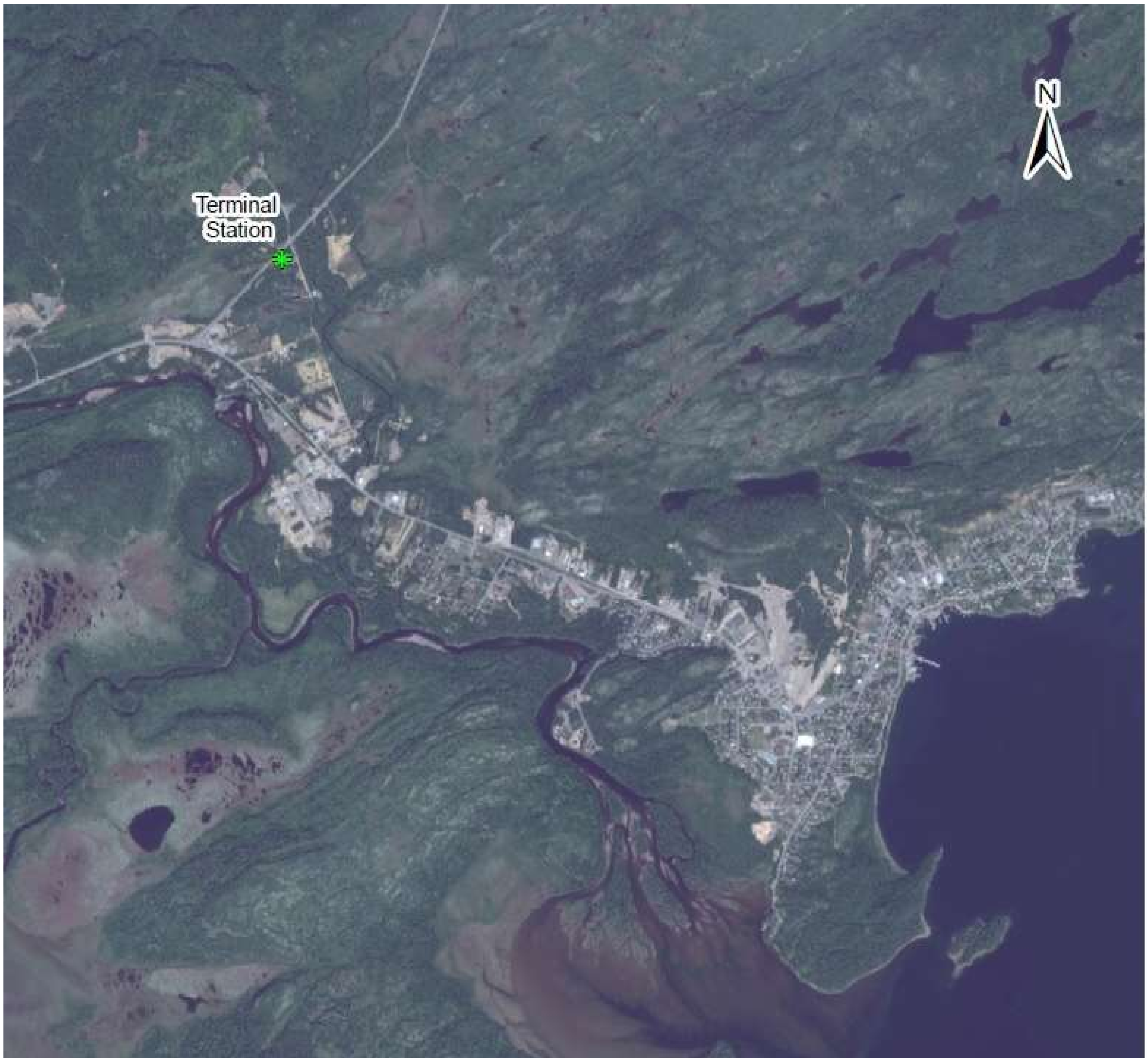


Figure 2 Location of Terminal Station in Town of Springdale

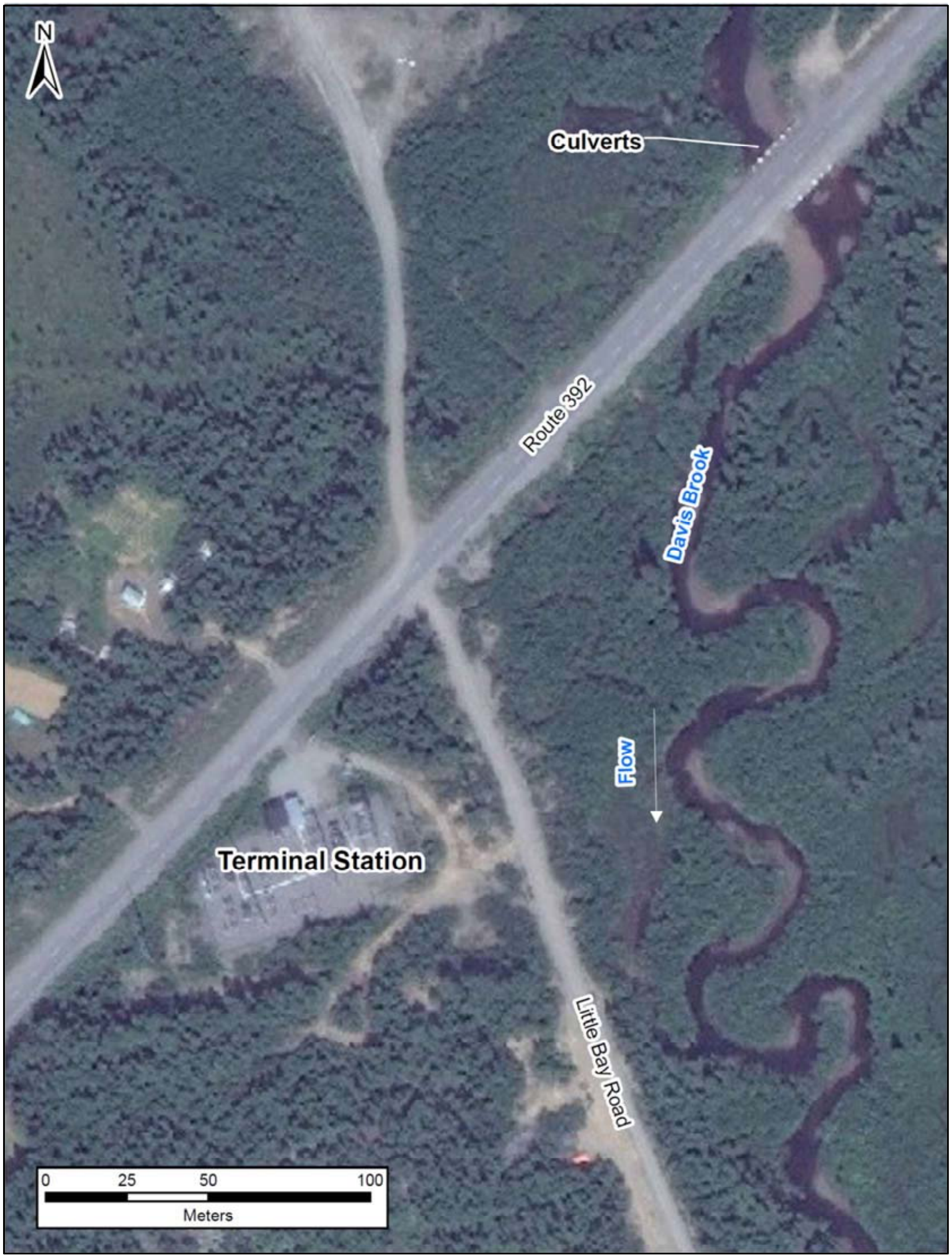


Figure 3 Proximity of Terminal Station to Davis Brook

2.2 HISTORY OF FLOODING

Davis Brook flows south, as shown in Figure 3, and flooding reportedly occurs at the terminal station via overflow across Route 392, apparently resulting from pooling upstream of the Route 392 culverts.

Notable flood events occurred on April 18, 2006 and April 29, 2015; associated photos are included in Figures 4 through 9 below. During the 2015 event, the relay switch shown in Figures 10 through 12 (located inside the terminal station building) tripped as a result of water damage and was subsequently removed and replaced. The peak water level experienced during the 2015 event (as evidenced by the water line in Figure 12) was used for hydraulic model calibration purposes. As shown in Figure 4, Route 392 is flooded and the water is flowing south toward the Terminal Station. This suggests that the Terminal Station is flooded via flow across Route 392 and not solely from the pooling of Davis Brook adjacent to the Terminal Station downstream of the roadway.

Figure 4 Flooding at Terminal Station (April 18, 2006) – Photo 1

Figure 5 Flooding at Terminal Station (April 18, 2006) – Photo 2

Figure 6 Flooding at Terminal Station (April 18, 2006) – Photo 3

Figure 7 Flooding at Terminal Station (April 18, 2006) – Photo 4

Figure 8 Flooding at Terminal Station (April 29, 2015) – Photo 1

Figure 9 Flooding at Terminal Station (April 29, 2015) – Photo 2

Figure 10 Location of Relay Switch inside Terminal Station Building

Figure 11 Relay Switch Removed after 2015 Flood

Figure 12 Watermarks on Relay Switch Removed after 2015 Flood

3.0 STUDY DATA

The data used to carry out this study originated from numerous sources, as discussed in the following sections.

3.1 INFORMATION FROM HYDRO

At project onset, Hydro provided the following information for use in this study:

- Photos of historical flooding on site (as shown in Section 2)
- Information and photos for hydraulic model calibration purposes
- Drawings of Springdale Terminal Station grounding and foundation details

3.2 PUBLICLY AVAILABLE INFORMATION

Numerous publicly available data sources were used in carrying out this study, as outlined below:

- Water Survey of Canada (WSC) hydrometric data (water level and flow records)
- National Topographic Series Mapping
- Bing Aerial Imagery
- Digital orthophotos purchased from the Province, which include a 50 x 50 m elevation grid with a vertical accuracy of +/- 2 m
- Canadian Vector (CanVec) hydrology data

3.3 SITE VISIT

A site visit was carried out on October 26, 2016, by Carissa Sparkes (Hydro) and Wendy Warford (Stantec). During the site visit, the following observations were made:

- Davis Brook flow direction and regime in the vicinity of the Terminal Station
- Floodplain geometry, including in-stream and overbank conditions
- Location, functionality and condition of hydraulic structures
- Terminal Station layout and logistics

The site investigation revealed that the area surrounding the Terminal Station is quite flat, with little relief along Davis Brook upstream and downstream of Route 392. The seven culverts running beneath Route 392 in the vicinity of the Terminal Station (i.e. 6 at Davis Brook and 1 west of Davis Brook) were observed, as well as the T'Railway Bridge located approximately 800 m downstream. A walk-about was conducted along Route 392 from east of Davis Brook to west of the Terminal Station, south along Little Bay Road to the T'Railway Bridge, and in the vicinity of the Terminal Station site. Numerous photos were taken that will aid in hydraulic model development, a sample of which are provided in Appendix A.

3.4 GROUND SURVEY

Red Indian Surveys (RIS) was engaged to conduct a ground survey of the site. The survey was completed on November 2, 2016 and included the following information:

- Culverts (7 in total)
  - Invert and obvert at inlet and outlet of each culvert
  - Bottom, top and side edges of each culvert to establish culvert shape and dimensions
- Bridges (2 in total)
  - T'Railway Bridge and Route 390 Bridge
  - Bridge deck and low chord elevation at each corner
  - Stream cross section under bridge including riprap/gabion baskets/bridge abutments
- Bathymetric Survey
  - 18 cross sections along Davis Brook
  - River centerline profile along Davis Brook
  - River centerline
- Roadway Centerlines (2 in total)
  - A shot at every 50 m along Route 392 and Little Bay Road
- Terminal Station Survey
  - Site perimeter
  - Fencing on all sides
  - Center of all gates
  - Guywires
  - Poles outside fencing perimeter
  - Corners of all buildings/pads
  - Centerline and extents of all driving surfaces
  - All obvious obstructions

Flow conditions on November 2 rendered it unsafe to collect bathymetric sections downstream of Route 390 bridge. All other bathymetric details upstream of this location were, however, collected. RIS indicated that there is a beaver dam located approximately 300 m downstream of Route 392 which appears to divert flow into a secondary channel. The location of the beaver dam and secondary channel are shown in Figure 13. This feature has been incorporated into our hydraulic model geometry.

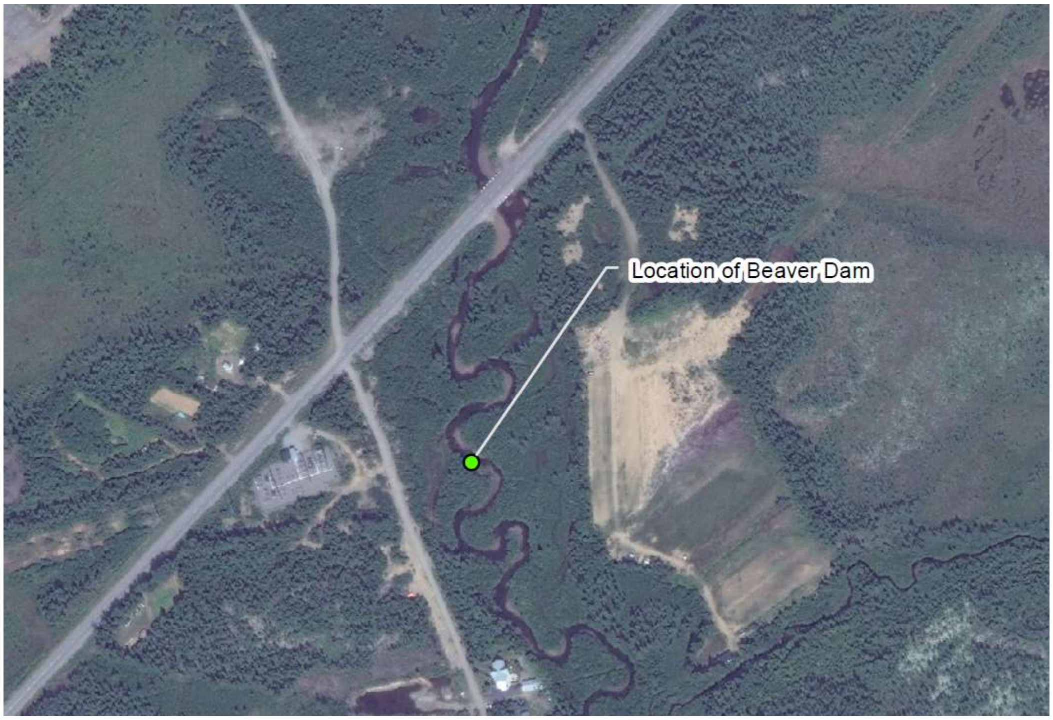


Figure 13 Location of Beaver Dam on Davis Brook

4.0 HYDROLOGICAL ANALYSIS

4.1 METHODOLOGY

4.1.1 Calibration Inflow Sequence

Hydro reported that the Terminal station has flooded in the past, both in 2006 and 2015 since construction of the station in 1967. Hydro provided information, including photos, measured water levels, and anecdotal information for the storm event occurring on April 29, 2015. The Water Survey of Canada (WSC) does not have a streamflow gauge on Davis Brook or near the station site and therefore flow data was not available. An objective of the hydrologic analysis was to generate a representative inflow sequence corresponding to the occurrence of the storm event for use in calibration of the hydraulic model.

Physiographic watershed parameters representing the watershed characteristics at Davis Brook were estimated following methodology outlined in the Regional Flood Frequency Analysis for Newfoundland and Labrador (AMEC, 2014) users guide. Physiographic parameters were compiled using the derived DEM (as discussed in Section 5.1.2) and available topographic datasets for the Davis Brook watershed, including the 1:50,000 National Topographic Series maps and Canada Vector (CanVec) hydrology layers. Table 4-1 summarizes the physiographic watershed parameters that were calculated for Davis Brook.

As presented in the 1999 Regional Flood Frequency Analysis (RFFA), the island of Newfoundland is divided into four hydrologically homogenous regions, based on such characteristics as floods, precipitation, and physiographic parameters. The Davis Brook watershed falls within the Northeastern hydrologic region of Newfoundland. In this region flooding occurs most frequently in April from rainfall and snowmelt (RFFA 1999) and the mean annual precipitation is between 1000-1100 mm. Physiographic parameters for Davis Brook were compared to parameters reported for other nearby catchments in the northeastern hydrological region of Newfoundland to identify similarities between watersheds.

A representative WSC hydrometric station was selected that has the following characteristics:

- similar physiographic parameters to Davis Brook,
- a period of record greater or equal to 18 years of record to meet requirements to perform a statistical analysis under the RFFA users guide update (AMEC 2014), and
- and an active station capturing the calibration storm event.

The hourly flow records of the representative hydrometric station were transposed based on drainage area to Davis Brook to derive the calibration inflow sequence during the April 29, 2015 storm event. For perspective, the hydrograph volume of the calibration inflow sequence was compared to the Intensity-Duration-Frequency return period rainfalls amounts for a 24 hour period.

The watershed drainage area was delineated based on the available provincial watershed delineations and available CANVEC digital elevation data. The watershed was delineated at Davis Brook just downstream of the Terminal Station.

Table 4-1 Summary of Physiographic Parameters

Physiographic Parameter	Description	Unit
DA	Watershed drainage area	km^2
PERIM	Watershed perimeter	km
FTREE	Fraction of watershed occupied by forest	-
FSWAMP	Fraction of watershed occupied by wetlands/swamps	-
FLAKE	Fraction of watershed occupied by lakes	-
FLSAR	Fraction of watershed occupied by lakes and wetlands/swamps	-
FBAR*N	Fraction of watershed occupied by barrens	-
FACLS	Fraction of drainage area controlled by lakes and wetlands/swamps	-
LAF	Lake Attenuation Factor[1]	-
LENGHTMAINR	Length of the main river (longest river reach)	km
ELEVDIFF	Elevation Difference between the outlet and the highest elevation on the divide in the vicinity of the main channel	m
SLOPEM1	Slope of the main channel - Method 1	%
SLOPEM2	Slope of the main channel – Method 2	%
DRAIND	Drainage Density	km/km^2
SHAPE	Shape Factor	-
Note:	LAF = a combination of the fraction of watershed area occupied by the lake and the fraction of watershed area controlled by the lake, for each lake that is greater than 1% area. SlopeM1 = LENGTHMAINR/ELEVDIFF SlopeM2 =slope of two points located at 10% and 85% of the LEGTHMAINR from the outlet. DrainD = total length of all streams in the watershed divided by the DA Percent swamps was negligible in the watershed and therefore the Lakes and Swamps Factor, as outlined in the guideline was not calculated. Shape Factor = Characterizes the physical shape of a watershed = 0.28* (PERIM/SQRT (DA))	

4.1.2 Design Inflow Sequence

AMEC (2014) RFFA correlates the physiographic parameters of a watershed with the statistical frequency flows and derived regional regression equations for four regions in Newfoundland. The regression equations are limited to minimum and maximum bounds of regional physiographic parameter. The estimated physiographic parameters for Davis Brook were compared against the reported parameter bounds for the development of the regional equations, to ensure that Davis Brook parameters are in range and the regional regression equations are applicable. As reported in the RFFA (AMEC 2014) sensitivity analysis for the regional regression equations, the anticipated error in peak flows ranged from 1.7% to 3.4% for all regions and return periods when the error in abstraction of Drainage Area was 3%.

The primary objective of the hydrologic analysis was to generate a representative design inflow sequence corresponding to the 100 yr precipitation event to simulate a peak flood condition at the terminal station in the hydraulic model. The one and two parameter regional regression equation for Northeast (NE) Newfoundland was applied to the ungauged watershed of Davis Brook to estimate the frequency flows. The independent physiographic parameters used in the one and two parameter regression equations were drainage area and drainage area and LAF, respectively. The upper and lower 95% confidence limits on the flood estimates were calculated using the method described in the RFFA (AMEC 2014). Tables 4-2 and 4-3 present the RFFA (AMEC 2014) one parameter and two parameter regional regression equations, respectively for 2 to 200 yr return periods associated to Annual Exceedance Probability (AEP) of 0.5 to 0.005. The regression correlation coefficient SMR and the standard error of the estimate SEE are provided for each equation in the tables.

Results of the regional regression equation method were compared against the Government of Newfoundland and Labrador (2014) single station frequency analysis results of the same AEP for nearby hydrometric gauging stations. Based on the results of the analysis, another flood estimation technique such as a deterministic watershed simulation was not required.

Table 4-2 One Parameter Equation for NE region $Q = a \times DA^b$

Return Period Flow	AEP	Base Parameter a	Coefficient b	SMR	SEE
2	0.5	0.836	0.755	0.902	0.161
5	0.2	1.271	0.733	0.882	0.173
10	0.1	1.582	0.722	0.87	0.181
20	0.05	1.895	0.712	0.858	0.187
50	0.02	2.322	0.702	0.844	0.195
100	0.01	2.658	0.695	0.834	0.2
200	0.005	3.009	0.688	0.824	0.205

Table 4-3 Two Parameter Equation for NE Region $Q = a \times DA^b$

Return Period Flow	AEP	Base Parameter a	Coefficient b	Coefficient c	SMR	SEE
2	0.5	2.911	0.767	-0.285	0.964	0.102
5	0.2	4.746	0.745	-0.302	0.954	0.112
10	0.1	6.128	0.734	-0.31	0.947	0.119
20	0.05	7.568	0.725	-0.317	0.94	0.126
50	0.02	9.597	0.715	-0.325	0.931	0.134
100	0.01	11.243	0.708	-0.33	0.925	0.14
200	0.005	12.997	0.702	-0.335	0.918	0.145

In Atlantic Canada, climate change is expected to result in increased rainfall frequencies and intensities causing flooding events of the magnitude of Hurricane Igor, a category 1 storm. As Atlantic sea surface temperatures warm, the ability for water temperatures south of Newfoundland to provide resistance and weakening of a storm is reduced. Storms are expected to mature into more intense hurricanes (higher category) and have an increased ability to survive their track towards Atlantic Canada, arriving with more force. The frequency and intensity of precipitation events is expected to increase under climate change. This was not accounted for in the hydrological analyses.

4.2 RESULTS

4.2.1 Calibration Inflow Sequence

Following the AMEC RFFA (2014) methodology, physiologic parameters were calculated for the Davis Brook watershed and compared to other nearby watersheds in the NE region. As summarized in Table 4-4, Peters River watershed had similar characteristics as Davis Brook, based on the physiographic parameters such as drainage basin area, percent lakes, wetlands, and waterbodies. Boot Brook was more comparable to the Davis Brook catchment with respect to drainage area and wetted perimeter, and less comparable with respect to land use. In addition, Boot Brook had a shorter period of record and the 2015 hourly flow data was unavailable at the time of the study. Figure 14 illustrates the delineated watershed drainage area for Davis Brook at the Terminal station of 69.5 km^2.

Table 4-4 Summary of Physiographic Parameters

Variable	Unit	Parameter Ranges (NE Region)			Davis Brook	Peter's River
		Max	Med	Min	At Terminal Station	Station 02YO006
DA	km^2	4447	266	39	69.5	177
PERIM	km	785	158	45	63.4	130
FTREE	-	0.91	0.75	0.11	0.78	0.83
FSWAMP	-	0.48	0.12	0.06	0.08	0.13
FLAKE	-	0.20	0.09	0.02	0.09	0.03
FLSAR	-	0.66	0.20	0.11	0.17	0.16
FBAR*N	-	0.40	0.02	0.00	0.06	0.02
FACLS	-	1.00	0.89	0.40	0.95	0.97
LAF	-	881	89	50	118	50
LENGHTMAINR	km	133.80	42.25	11.20	20.97	42.7
ELEVDIFF	m	372	207	95	180	190
SLOPEM1	%	1.65	0.57	0.20	0.86	0.45
SLOPEM2	%	1.11	0.44	0.12	0.76	0.45
DRAIND	km/km^2	1.24	0.68	0.26	1.7	0.8
SHAPE	-	3.37	2.61	2.01	2.30	2.72

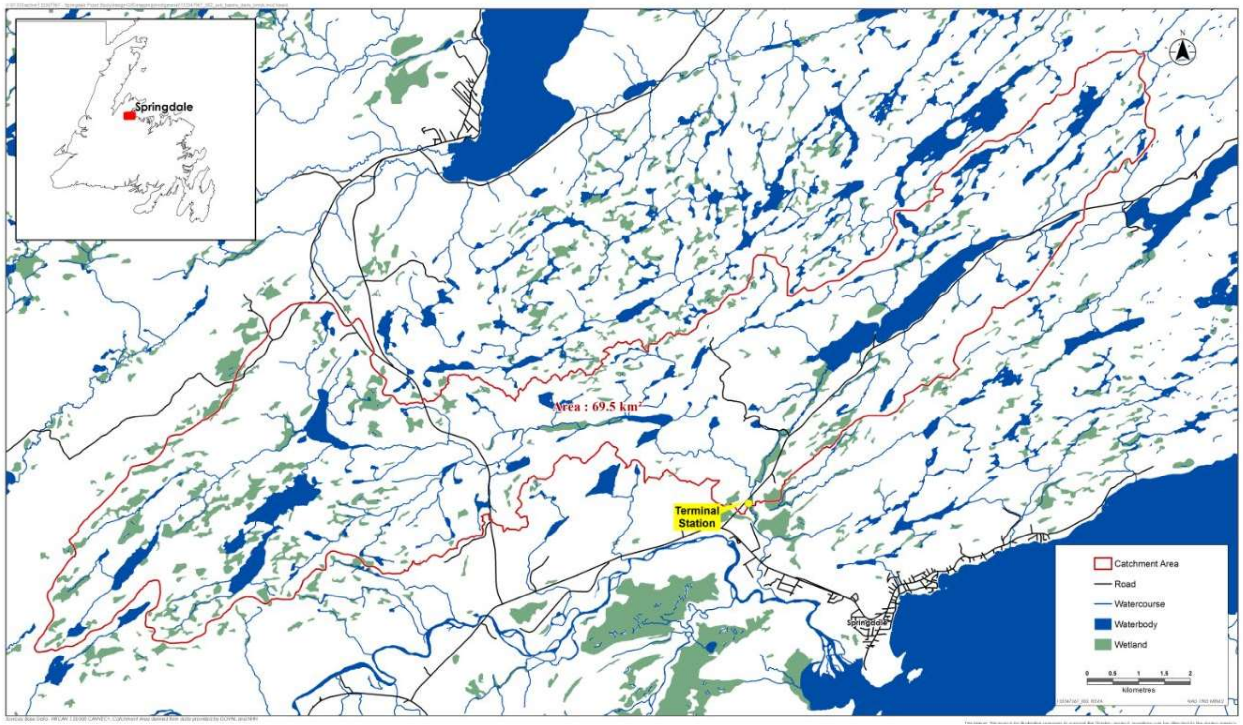


Figure 14 Davis Brook Watershed Area

Based on the comparison of physiologic parameters, a representative inflow sequence for Davis Brook was derived based on the hourly daily for the Environment Canada hydrometric gauging station at Peters River Near Botwood (02YO006). The Peters River station is located approximately 68 km south-southeast of the terminal station. The period of record for the Peters River station is from 1981- 2015 (in operation for 35 years), covering the calibration storm event on April 29, 2015. The resulting inflow sequence for the calibration period was transposed based on drainage area to Davis Brook. The calibration inflow sequence is presented in Figure 15.

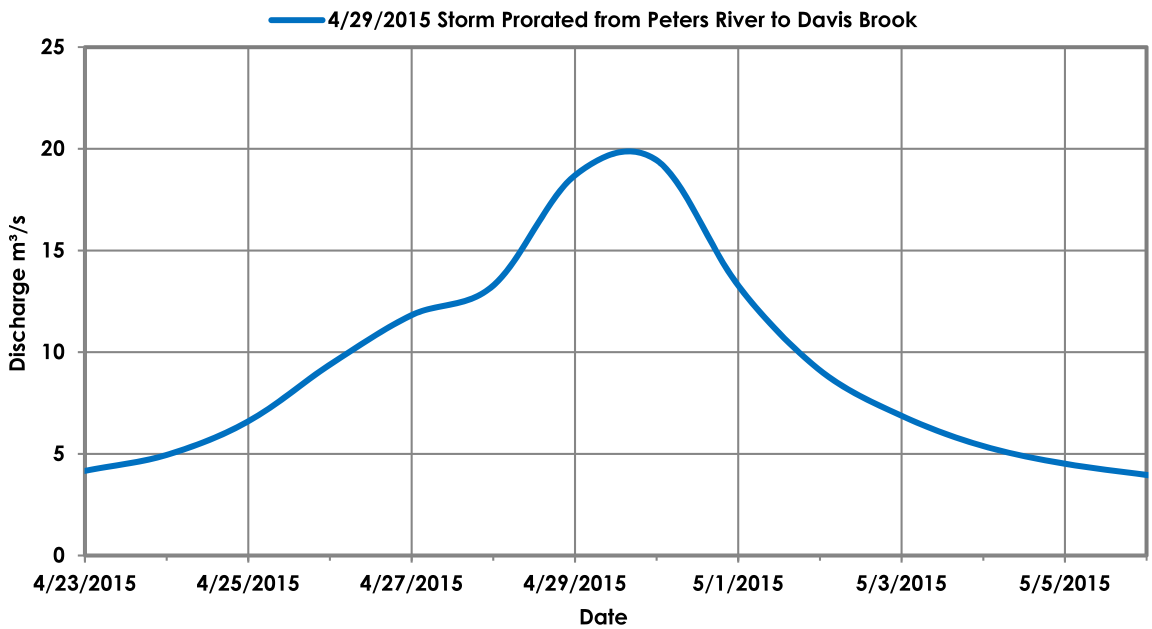


Figure 15 Flood Calibration Inflow Sequence for Davis Brook

Comfort Cove Climate Station (8401259, EC 2014) is assumed to be representative of total rainfall at the Terminal station based on proximity to the station, period of climate record, and relative elevation. The 24 hour Intensity-Duration-Frequency rainfall at Comfort Cove station for the 100 yr return event is approximately 91 mm over 24 hours, representing an approximate volume of 4 million cubic meters (Mm^3) associated to a runoff coefficient of 1. This volume is comparable to the runoff volumes for the Peters River April 29, 2015 calibration storm of approximately 4 Mm^3, associated to roughly 50% of the hydrograph peak. The additional runoff volume represented in the Flow data is assumed to be attributed to snowmelt contributing to the flow upstream of the Terminal station. The trend of hydrograph volumes exceeding IDF volumes for storms in April is common to the NE region hydrometric gauging stations that were reviewed as part of this study.

Hydro reports that flooding at the terminal station occurs as a result of flow across Route 392. This suggests that the conveyance capacity of the culverts is exceeded during periods when the Terminal Station floods. The total flow capacity of the six (6) culverts flowing full, is approximately 30 m^3/s, based on an inlet control nomograph for a corrugated steel pipe (CSPI 1984). The estimated calibration peak inflow of approximately 20 m^3/s on April 29, 2015 does not exceed the conveyance capacity of the six (6) culverts. This suggests that the calibration inflow sequence may be underestimated. Areas of uncertainty include:

1) Davis Brook is near the western boundary of the NE hydrographic region and thus may be at the limits of NE region representivity
2) Large Woody Debris and/or snow and ice may have blocked/partially blocked or temporarily blocked the culverts under the road resulting in short term hydraulic peaking
3) The precipitation event may have been different at the Davis Brook watershed at the Terminal station than in the Peters River watershed
4) Snowpack characteristics and meltwater contribution may have been different at the Davis Brook watershed at the Terminal station than in the Peters River watershed
5) Other watershed storage factors such as Flake and FSwamp in addition to FLR have strong peak flow influences and may skew simple areal reduction/prorating from Peter River to Davis Brook
6) Based on a review of nearby hydrometric stations, the ability of the watersheds to attenuate flows appears to be related to the size of the catchment area.

As a result of the areas of uncertainty, a peaking factor was derived for the calibration storm event to simulate the effects of less attenuation at the Davis Brook catchment. The peaking factor was based on the peaking relationship between Peters River catchment 02YO006 and Boot Brook at Trans-Canada Highway Station 02KY008 (a smaller watershed from among those used in the NE region). Figure 16 presents the calibration inflow hydrograph in comparison to the hydrograph applying a peaking factor of 2.0. The resulting calibration inflow sequence used in the hydraulic model has a higher peak flow while maintaining the same storm volume and rising/falling limb flows as the initial prorated hydrograph.

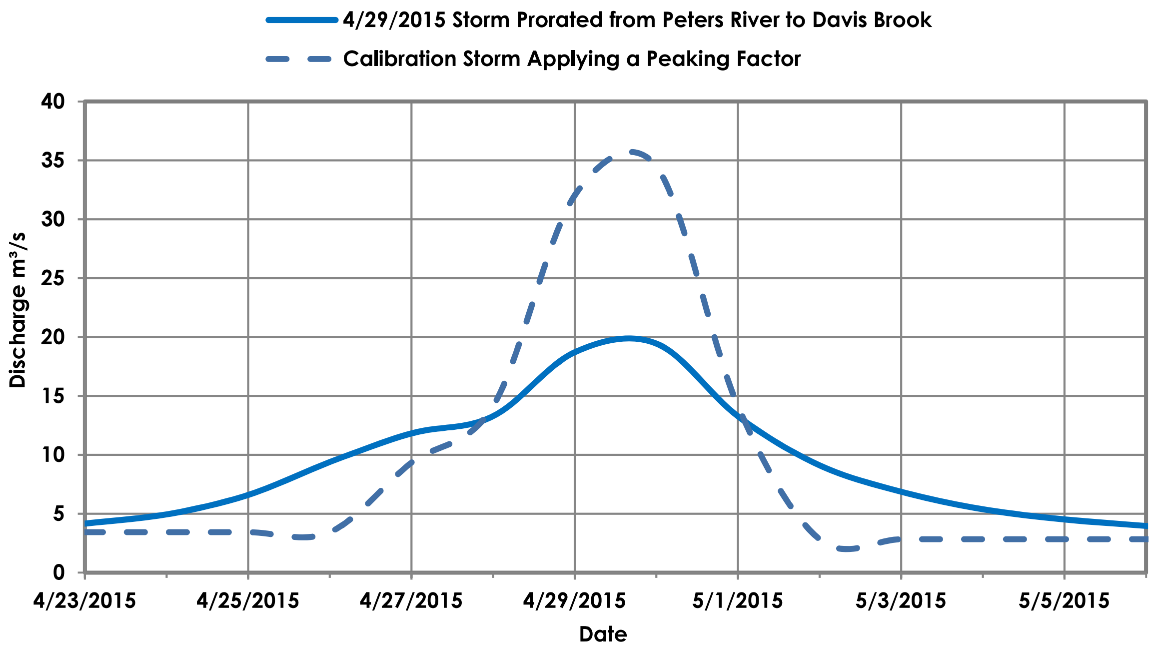


Figure 16 Final Inflow Calibration Sequence with Peaking Factor Applied

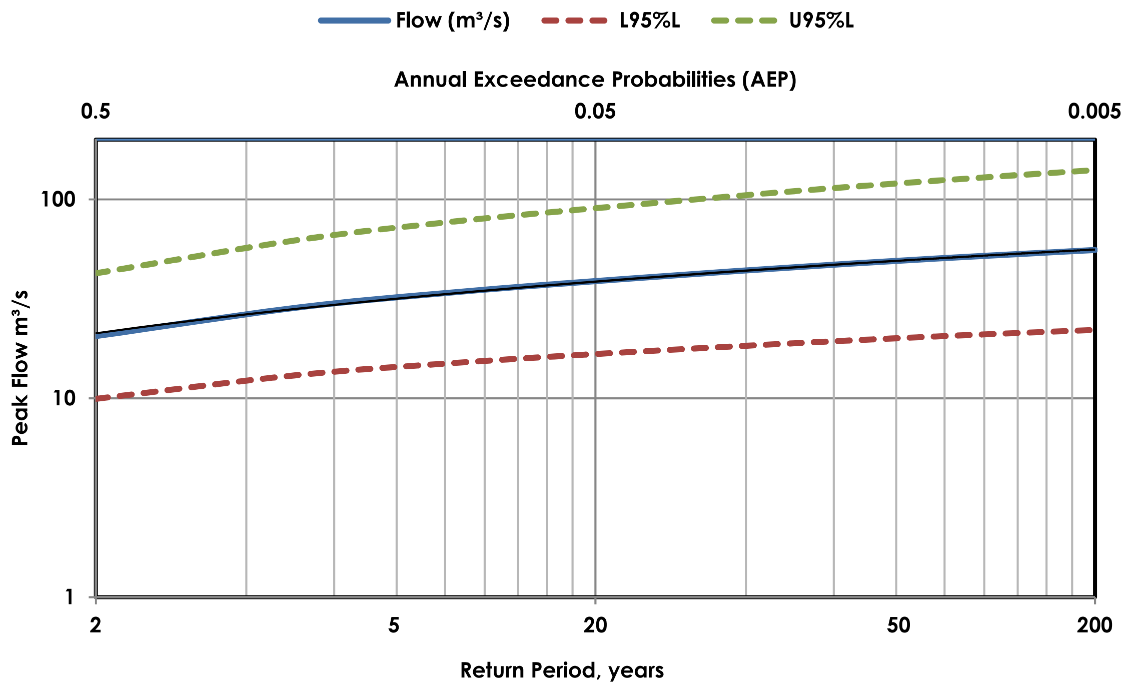
4.2.2 Design Inflow Sequence

Davis Brook physiographic parameters were found to be within the range of those used for development of the RFFA regression equations (AMEC 2014). Therefore, application of the regression equations was applicable for the flow frequency analysis at Davis Brook. As illustrated in Figure 17, flow frequency was calculated for the 2, 5, 10, 20, 50, 100, 200 return periods associated with AEP between 0.5 and 0.005. The one and two parameter NE region regression equations were applied for Davis Brook at the Terminal station. Each equation resulted in a coefficient of determination of almost 1 to the fitted logarithmic trend line. The one parameter equation resulted in an approximately 8% higher 100 yr peak flow than the two parameter equation; the maximum peak flow was carried forward in the analysis. The upper and lower 95% confidence limits were calculated for the one parameter peak flow results and illustrated on Figure 17.

The 100 yr return period peak flow of 50.7 m^3/s - associated to a 0.01 AEP, represents the peak flow event in the design inflow sequence for the hydraulic model. Results of the regional regression method were compared to single station frequency analysis results for six nearby hydrometric gauging stations. The single station frequency analysis results for the 100 yr peak flows ranged between 18 and 106 m^3/s of the six gauging stations reviewed within 70 km of the Terminal station. This large range in peak flow further supports the use of the regional regression equations. The single station 100 yr peak flow frequency result for Peters River gauging station was approximately 48 m^3/s, more comparable to the regional regression flow frequency results for Davis Brook than other single station results.

The hydrographs for five of the largest floods in the period of record (1981-2015) for the Peters River Near Botwood station (02YO006) were extracted and plotted against each other and the April 29, 2015 calibration storm. The daily discharge was normalized by dividing flows by the peak flow event for flood and lagged in time to align the peak flow rates as shown in Figure 18. All but one flood event had pre-flood events prior to the peak flow, and was associated to a January rainfall event opposed to an April rainfall event for all other storms. A synthesized hydrograph was derived based on the average of the normalized flow for all six flood events. Figure 19 presents the regional flood peak applied to the normalized synthetic hydrograph.

The synthetic daily flow hydrograph was converted to an hourly hydrograph to support the development of the hydraulic model. The incremental flow by hour was assumed to be linear over a 24 hour period to convert daily flows to 24, 1 hour flow records. The hourly record was extended 7 days following the rainfall event, accounting for approximately 80% of the peak flow. Figure 20 presents the synthetic flow hydrograph for the regional regression frequency flow events.



Return Period	2	5	10	20	50	100	200
AEP	0.5	0.2	0.1	0.05	0.02	0.01	0.005
U95%	42.5	62.2	76.6	90.3	110.0	125.0	140.5
Flow (m^3/s)	20.6	28.7	33.8	38.8	45.6	50.7	55.7
L95%	9.9	13.0	14.9	16.7	18.9	20.6	22.1

Figure 17 FFA Results for Davis Brook at the Terminal Station

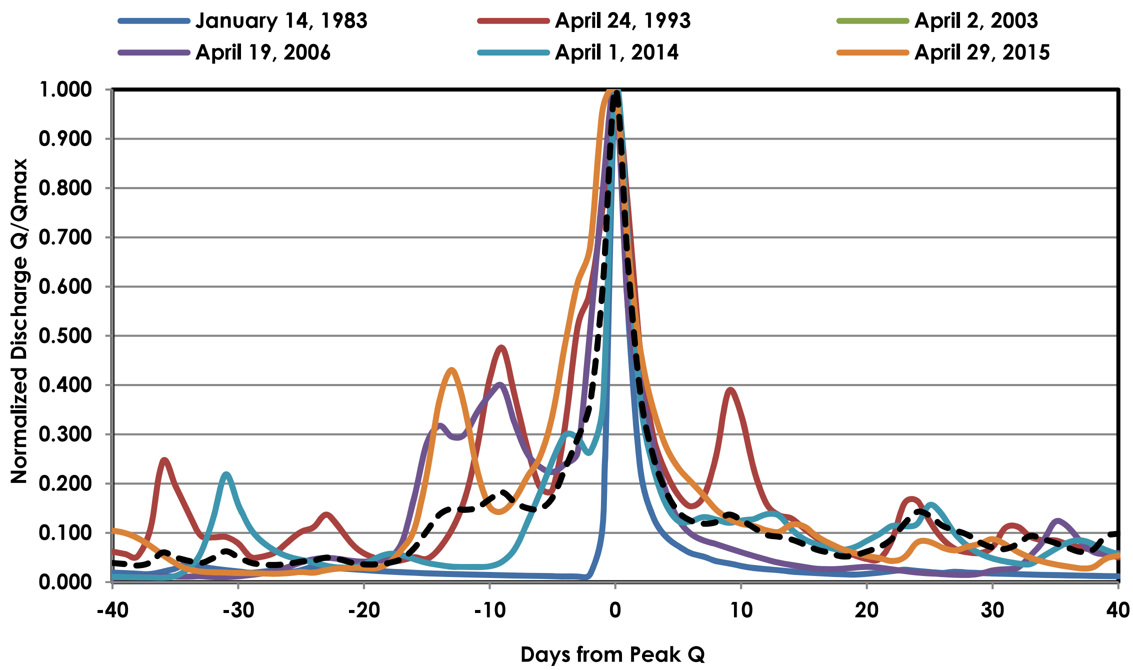


Figure 18 Normalized Flow Hydrographs at Peters River, prorated to Davis Brook

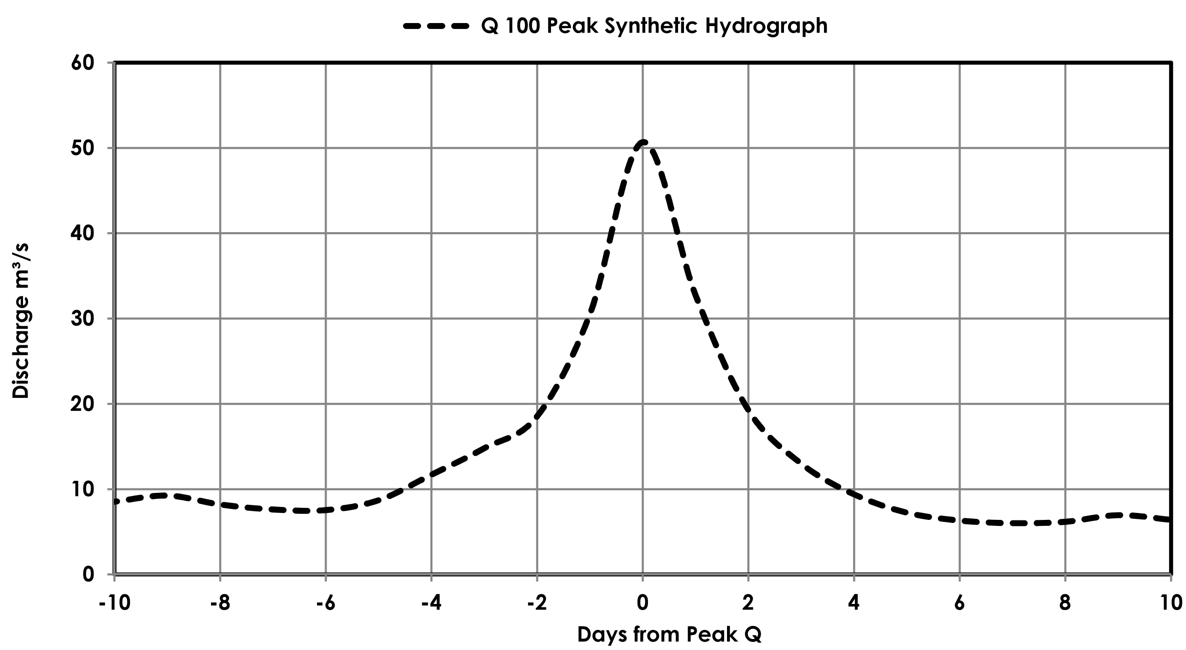


Figure 19 1:100 Year Design Inflow Hydrograph for Davis Brook

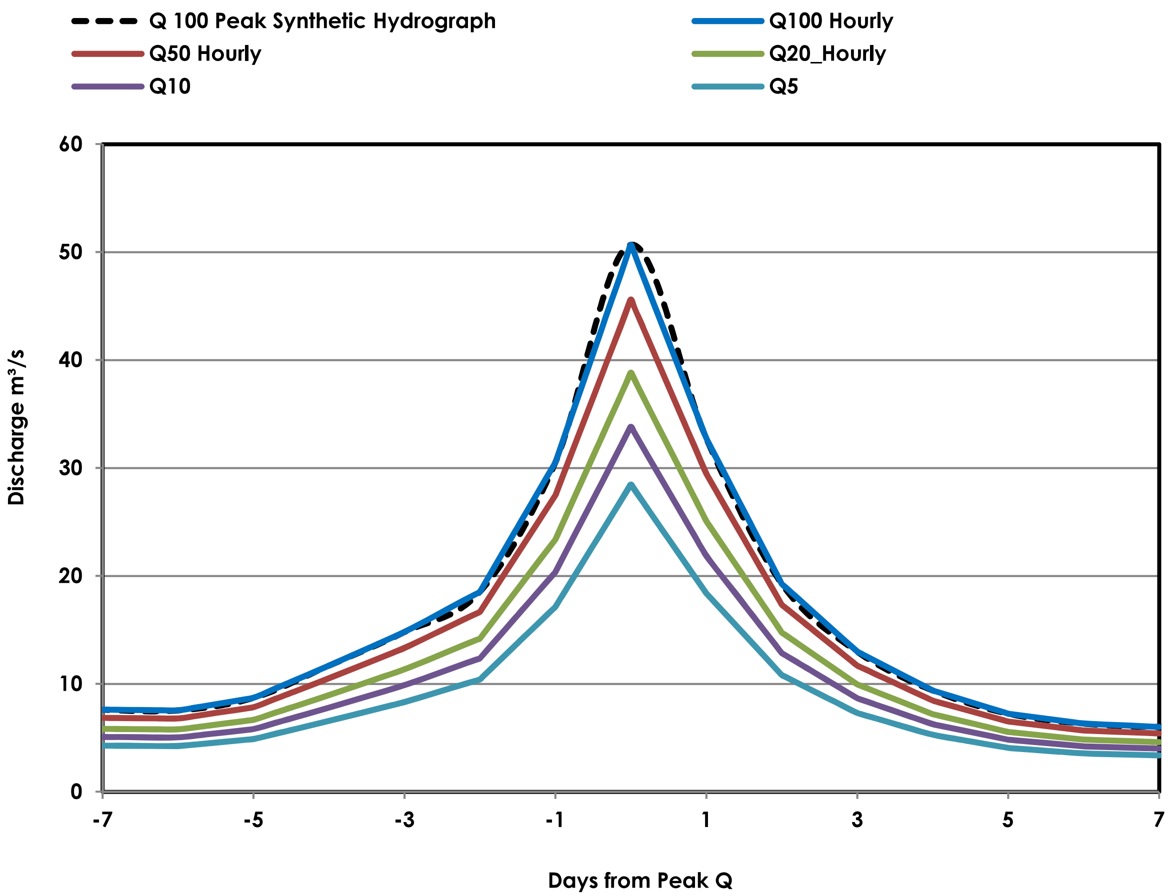


Figure 20 Synthetic Hydrographs for Various Return Periods

5.0 HYDRAULIC ANALYSES

5.1 MODEL SETUP

5.1.1 Modeling Platform

Due to the off-stream location of the Terminal Station relative to Davis Brook, we developed a 2-Dimensional hydraulic model for this application. A 1-Dimensional solution would not appropriately model the relevant flood mechanisms (i.e. secondary channel routing or pooling). A 2D solution provides more accurate model results since it allows for a watercourse to divert and split, and pool in ineffective flow areas. We have therefore utilized the newly developed 2D functionality in HEC-RAS 5.0 for this hydraulic modeling application.

5.1.2 Digital Elevation Model Development

Due to the relatively small spatial (x-y) dimensions of the terminal station site, in combination with its close proximity to the river (approximately 150 m), an adequately high resolution and accuracy dataset was required to ensure model validity. The ground survey information outlined in Section 3.4 was supplemented with the 50 m x 50 m digital elevation data purchased from the province to develop the Digital Elevation Model (DEM). This bare earth DEM, as shown in Figure 21, was used to develop the hydraulic model.

The coarseness of the 50 m x 50 m grid portion of the DEM is evidenced by the obviously unnatural geometric irregularities. Since the scope of this project is to develop flood mitigation strategies and test their appropriateness, a high level of precision in the hydraulic model geometry is not required. The DEM is therefore considered to be adequate for this application.

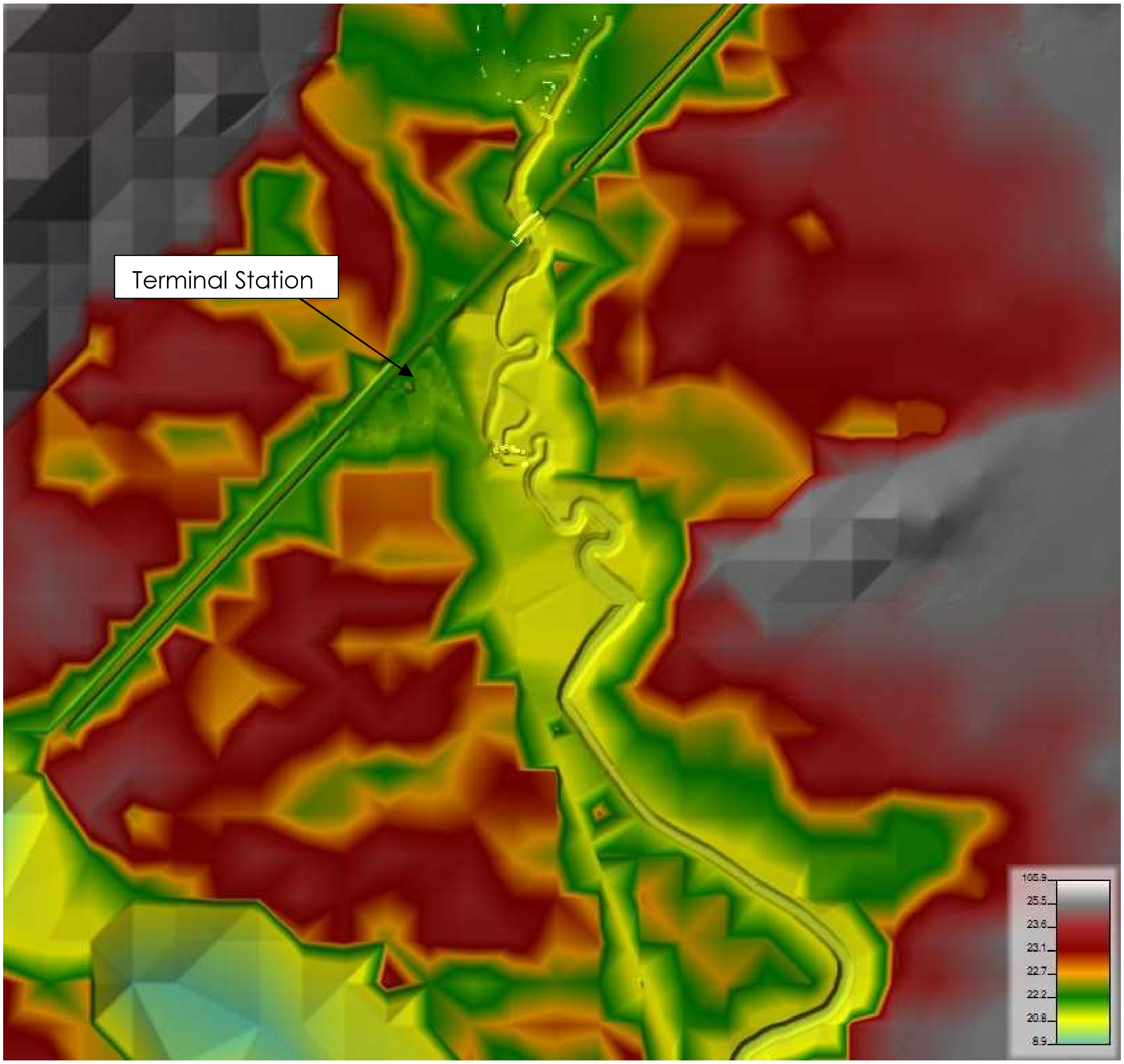


Figure 21 Bare Earth Digital Elevation Model

5.1.3 Model Geometry

The 2D hydraulic model extents (as shown in Figure 22) were selected to ensure that any upstream pooling or downstream backwater effects were captured. A mesh size of 10 m x 10 m was selected to adequately define the model terrain. Additional resolution was added at areas of interest, such as the channel and the terminal station buildings. Nested 2 m x 2 m meshes were applied at these locations.

The 7 culverts at Route 392 (6 at Davis Brook and 1 west of Davis Brook), and 2 bridges (T'Railway Bridge and Route 390 Bridge) were modeled to ensure any associated hydraulic effect is captured. Hydraulic structure geometry was derived solely from ground survey data.

Four boundary conditions were defined in the model. Three of these boundary conditions were inflows and one was a normal depth boundary condition at the downstream extent of the model. Two inflow boundary conditions represent Davis Brook inflow. This inflow was split into two to account for the confluence just upstream of Route 392. The inflow hydrographs, as described in Section 4.0, were split based on a ratio of the drainage area of each reach. The third inflow boundary condition was applied to account for a lateral inflow into Davis Brook from the east, approximately 400 m downstream of the culverts at Route 392. This lateral inflow has a drainage 6.0 km^2 and the inflow hydrographs were prorated from those described in Section 4.0 above.

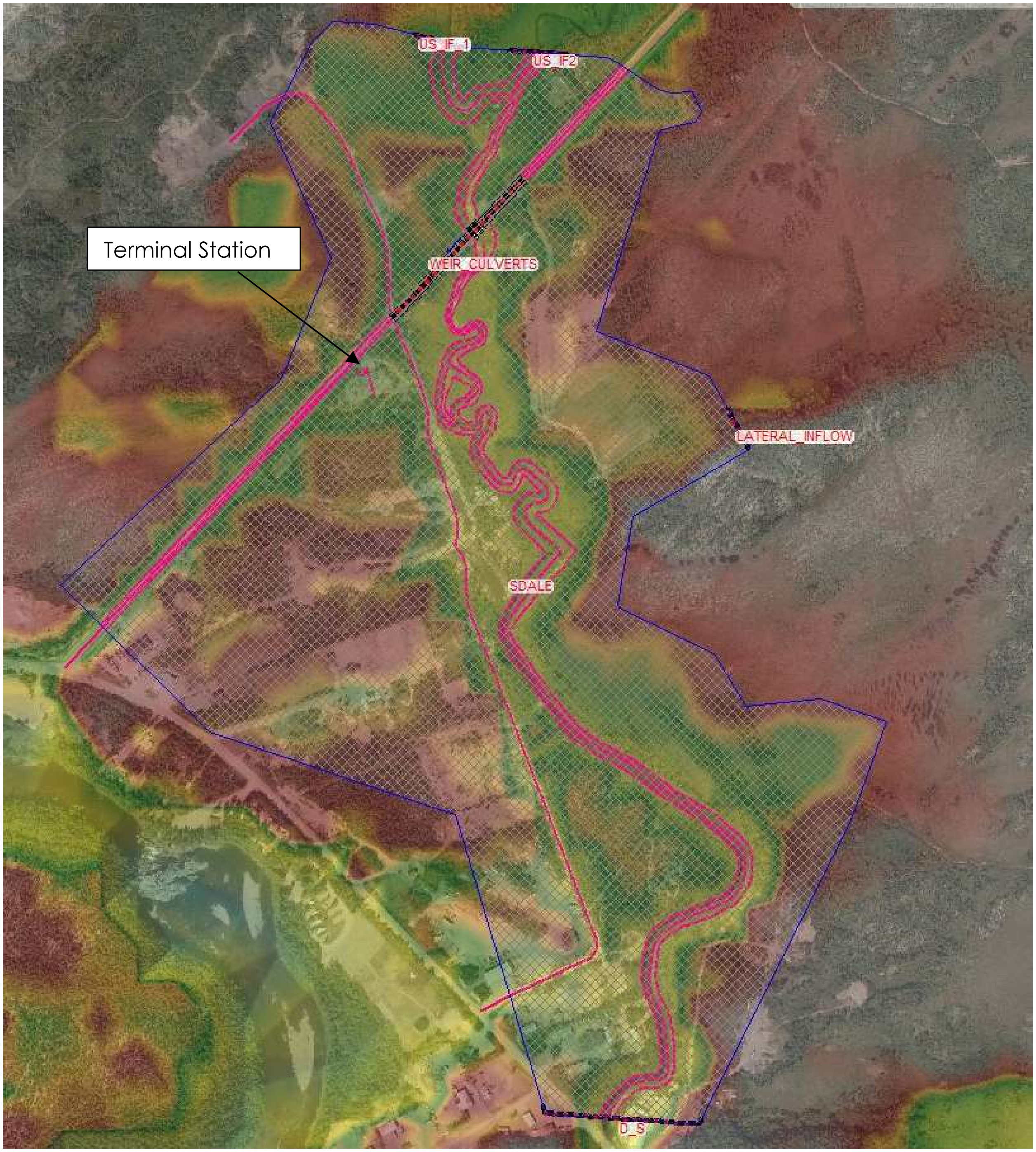


Figure 22 Hydraulic Model Extents

The hydraulic model also requires the determination of Manning's roughness coefficients at each computational cell to account for friction forces that are exerted to the flow by land and channel bed/bank roughness. As such, friction forces are dependent on the characteristics of the surface over which the flow is being conveyed, where the Manning's coefficients increases as the surfaces become coarser.

HEC-RAS 5.0 applies Manning's roughness values spatially, by way of a GIS layer that applies values based on a land classification. Similar land types are joined, and a single coefficient is then assigned to each land type.

A total of four predominant land types were identified within the model domain. Manning's coefficients were selected based on land use classification. A summary of land types and their assigned roughness coefficient are shown in Figure 23.

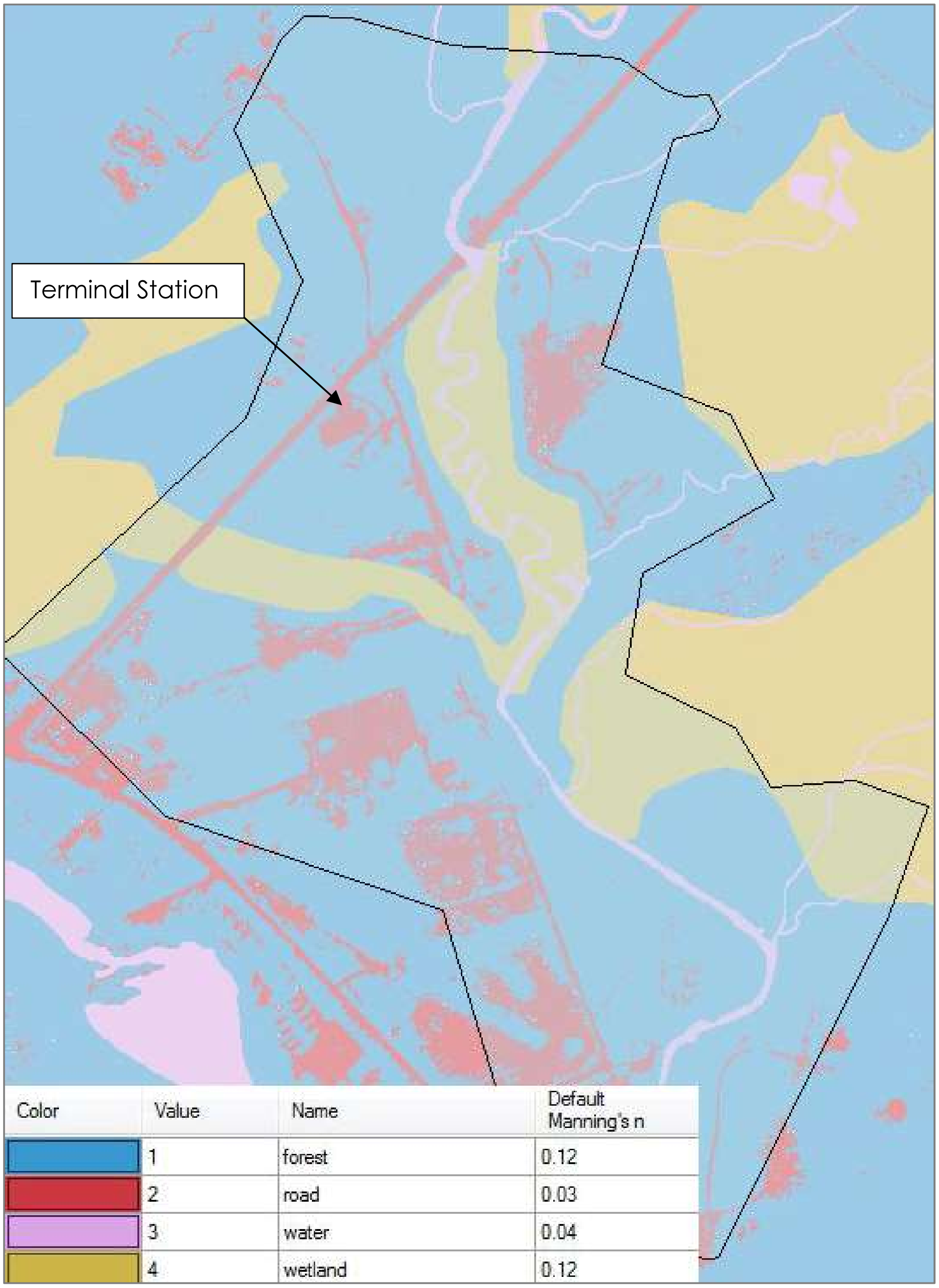


Figure 23 Manning's Roughness Layer

5.1.4 Model Calibration

The final calibration inflow sequence, as discussed in Section 4.2.1, was applied to the hydraulic model domain. Attempts were made to calibrate the model and reproduce the Terminal Station flooding (i.e. peak water level of 22.05 m or a depth of approximately 0.25 m at site) by iteratively adjusting the spatial Manning's n values. We were not able to reproduce the Terminal Station flooding by way of Manning's n adjustments, while maintaining reasonable roughness values.

Figure 24 below shows the peak water surface profile using maximum reasonable roughness values. Note that the Terminal Station is not inundated.

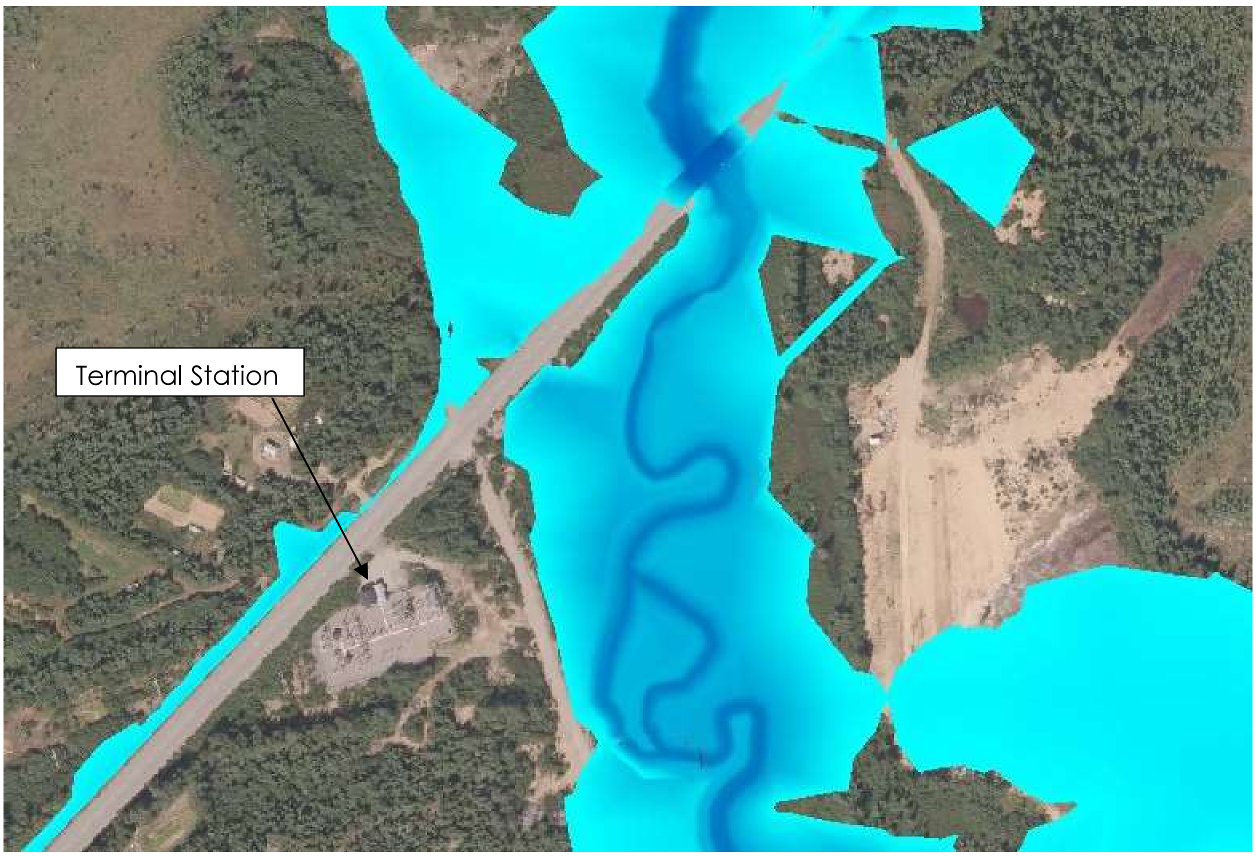


Figure 24 Flood Inundation – Calibration Storm with Free Flowing Culverts

The fact that the calibration inflow does not reproduce flooding at the Terminal Station, even with a peaking factor applied, suggests that some degree of culvert blockage occurred during the April 29, 2015 event. We therefore iteratively tested varying degrees of culvert blockage at Route 392. It was found that a culvert capacity restriction of 60% was required to reproduce the level of flooding observed at site in April, 2015.

As shown in some of the site visit photos included in Appendix A, woody debris has accumulated at the culvert crossing at Route 392. Also, the riverbed contains much sediment that could potentially restrict culvert capacity. The flood event also occurred in April during a spring melt which suggests that deadfall or ice may have caused the blockage. As such, it was assumed that culvert capacity restriction is the probable cause of the flooding observed in April, 2015. Figure 25 below, and the inundation map in Appendix B, shows the approximate extent of flooding.

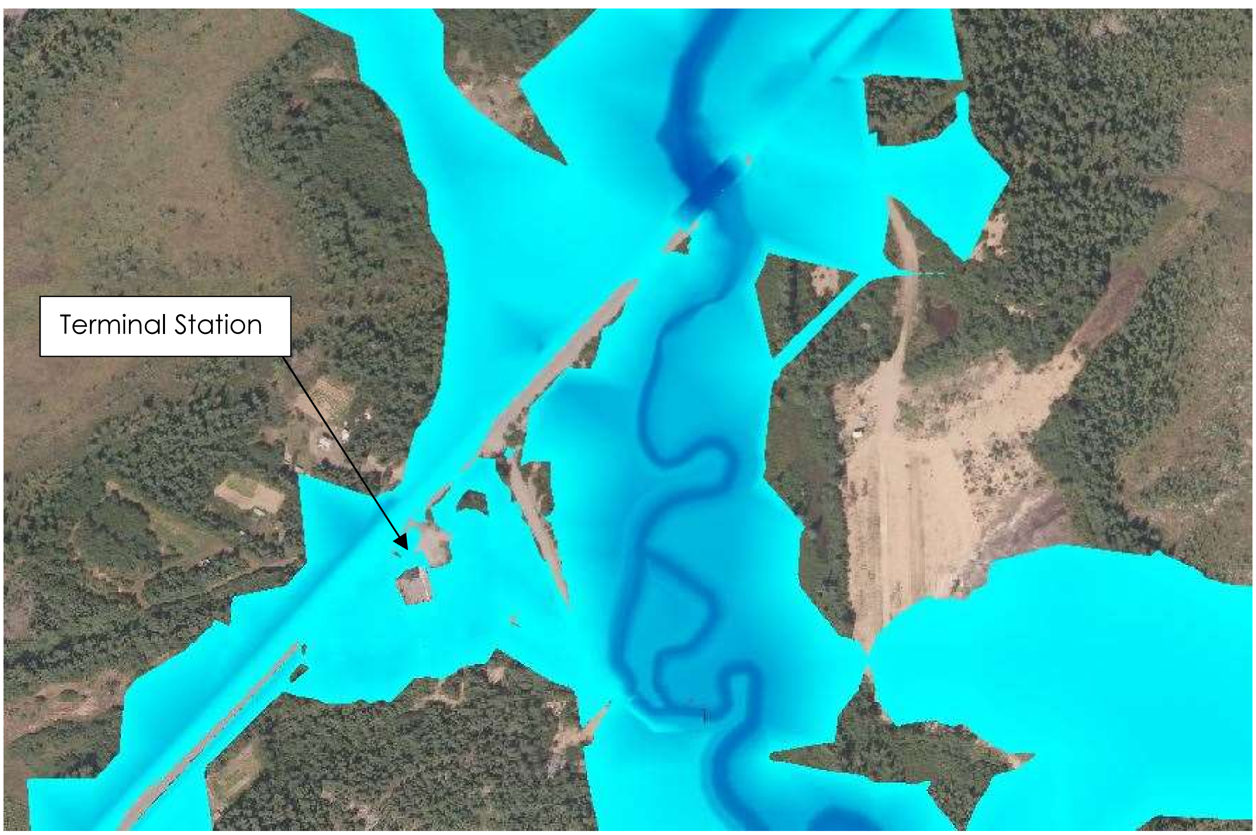


Figure 25 Flood Inundation – Calibration storm with 60 % Culvert Blockage

5.2 RESULTS

5.2.1 Flood Mechanism and Site Susceptibility

As suspected, hydraulic modeling has confirmed that the Terminal Station floods via overflow at Route 392. A range of inflows were run through the hydraulic model for the 2, 5 10, 20, 50, and 100 year return periods floods. Capacity exceedance at the six Davis Brook culverts appears to cause flooding at the Terminal Station (without culvert blockage) for inflow events with an associated Annual Exceedance Probability (AEP) of 1:50 or greater. The actual return period likely resides between the 1:20 and 1:50, however we did not test additional AEPs in this range.

For clarity, Table 5-1 below provides a summary of the effect of culvert blockage on the various return periods tested.

Table 5-1 Summary of Flooding at Terminal Station by AEP

Annual Exceedance Probability (AEP)	Terminal Station Flooded?	
	No Culvert Blockage	60% Culvert Blockage
1:2	N	Y
1:5	N	Y
1:10	N	Y
1:20	N	Y
1:50	Y	Y
1:100	Y	Y

As can be seen from the above table, the 1:20 AEP appears to be the threshold return period at which the Terminal Station will not flood with the culverts operating at full capacity. Inundation maps for the 1:20 event, with and without culvert blockage area presented in Appendix B.

Our hydraulic model simulations suggest that 60% culvert blockage results in flooding at even the 1:2 AEP storm event.

5.2.2 1:100 AEP Flood Event

The 1:100 AEP flood event has a peak flow magnitude of 50.68 m^3/s, as discussed in Section 4.2.2, and is the design event selected by Hydro for assessment of flood mitigation strategies. Hydro elected to maintain the assumption of 60% culvert blockage that was used for calibration for the design condition. A flood inundation map illustrating the expected extent of flooding during the 1:100 AEP flood event with both free and 60% blocked culvert conditions is provided in Appendix B. As shown in the map, the 1:100 AEP flood event will cause flooding at the Terminal Station both with and without culvert blockage. Therefore, the clearing of culvert blockages alone will not address flooding at the Terminal Station for 1:100 AEP event.

Simulations both with and without the beaver dam were run and the results did not appreciably differ due to the presence of the dam.

6.0 FLOOD MITIGATION STRATEGIES

6.1 ANALYSIS OF POTENTIAL MITIGATION STRATEGIES

Part of the scope of work for this assignment was to consider flood mitigation strategies at the Terminal Station and hydraulically asses their viability. On December 12, 2016 we met with Hydro to present our existing condition hydraulic model results and brainstorm options for flood mitigation. During this meeting, Table 6-1 below was developed to summarize options for flood mitigation. Entries shaded green were selected for further assessment.

Table 6-1 Summary of Flood Mitigation Options

Option Number	Option Details	Onsite/Offsite	Cost
1	Route 392 Culvert Replacement	Offsite	$$$$
2	Upstream Detention with Berms	Onsite &Offsite	$$
3	Perimeter Site Ditching	Onsite	$
4	Berm Around Site	Onsite	$$$
5	Realign Lower Little Bay Road	Offsite	$$$
6	Underground/Above Ground Detention	Onsite	$$
9	Redirecting Runoff to Indian Brook	Offsite	$$
10	Redirecting Portion of Watershed	Offsite	$$$$

Options of relocating and raising the Terminal Station were also discussed but were not considered flood mitigation options and received no further investigation as part of this study.

For some mitigation strategies to be effective, it is necessary that they be combined. For example, upstream detention does not prevent the Terminal Station from flooding via pooling downstream of Route 392. The upstream berms must therefore be supplemented with a downstream control measure.

The three (3) mitigation strategies selected for further analysis are summarized below:

- Option 1 – Upstream Retention Berms
- Option 2 – Upgrading of Route 392 Culverts
- Option 3 – Diversion of flow to Indian Brook

The sections below outline the results of the hydraulic analyses of the three selected mitigation strategies. Note that the 100 year AEP event with 60% culvert blockage was utilized as the design condition for all mitigation strategies considered.

6.1.1 Option 1 – Upstream Retention Berms

This strategy involves the construction of one or more berms upstream of Route 392 to prevent the progression of flow southwest along the upstream side of Route 392 to a point where it may overtop the road and flood the Terminal Station. We tested berms at numerous locations. It quickly became evident that the proposed alignment, as shown in Figures 26 through 29, is the only arrangement that would prevent flood at the Terminal Station via roadway overflow, without adjusting the roadway elevation. The berms tested in the model hat a 2.0 m top with and 2:1 side slopes to existing ground. Overall berm width varies from approximately 6.0 m to 10.0 m. Actual berm parameters must be determined during detailed design if the berm option is pursued.

Due to restrictions regarding the roadway elevation, and the requirements for any berms to tie into the roadway elevation, there appears to still be some overflow of the berm where it meets Route 392. The construction of these berms will also require discussion and coordination with the appropriate regulatory authorities. This may include the Department of Transportation and Works for the construction of berm segments within their road right-of-way, the Department of Environment and Conservation as the construction of these berms is in a potentially environmentally sensitive area, and the Department of Fisheries and Oceans for protection of fish habitat on a scheduled salmon river.

Although this overflow does not appear to result in flooding at the Terminal Station for the design event, it is questionable how effective this flood mitigation strategy would be for events in excess of the design event.

The selected alignment involves the construction of approximately 400 m of berm upstream of route 392 which prevents flooding of the Terminal Station from across Route 392. Hydraulic modeling suggests that the site still floods via pooling from Davis Brook downstream of the roadway. We therefore added a detention pond south of the Terminal Station, in addition to a cross culvert below Little Bay Road to convey water from the detention pond back to Davis Brook, to address this flooding. The hydraulic model DEM was modified to include the berm and detention pond as shown below in Figure 26.

Several iterations of pond size were modeled. It was determined that the pond is not a viable solution as it results in spillage of water onto the Terminal Station site. The pond shown in Figure 26 below is 120 m x 40 m. Even at that large size, the detention pond did not contain sufficient storage capacity to prevent flooding at site. The detention ponds ineffectiveness is attributable to the minimal relief between the Terminal Station site and the river, which greatly limits the depth at which the detention pond can be constructed. An inundation map for this option is provided below in Figure 27. Note that the Terminal Station is inundated at the design return period.

A second strategy was assessed to prevent flooding via pooling downstream of Route 392: construction of a berm along the east boundary of the Terminal Station site and the west side of

Little Bay Road, as shown in Figure 28. This option effectively prevented flooding at site for the 1:100 year return period, as shown in Figure 29 and on the inundation Map in Appendix B.

Table 6-2 below compares pre and post mitigation water levels for this option using the 1:100 year return period event to assess if the mitigation will have any effect on downstream flooding. Please note this table is only applicable to the three berm option as the two berm and detention option did not prevent flooding at the terminal station infrastructure.

Table 6-2 Comparison of Pre and Post Mitigation Water Levels – Option 1

Location	Pre-Mitigation Water Level (m)	Post-Mitigation Water Level (m)
Terminal Station Building	0.23	0.00
Little Bay Road Dwelling	0.86	0.54

As shown in the above table, the berm mitigation strategy reduces downstream flooding levels. This is likely due to the inability of water to reach the Little Bay Road dwelling via overland flow across Route 392 and at the Terminal station, due to the upstream retention berms.

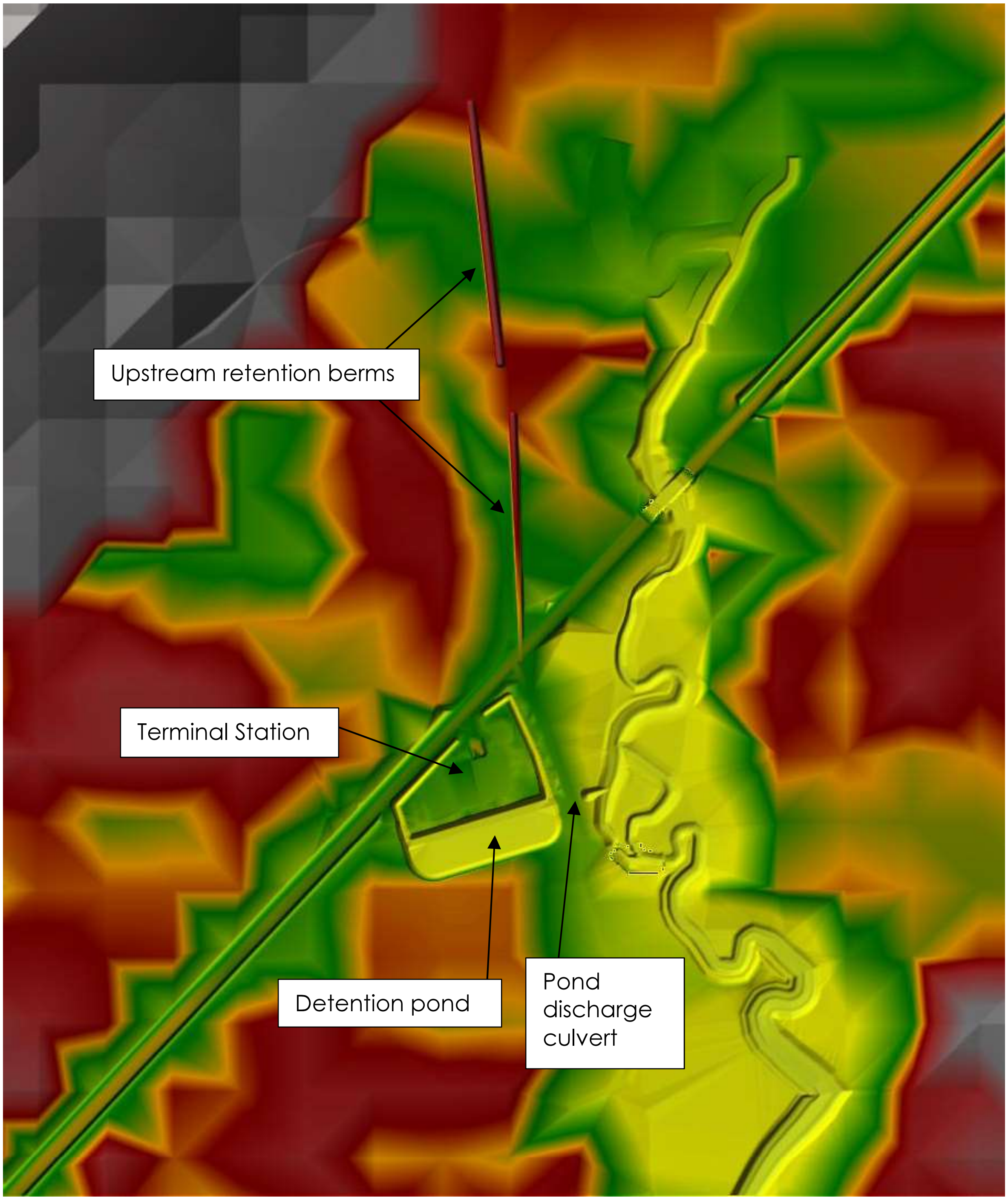


Figure 26 Option 1A – Two Berms Upstream of Route 392 and Detention Pond at the Terminal Station – Digital Elevation Model

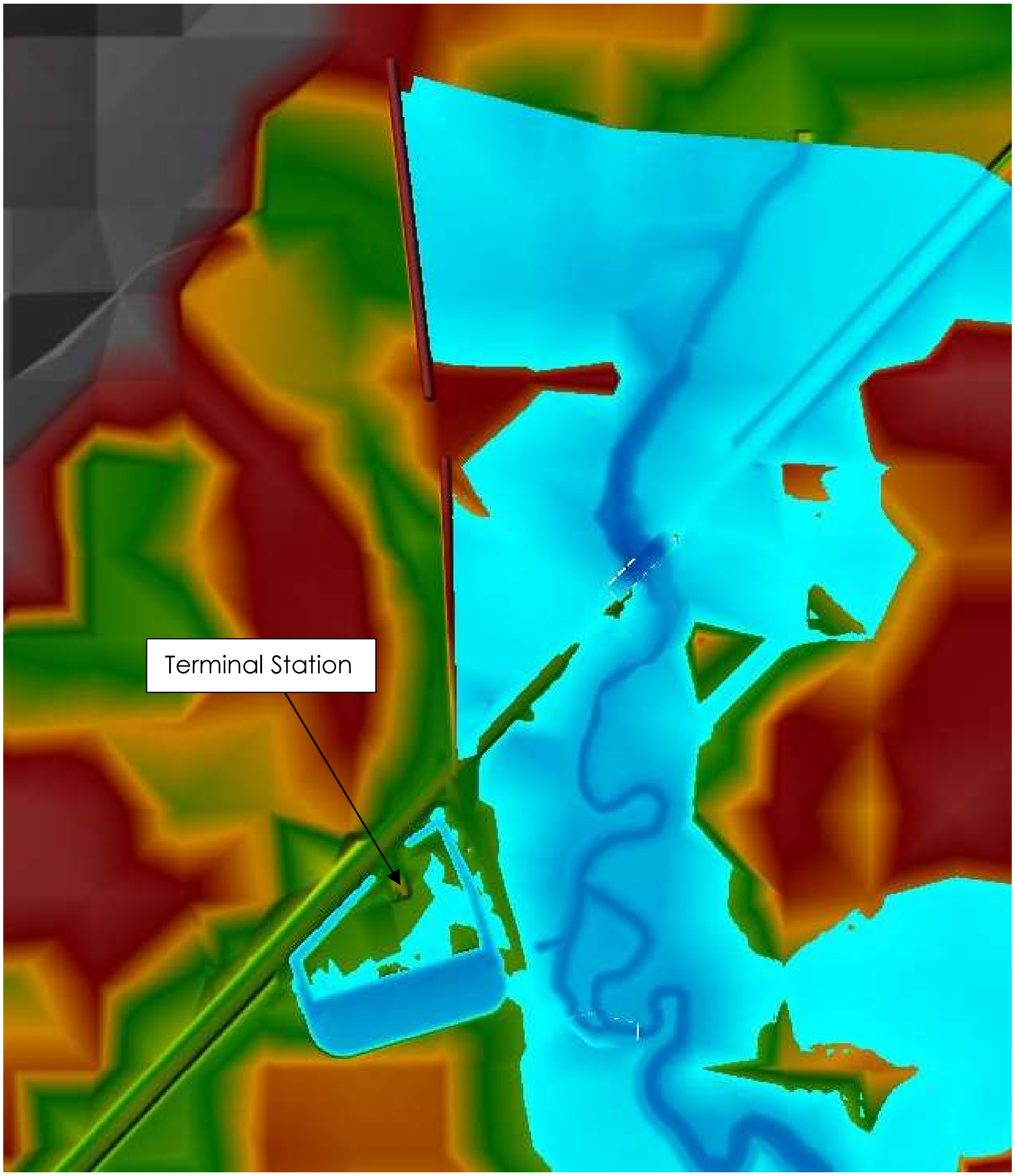


Figure 27 Option 1A – Flood Inundation

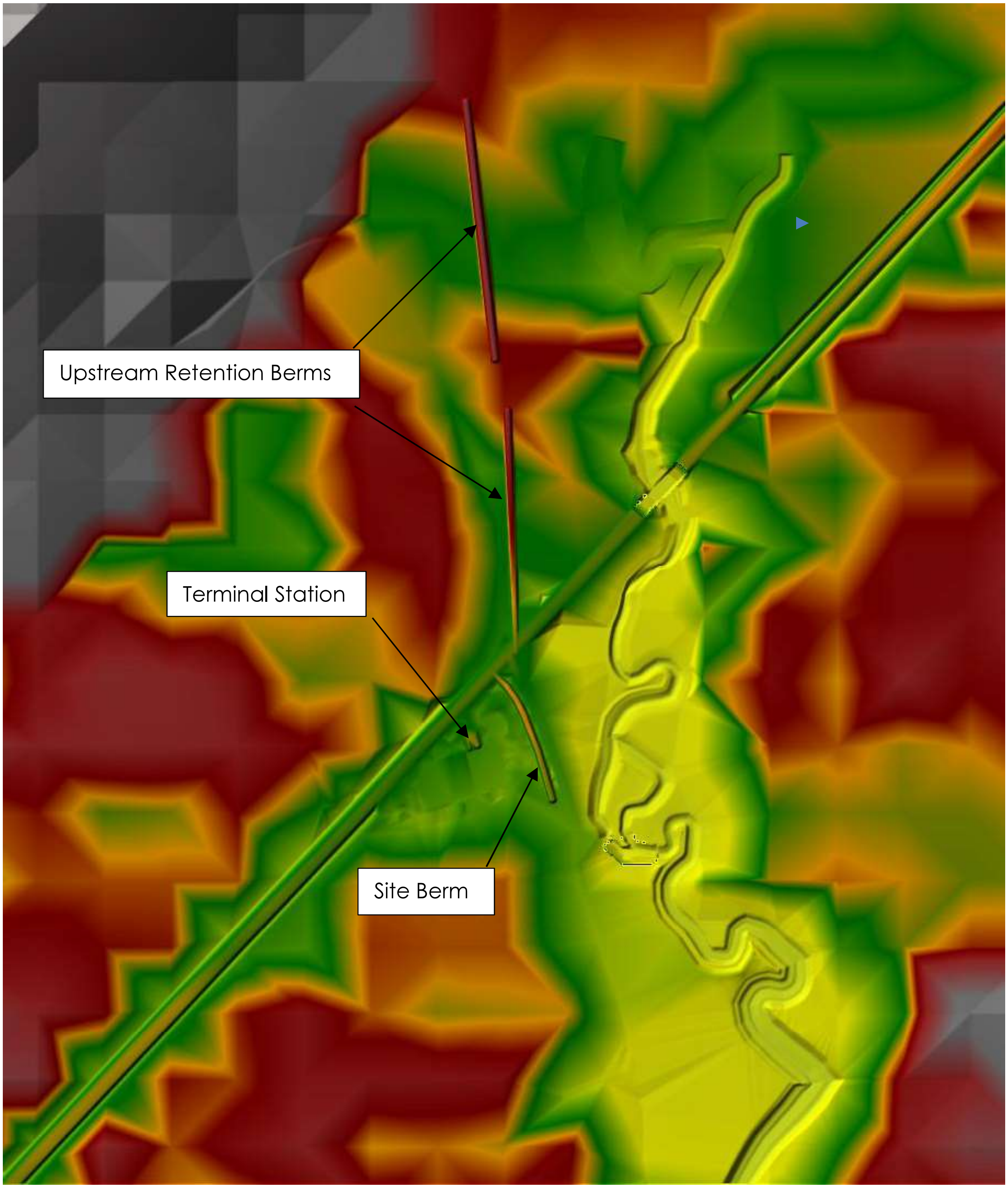


Figure 28 Option 1B – Two Berms Upstream of Route 392 and one Berm Downstream at Terminal Station – Digital Elevation Model

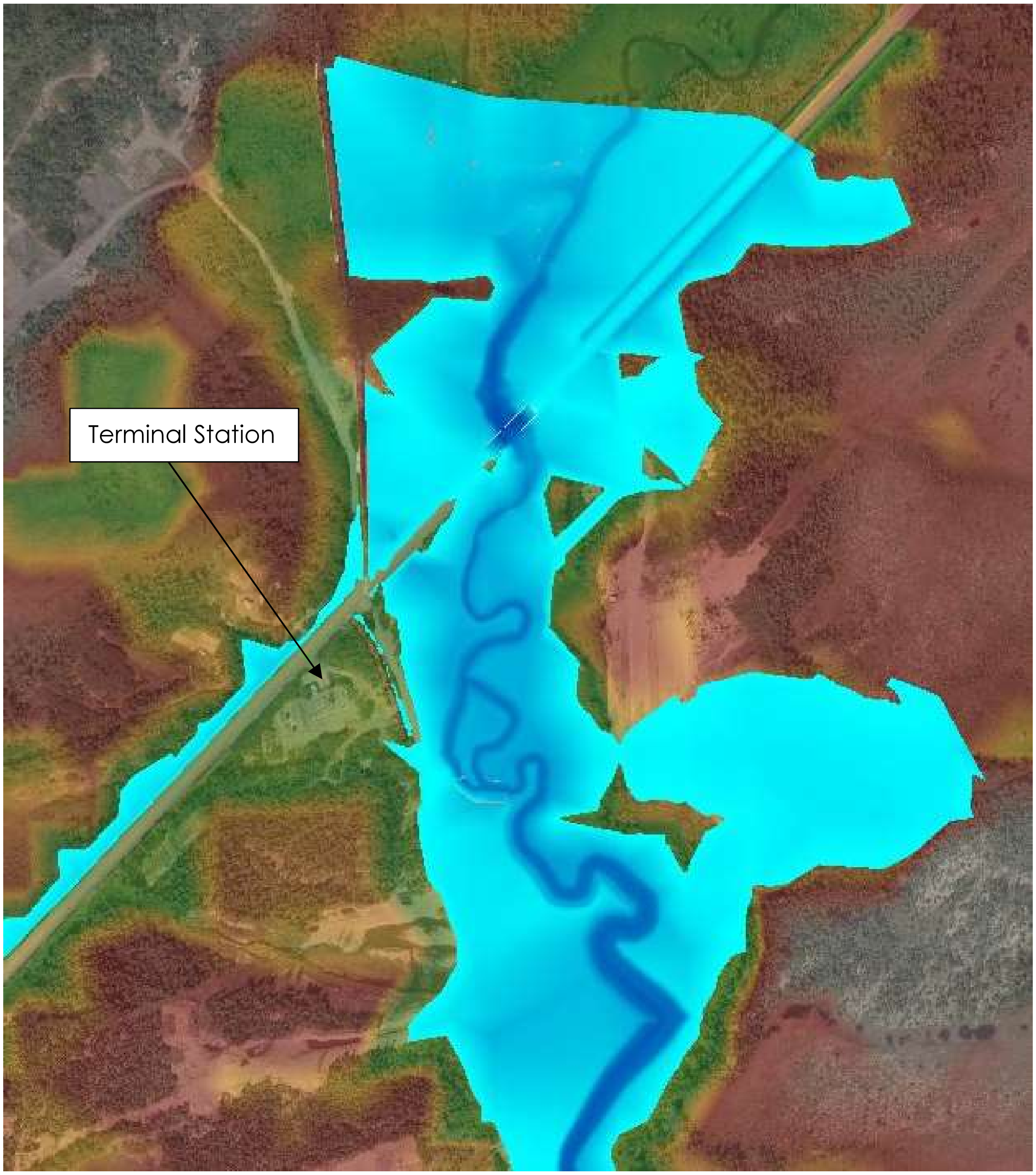


Figure 29 Option 1B – Flood Inundation

6.1.2 Option 2 – Upgrade of Route 392 Culverts

This mitigation strategy consists of the replacement of the existing 6 barrel culvert arrangement at Route 392 with a larger span structure that would be less susceptible to debris blockage and have a larger flow capacity than the existing arrangement. As such, the design condition for this mitigation strategy was the 1:100 AEP flow event and did not include any culvert blockage at Route 392. This larger span structured was sized to accommodate the 1:100 AEP flow without blockage.

Based on the survey data, the 6 existing culverts at Route 392 are 1.52 m high x 2.06 m wide corrugated steel pipe arches with an end area of 2.49 m^2 each, for a total end area of 14.94 m^2. The structure selected to replace the existing culvert arrangement in the hydraulic model was a 12.0 m wide by 2.8 m high corrugated steel plate bottomless box culvert with an end area of 26.69 m^2. The installation of such a structure would necessitate raising Route 392 to provide the approximately 2.0 m of cover required by the large box culvert. The existing and proposed culvert arrangements are shown in Figures 30 and 31 below.

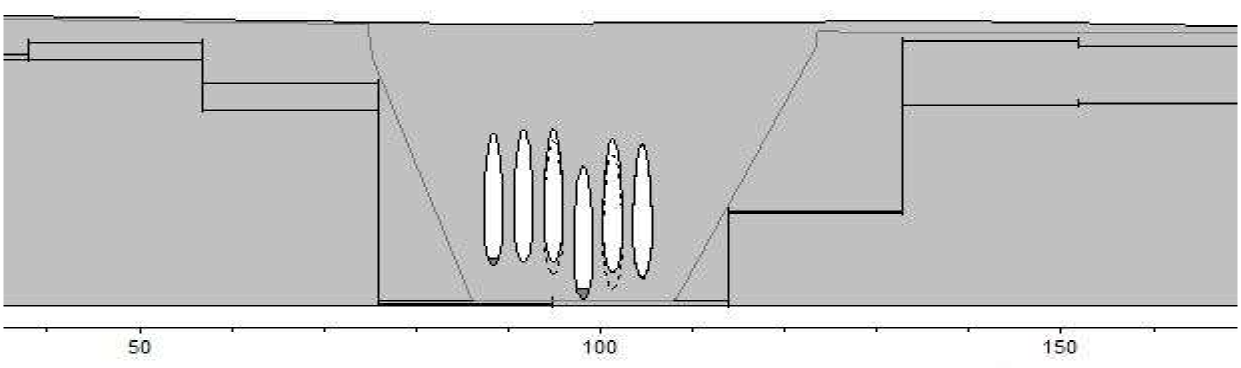


Figure 30 Existing Culverts at Route 392

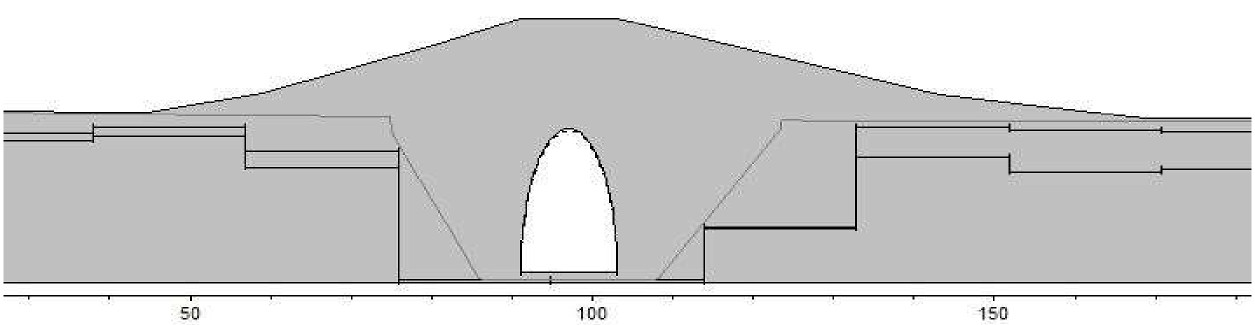


Figure 31 Proposed Culvert Arrangement at Route 392 (not to scale)

Hydraulic analyses revealed that this culvert upgrade is ineffective in reducing flooding at the Terminal Station for the 1:100 AEP storm event. It appears that the very flat nature of the riverbed and terrain downstream of the culverts causes water to naturally pool and attenuate in this area, resulting in flooding at site. To confirm this result, we ran the hydraulic model with the culvert structure and roadway embankment removed to allow Davis Brook to flow unimpeded through route 392, and a similar level of flooding resulted. Table 6-3 below shows Pre and Post-Mitigation water level for the option of upgrading the culvert.

Table 6-3 Comparison of Pre and Post Mitigation Water Levels – Option 2

Location	Pre-Mitigation Water Level (m)	Post-Mitigation Water Level (m)
Terminal Station Building	0.23	0.30
Little Bay Road Dwelling	0.86	1.03

As shown in the table above the flooding at the Terminal Station and Dwelling at Little Bay Road increases when the upgraded culvert is introduced. The model shows that flooding at the Terminal Station under this arrangement initially comes from the channel downstream of Route 392. This is because the upgraded culvert arrangement allows more water into the channel than the existing arrangement.

Based on the results noted above, it was concluded that upgrading the culverts at Route 392 is not a viable option for flood mitigation during a 1:100 AEP flood event Therefore, it was given no further consideration.

6.1.3 Option 3 – Diversion of Flow to Indian Brook

This mitigation strategy involves the diversion of flood flow to Indian Brook via construction of approximately 720 m of ditching along the northwest side of Route 392. To facilitate this diversion, installation of two (2) cross culverts at Little Bay Road and Route 390, as well as approximately 50 m of ditching between route 392 and Indian Brook, is required. The cross culverts modeled were 2000 mm and 600 mm at Route 392 and Little Bay Road respectively. The ditch that was modeled is trapezoidal with a 2.0 m wide bottom and 2:1 side slopes to original ground. The ditch depth is variable due to the elevation constraints at the upstream and downstream ends of the ditch. It's approximate maximum and minimum depth are 3.1 m and

1.0 m. Exact ditch dimensions are to be determined during a detailed design phase. This strategy is intended to divert water to Indian Brook prior to it overtopping Route 392.

The Digital Elevation Model and hydraulic model geometry files were modified to extend the model to the west to capture a portion of Indian Brook. This modification included a simple, assumed bathymetry at Indian Brook. The updated DEM is shown Figure 32.

Hydraulic modeling of this strategy, assuming a 1:100 AEP inflow with 60% culvert blockage, reveals that it is an effective means of preventing flooding at the Terminal Station. Flood inundation for this option is provided in Figure 33, as well as in Appendix B. Table 6-3 below shows a comparison of pre and post-mitigation water levels.

Table 6-4 Comparison of Pre and Post-Mitigation Water Levels – Option 3

Location	Pre-Mitigation Water Level (m)	Post-Mitigation Water Level (m)
Terminal Station Building	0.23	0.00
Little Bay Road Dwelling	0.86	0.43

As shown in the above table, the ditch mitigation strategy reduces downstream flooding levels. This is due to the fact that a portion of the flood inflow is being diverted to Indian Brook.

This option will still require coordination with appropriate regulatory authorities such as the Department of Transportation and Works for the construction of ditching within their right of way, and the installation of culverts traversing their roads. The Department of Environment and Conservation and the Department of Fisheries and Oceans may also may also require consultation and coordination.

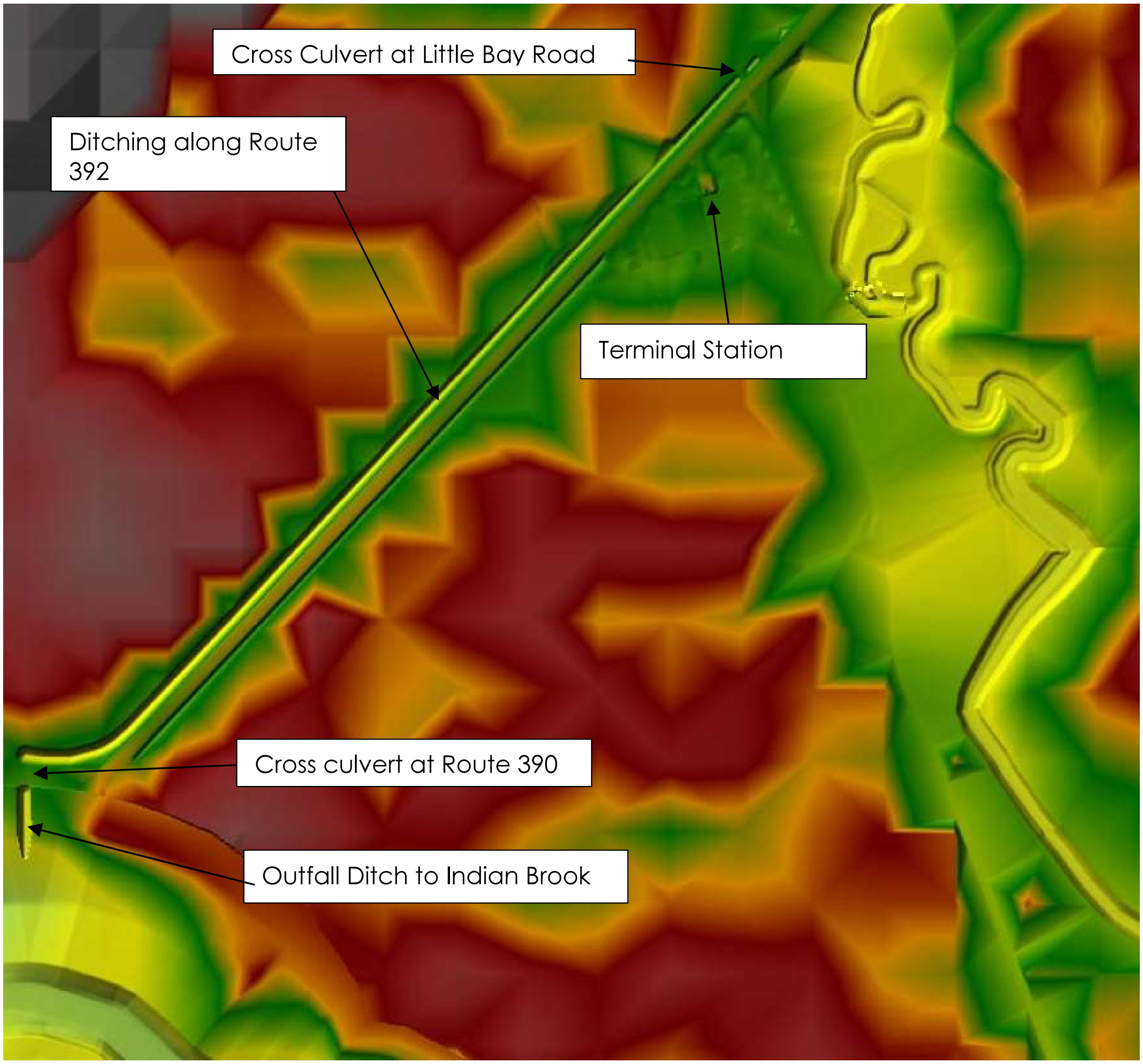


Figure 32 Option 3 – Digital Elevation Model

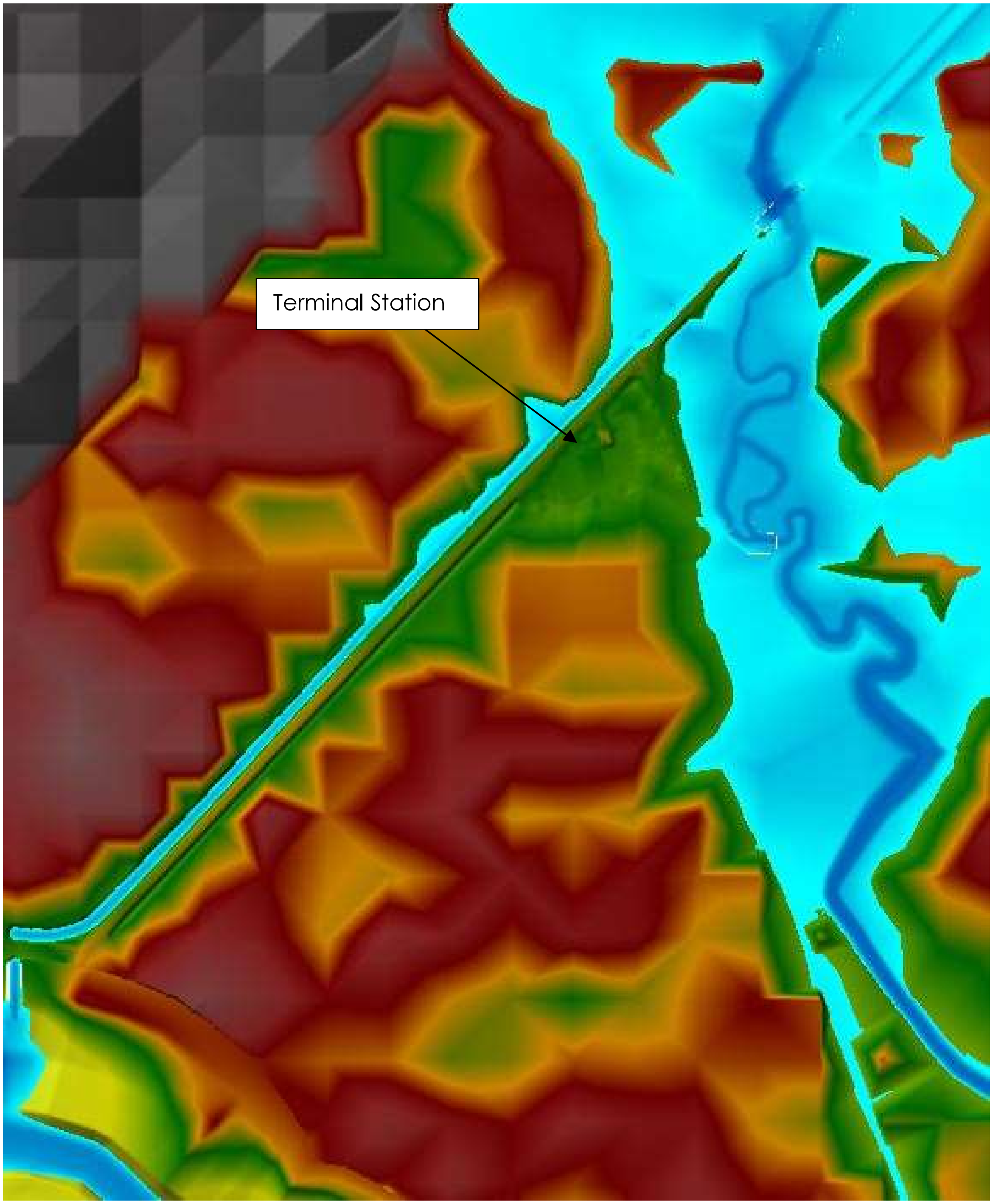


Figure 33 Option 3 – Flood Inundation

6.2 COST ESTIMATES

Of the mitigation strategies detailed above in Section 6.1, two were found to be effective in mitigating the risk of flooding at the terminal station (Option 1B and Option 3). As such we have completed budgetary cost estimates for these two strategies, which include supply, installation and construction of all components. The estimated costs are provided below in Table 6-4.

Table 6-5 Cost Estimates

Mitigation Strategy Description	Estimated Cost
Option 1B – Three berms	$380,000
Option 3 - Diversion of flow to Indian Brook	$410,000

Note that the scope of this assignment does not include optimization of the outlined conceptual flood mitigation measures. The above cost estimates are therefore based on quantities associated with simple hydraulic model geometries and standard construction practices. Cost estimates are therefore subject to change during detailed design of the noted mitigation measures. These are budgetary cost estimates with an expected accuracy of +/-50%. Cost Estimates do not include HST. A breakdown of the above cost estimates are included in Appendix C.

7.0 CONCLUSIONS AND RECOMMENDATIONS

Conclusions and recommendations arising from this study are as follows:

Conclusions

- Analysis of the existing conditions at Davis Brook suggest that culvert blockage was the cause of the flooding at the Terminal Station for the April 29, 2015 storm event.
- Culvert Blockage has the potential to cause flooding at the Terminal Station for the 1:2 AEP flood event.
- The below flood mitigation options effectively prevent flooding at the Terminal Station under the design condition:
  - Option 1B: Construction of two retention berms upstream of Route 392 combined with a downstream berm to the east of the Terminal Station
  - Option 3: Diversion of flow upstream of Route 392 to Indian Brook
- As indicated in the comparison of pre and post-mitigation water levels of each of the analyzed options, options 1B and 3 do not show any increase in downstream flooding in the model.

Evaluation of Viable Options

Although Option 3 appears to be slightly more costly, it may be the more preferable option than Option 1B for the following reasons:

- It avoids the construction of berms in environmentally sensitive areas which could increase costs due to permitting
- It eliminates the risk of flooding from a potential berm breach
- It does not disturb any infrastructure at the Terminal Station, whereas the berm strategy may require the relocation of some site features. The berm modeled at the Terminal Station site currently impedes on the locations of three poles and associated guy wires.
- It provides a clear path for water to flow away from the Terminal Station, whereas there is still some inherent uncertainty with the berm option as it relates to overtopping at the south end of the berm at Route 392

Recommendations

- It is recommended that additional survey data be collected during the detailed design phase of any remedial measures. This data should be incorporated into the hydraulic model to confirm the validity of the selected mitigation measure. Additional survey data may alter the scope of work necessary to achieve the desired mitigation option. For example, the northern most berm for Option 1B is in an area that contains no ground survey data and is based entirely on the sparse orthophoto dataset. As such, collecting detailed survey information in this area will confirm with a greater degree of certainty the extent of berm required.

- Since the estimated costs for the construction of the viable options do not vary significantly from each other, they should each be reviewed further prior to determining which one to proceed with.
- Given that that the flooding occurred in April and that snow/ice and debris appear to be a contributing factor to the flooding, both viable remedial options are subject to capacity reductions due to the presence of snow, ice, or debris. Therefore, it is recommended that all flood control infrastructure including ditches, berms and culverts be monitored for the and cleared of potential performance reducing debris.

8.0 REFERENCES

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APPENDIX A
SITE VISIT PHOTOS

Photo #	Description
Photo 1	Upstream culvert structure at Route 392 looking southwest.
Photo 2	Downstream culvert structure at Route 392 looking northeast.
Photo 3	Woody debris at upstream of culverts at route 392.
Photo 4	Heavy brush on overbanks upstream of Route 392 culverts.
Photo 5	Heavy brush and sediment on overbanks downstream of Route 392 culverts.
Photo 6	Woody debris and sediment on overbank downstream of culverts at Route 392.
Photo 7	Photo 7: Downstream culvert structure at Route 392 looking north.
Photo 8	Upstream of cross culvert at Route 392 looking northeast.
Photo 9	Downstream of cross culvert at Route 392.
Photo 10	Little Bay Road at intersection with Route 392 looking north.
Photo 11	View of Terminal Station From Little Bay Road.
Photo 12	View of Terminal Station Buildings near Route 392.
Photo 13	Entrance to Terminal Station from Route 392.
Photo 14	Terminal Station Building and concrete pad looking south.
Photo 15	Terminal station access road from Route 392.
Photo 16	Davis Brook channel near Little Bay Road.
Photo 17	Little Bay Road Looking South.
Photo 18	Dwelling near Davis Brook on Little Bay Road.
Photo 19	Dwelling near Davis Brook on Little Bay Road.
Photo 20	Man mand pond near Little Bay Road.
Photo 21	T'Railway bridge across Davis Brook.
Photo 22	Davis Brook channel from T'Railway bridge.
Photo 23	Flow passing through woody debris in Davis Brook Channel Near Route 392.
Photo 24	Route 392 looking southwest.
Photo 25	Route 392 looking northeast.
Photo 26	Heavy brush and wetland near Route 392.
Photo 27	Route 392 Looking northeaast from Davis Brook.
Photo 28	Little Bay Road looking south from Route 392.
Photo 29	Heavy brush on overbanks near Little Bay Road.
Photo 30	Residential development near Little Bay Road.


Photo 1: Upstream culvert structure at Route 392 looking southwest.


Photo 2: Downstream culvert structure at Route 392 looking northeast.


Photo 3: Woody debris at upstream of culverts at route 392.


Photo 4: Heavy brush on overbanks upstream of Route 392 culverts.

Photo 5: Heavy brush and sediment on overbanks downstream of Route 392 culverts.

Photo 6: Woody debris and sediment on overbank downstream of culverts at Route 392.

Photo 7: Downstream culvert structure at Route 392 looking north.

Photo 8: Upstream of cross culvert at Route 392 looking northeast.

Photo 9: Downstream of cross culvert at Route 392.

Photo 10: Little Bay Road at intersection with Route 392 looking north.

Photo 11: View of Terminal Station From Little Bay Road.

Photo 12: View of Terminal Station Buildings near Route 392.

Photo 13: Entrance to Terminal Station from Route 392.

Photo 14: Terminal Station Building and concrete pad looking south.

Photo 15: Terminal station access road from Route 392.

Photo 16: Davis Brook channel near Little Bay Road.

Photo 17: Little Bay Road Looking South.

Photo 18: Dwelling near Davis Brook on Little Bay Road.

Photo 19: Dwelling near Davis Brook on Little Bay Road.

Photo 20: Man mand pond near Little Bay Road

Photo 21: T'Railway bridge across Davis Brook.


Photo 22: Davis Brook channel from T'Railway bridge.

Photo 23: Flow passing through woody debris in Davis Brook Channel Near Route 392.

Photo 24: Route 392 looking southwest.


Photo 25: Route 392 looking northeast.


Photo 26: Heavy brush and wetland near Route 392.


Photo 27: Route 392 Looking northeaast from Davis Brook.


Photo 28: Little Bay Road looking south from Route 392.

Photo 29: Heavy brush on overbanks near Little Bay Road.

Photo 30: Residential development near Little Bay Road.

APPENDIX B
FLOOD INUNDATION MAPS

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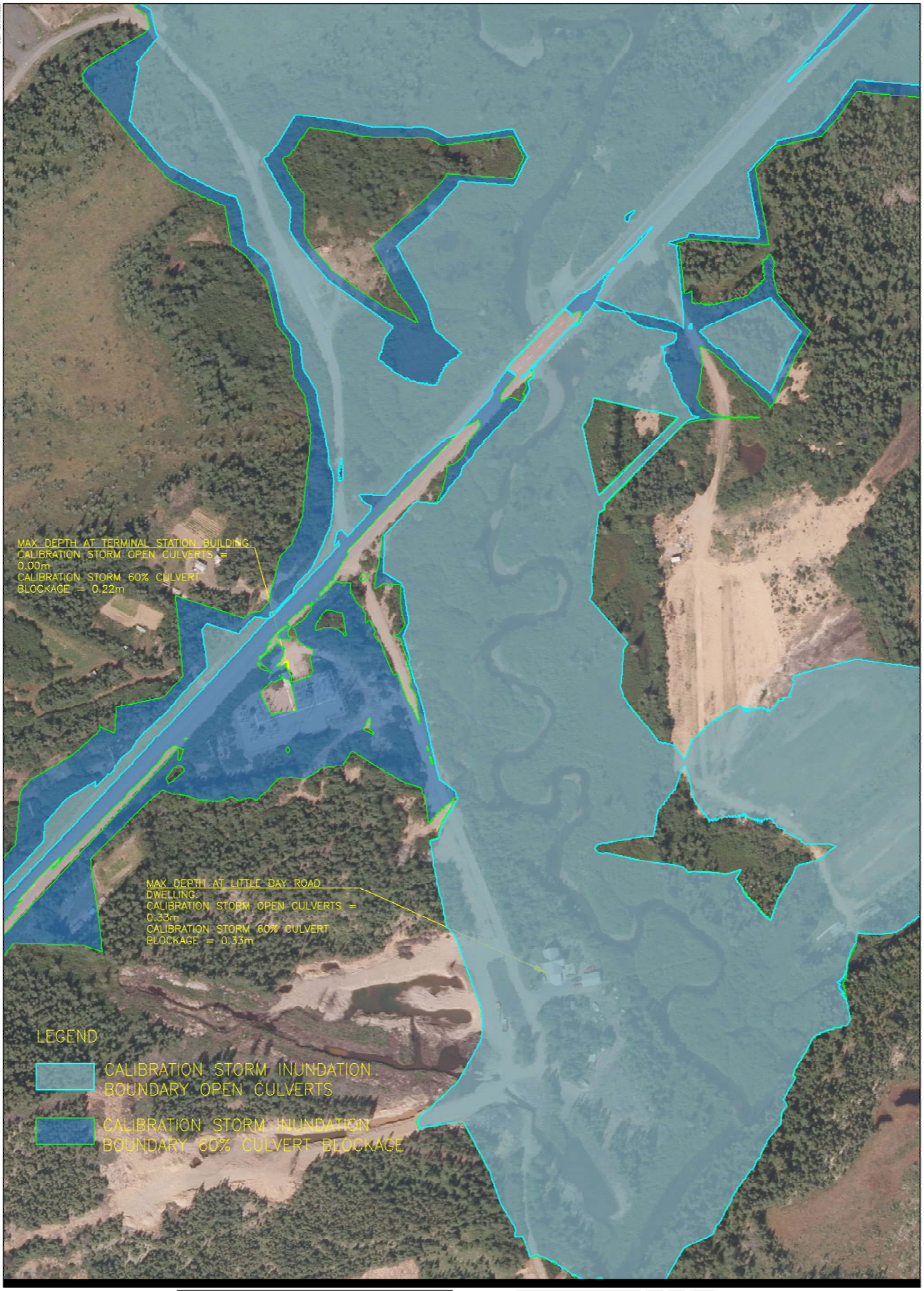

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SPRINGDALE FLOOD STUDY

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INUNDATION MAP - APRIL 2015 CALIBRATION STORM OPEN AND BLOCKED CULVERTS

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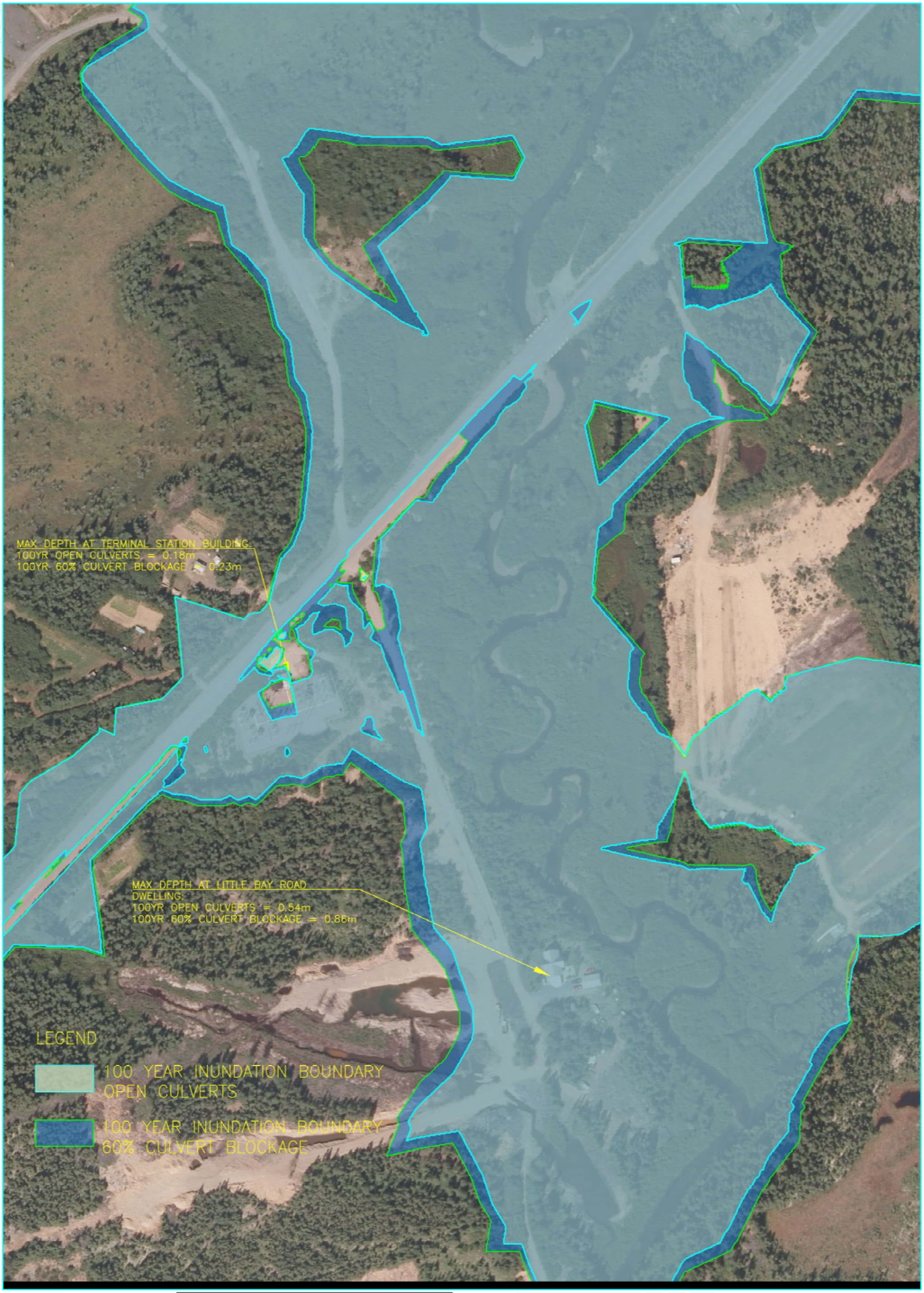

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SPRINGDALE FLOOD STUDY

Springdale, NL

INUNDATION MAP - 100 YEAR OPEN AND BLOCKED CULVERTS

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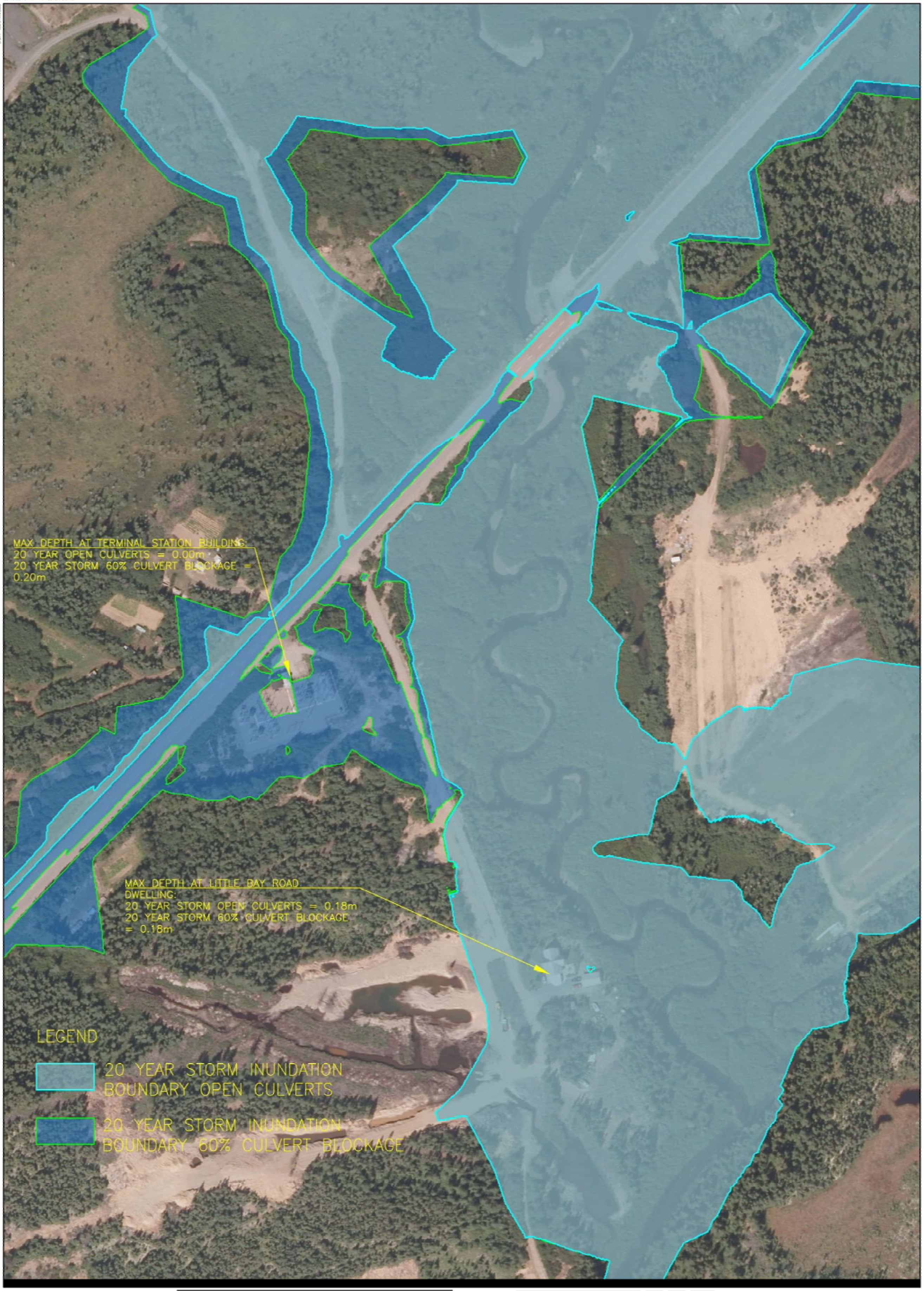

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SPRINGDALE FLOOD STUDY

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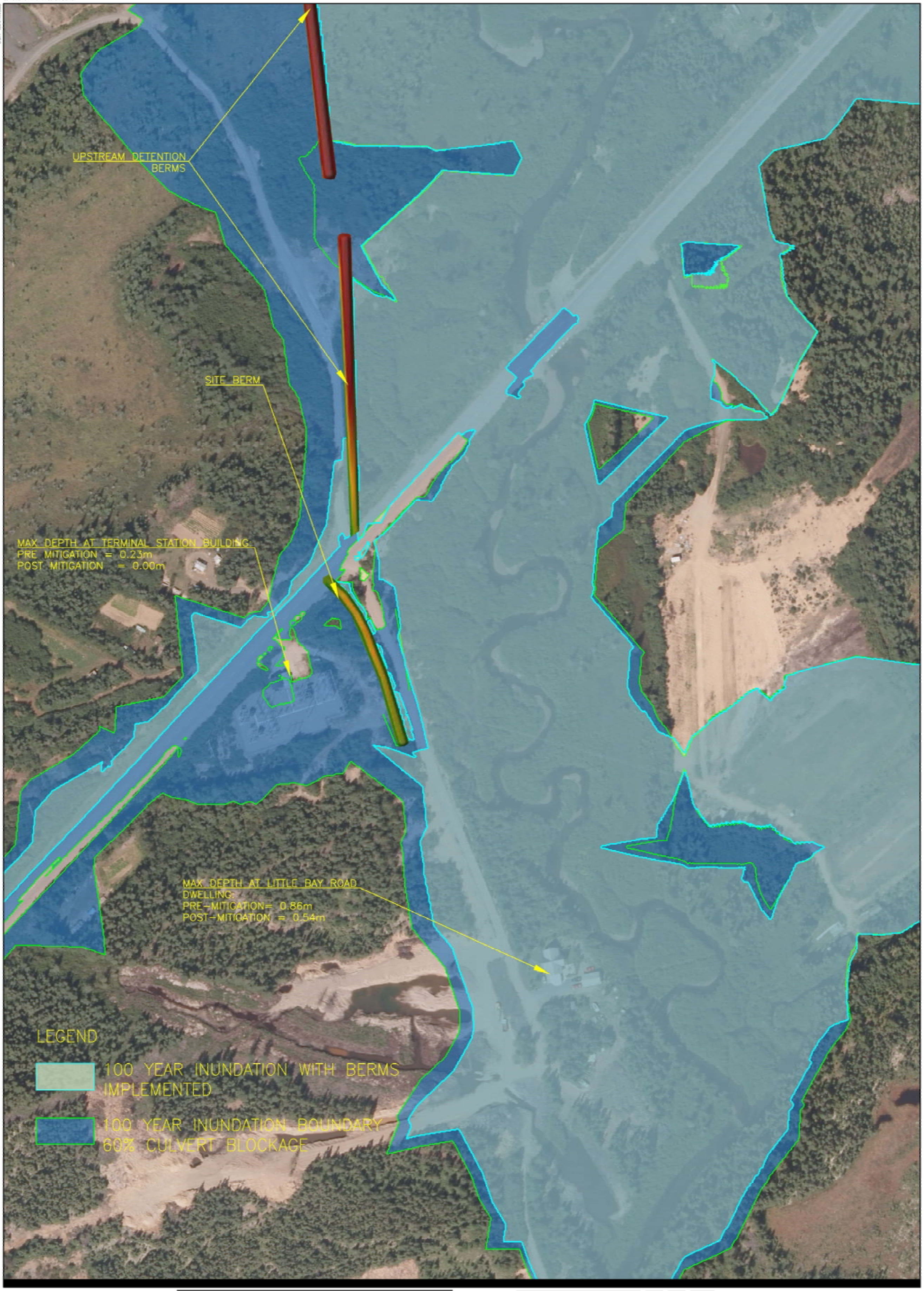

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SPRINGDALE FLOOD STUDY

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INUNDATION MAP - 100 YEAR BLOCKED CULVERTS AND BERM MITIGATION STRATEGY

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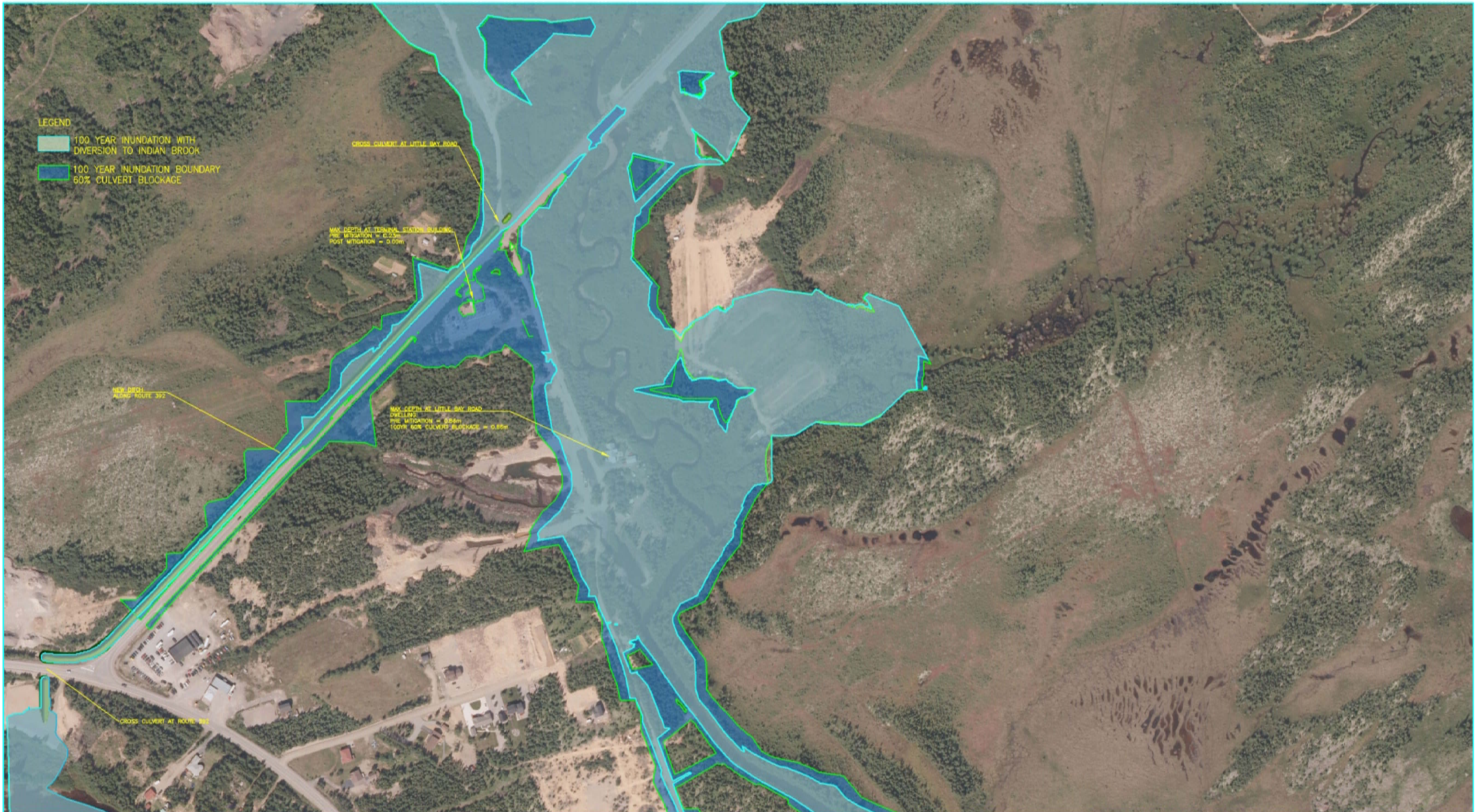

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INUNDATION MAP - 100 YEAR BLOCKED CULVERTS AND INDIAN BROOK DIVERSION MITIGATION STRATEGY

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APPENDIX C
COST ESTIMATES

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Option 1B Berm Retention

Item	Description	Quantity	Unit	Unit Price	Total
211	**Mobilizatin/ Demobilization**				$10,000
311	**Clearing and Grubbing**				
	Claearing and Grubbing	0.4	HA	$ 10,000.00	$ 4,000.00
321	**Excavation and Errosion Protection**				
	USM Removal	3701	CM	$ 15.00	$ 55,515.00
	Imported Structural Fill for BErms(Placed and Compacted)	6789	CM	$ 25.00	$ 169,725.00
	200mm minus errosion protection	1692	CM	$ 25.00	$ 42,300.00
	Geotextile	5500	SM	$ 7.00	$ 38,500.00
511	**Topsoiling, Sodding and/or Hydroseeding**				
	150mm topsoil and nursury sod	2750	SM	$ 17.00	$ 46,750.00
	Contengcy (5%)				$ 18,339.50
			Total(HST EXTRA)		**$ 385,129.50**

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Option 3 Indian Brook Diversion

Item	Description	Quantity	Unit	Unit Price	Total
	Mobilization/Demobilization				$ 10,000.00
211	**Trench Excavation**				
	SR	25	CM	$ 60.00	$ 1,500.00
	OM	250	CM	$ 20.00	$ 5,000.00
	USM	210	CM	$ 25.00	$ 5,250.00
	100mm minus blasted rock	210	CM	$ 25.00	$ 5,250.00
	Class 'B' Bedding	41	CM	$ 20.00	$ 820.00
	Concrete Pipe Surround	1	CM	$ 10.00	$ 10.00
222	**Storm Sewer**				
	600mm CHDPE Culverts	8	LM	$ 600.00	$ 4,800.00
	2000mm CSP Culverts	25	LM	$ 1,029.00	$ 25,725.00
223	**Manholes Catch Basins, Ditch Inlets, Headwalls and Chambers**				
	Headwall CW HANDRAIL	4	EA	$ 5,400.00	$ 21,600.00
321	**Street Excavation**				
	Asphalt Removal	12	CM	$ 20.00	$ 240.00
	OM				
	Excavation and Errosion Protection for Ditching				
	Excavation for Ditching	6196	CM	$ 30.00	$ 185,880.00
	Ditch Errosion Protection	1692	CM	$ 25.00	$ 42,300.00
	Class III Rip-Rip	400	CM	$ 100.00	$ 40,000.00
	Clearing and Grubbing	0.7	HA	$ 10,000.00	$ 7,000.00
323	**Gravel for Streets**				
	Class B	160	tonne	$ 25.00	$ 4,000.00
	Class A	80	tonne	$ 28.00	$ 2,240.00
351	**Hot Mix Asphaltic Concrete**				
	Surface Course 80mm tk	25	tonne	$ 160.00	$ 4,000.00

Item	Description	Quantity	Unit	Unit Price	Total
511	**Topsoiling, Sodding and/or Hydroseeding**				
	150mm topsoil and nursury sod	1410	SM	$ 17.00	$ 23,970.00
	Contengcy (5%)				$ 19,479.25
			Total(HST EXTRA)		**$ 409,064.25**

Engineering Flood Mitigation Analysis - Springdale Terminal Station

FINAL REPORT

November 1, 2018

Prepared for:

Newfoundland and Labrador Hydro
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Revision	Description	Author		Quality Check		Independent Review	
0	DRAFT	D. Erl	09/18/18	J. Innes	09/18/18	W. Warford	09/17/18
1	Final	D.Erl	11/01/18	J. Innes	09/18/18	P.Porter	11/01/2018

Sign-off Sheet

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Approved by ____

(signature)

Lorne Boone M. Eng, P. Eng, P. Geo.

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Executive Summary

Newfoundland and Labrador Hydro (NL Hydro) has experienced flooding at the Springdale Terminal Station on two occasions in the past 12 years on April 18, 2006 and April 29, 2015. The April 2015 flood event caused damage to equipment at the terminal station.

In 2017 Stantec Consulting Limited conducted a flood study to investigate the cause of flooding and to recommend viable options for flood mitigation. The viability assessment utilized the 1 in 100 AEP flow event as the design criteria. This analysis identified two options for flood mitigation as follows:

- **Option 1:** Construct flood retention berm upstream of Route 392 as well as on the east side of the Terminal Station
- **Option 2:** Construct a diversion ditch on the northwest side of Route 392 to direct flood flow to Indian River

The 2017 flood study noted some uncertainty in these options due to accuracy limitations associated with provincial orthophoto elevation data used in the hydraulic model in the areas of the proposed mitigation measures. This current Engineering Flood Mitigation Analysis study will further analyze and validate these options with more accurate topographic data, develop appropriate design parameters for each option, assess permitting and coordination considerations with regulatory authorities, refine cost estimate for each option +/- 25% and provide recommendations on how to proceed.

The results of this updated analysis found that of the two options identified in the 2017 study the only viable option was **Option 1** to construct a flood retention berm upstream of Route 392. However, it was found that the berm on the East side of the Terminal Statin was not required instead an optional site berm near the south boundary of the Terminal Station was found to prevent water from entering the fenced yard. This berm is optional as the area it prevents from flooding does not contain the building in which the relay equipment is housed.

Although **Option 1** was found to be the only viable option, opinions of probable construction cost are provided for both options as follows:

- **Option 1: $902,864.55 (Plus HST)**
- **Option 2: $423,570.00 (Plus HST)**

It is recommended that NL Hydro proceed with the detailed design of Option 1, flood mitigation berms. To first step this process is to undertake a geotechnical investigation to determine appropriate berm foundation design, as well as a suitable source of berm construction material. This geotechnical investigation has been included and will be undertaken in Phase 2 of the project. Once the geotechnical investigation in complete, it is recommended that the preliminary design drawings including plan, profile and sections be produced and sent to the appropriate regulatory authorities for review and approval.

1.0 INTRODUCTION

Newfoundland and Labrador Hydro (NL Hydro) has experienced flooding at the Springdale Terminal Station on two occasions in the past 12 years on April 18, 2006 and April 29, 2015. The April 2015 flood event caused damage to equipment at the terminal station. The terminal station is located near the north end of Little Bay Road, and approximately 150 m west of where Davis Brook passes under Beachside Road (Route 392) as shown in Figure 1 and Figure 2, respectively.

Figure 1: Location of Terminal Station in the Town of Springdale

Figure 2: Proximity of Terminal Station to Davis Brook

In 2017 Stantec Consulting Limited conducted a flood study to investigate the cause of flooding and to recommend viable options for flood mitigation. The 2017 study included Hydrological analysis to determine inflow sequences with consideration of the April 2015 event that caused flooding, as well as return period high flow events. The derived April 2015 inflow sequence was utilized to develop a calibrated 2D hydraulic model using which potential mitigation measures could be assessed for viability. The viability assessment utilized the 1 in 100 AEP flow event as the design criteria. This analysis identified two options for flood mitigation as follows:

- **Option 1:** Construct flood retention upstream of Route 392 as well as on the east side of the Terminal Station
- **Option 2:** Construct a diversion ditch on the northwest side of Route 392 to direct flood flow to Indian River

The 2017 flood study noted some uncertainty in these options due to accuracy limitations associated with provincial orthophoto elevation data used in the hydraulic model in the areas of the proposed mitigation measures. This current Engineering Flood Mitigation Analysis study will further analyze and validate these options with more accurate topographic data, develop appropriate design parameters for each option, assess permitting and coordination considerations with regulatory authorities, refine cost estimate for each option +/- 25% and provide recommendations on how to proceed.

2.0 BACKGROUND REVIEW

Stantec conducted a thorough review of the of the 2017 flood study and its models, analyses, assumptions and methods. The purpose of this review was to identify areas in the 2017 digital elevation model that require additional topographic information for use in the hydraulic model validation. Additionally, Stantec conduced desktop review of updated mapping and aerial imagery to determine the potential locations of infrastructure such as culverts, driveways and signs that would have to be picked up in the topographic survey. The presence of such infrastructure was to be verified during the site visit.

In addition to identifying gaps in the topographic information utilized in 2017, the previous study also provided the Hydrological inputs utilized for the current study. Inflow sequences for Davis Brook, Indian River and lateral inflows are based on the Hydrological analysis performed in the 2017 study.

3.0 SITE VISIT

On July 30, 2018 Stantec conducted a site visit to perform the following tasks:

- Assess and photograph locations of proposed mitigation options
- Conduct hydraulic reconnaissance for the ditch diversion option including photographing and assessing the existing culverts along the proposed ditch path
- Provide cursory assessment of the ground conditions where berms are to be founded, i.e. where there is bog to be removed, etc.
- Assess and photograph any potential infrastructure conflicts such as poles and guy wires
- Asses Davis Brook in the area within the hydraulic model domain to determine if any hydraulic conditions have appreciably changed since the completion of the 2017 flood study

3.1 OPTION 1 SITE VISIT OBSERVATIONS

During the site visit the potential areas of the berms were assessed and photographed. These areas are shown in Figure 3 below:

Figure 3: Area Assessed for Option 1 During Site Visit

Key observed conditions that could influence the design and construction of the proposed flood mitigation berms for Option 1 are as follows:

1. Thick alder bush cover near Route 392 in the vicinity of the proposed berms.
2. There is an existing higher elevation berm type structure surrounding a wood storage area located on the side of Little Bay Road north of Route 392.
3. Wet boggy area near proposed berm at Little Bay Road north of Route 392.
4. Elevation rises near curve in Little Bay Road north of Route 392 for termination of the north berm.
5. The land downstream of the cross culvert on Route 392 is “bowled” and has no clear conveyance path to Davis Brook. Improvement of this conveyance path may provide opportunity to slightly reduce berm height.
6. There is a contractor’s pit of gravel and earthen material at the end of Little Bay Road north of Route 392 that could potentially serve as a nearby source of material for berm construction.
7. There are poles and guy wires that could potentially require relocation or effect the location of the Terminal Station berm

Figure 4 below shows the locations of the above observations utilizing the same numbering system:

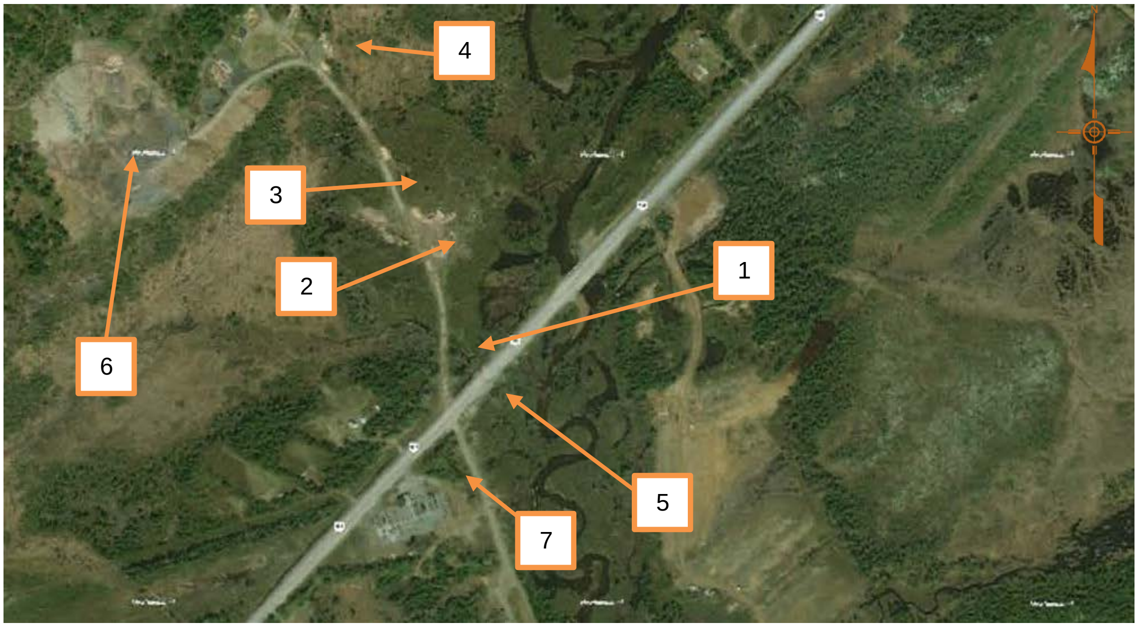

Figure 4: Option 1 Site Visit Observation Locations

Photographs of the above observations are shown in Figure 5 through Figure 11 below.

Figure 5 : Option 1 Site Visit Observation 1 - Thick Alder Cover Rear Route 392

Figure 6: Option 1 Site Visit Observation 2 – Existing Berm Type Structure

Figure 7: Option 1 Site Visit Observation 3 – Wet Boggy Area Near Proposed Berm

Figure 8: Option 1 Site Visit Observation 4 – High Elevation Berm Tie in Area

Figure 9: Option 1 Site Visit Observation 5 – Contractor's Stockpile Near Proposed Berm Location

Figure 10: Option 1 Site Visit Observation 6 - Bowled Area Downstream of Route 392 Culvert

Figure 11: Option 1 Site Visit Observation 7 – Existing Pole Infrastructure Near Terminal Station

3.2 OPTION 2 SITE VISIT OBSERVATIONS

During the site visit, the alignment of the proposed ditch was assessed and photographed. The area assessed is shown in Figure 12 below:

Figure 12: Area Assessed for Option 2 During Site Visit

Key observed conditions that could influence the design and construction of the proposed diversion ditch for Option 2 are as follows:

1. Ditch heavily overgrown in places.
2. Several existing culverts are present along the proposed diversion ditch alignment at the following locations:
    a. 450mm cross culvert under Little Bay Road at its intersection with Route 392
    b. 450mm accessway culvert approximately 50m southwest of Little Bay Road/Route 392 intersection
    c. 450mm accessway culvert approximately 120m southwest of Little Bay Road/Route 392 intersection
    d. 900mm culvert at highway directional sign embankment approximately 520m southwest of Little Bay Road/Route 392 intersection
    e. 900mm accessway culvert approximately 570m southwest of Little Bay Road/Route 392 intersection
    f. 1600mm cross culvert at Route 390 approximately 50m west of the intersection with Route 392
3. Ditch poorly graded along most of the alignment
4. Where ditch crosses existing transmission line easement, there are guy wires that may have to be adjusted or relocated for new ditch construction.
5. Ditch deepens and becomes more well defined near the intersection of Route 392 and Route 390
6. Exiting ditch between Route 390 and Indian River shows evidence of past erosion
7. Exiting ditch between Route 390 and Indian River terminates as sediment embankment in wet area on side of Indian River
8. There is a pole with guy wire that crosses the ditch near the intersection of Route 392 and Route 390

Figure 13 below shows the locations of the above observations utilizing the same numbering system:

Figure 13: Option 2 Site Visit Observation Locations

Photographs of the above observations are shown in Figure 14 through Figure 26 below.

Figure 14: Option 2 Site Visit Observation 1 – Ditch Heavily Overgrown

Figure 15: Option 2 Site Visit Observation 2a – 450mm Cross Culvert Under Little Bay Road

Figure 16: Option 2 Site Visit Observation 2b – 450mm Accessway Culvert Approximately 50m Southwest of Little Bay Road

Figure 17: Option 2 Site Visit Observation 2c - 450mm Accessway Culvert Approximately 50m Southwest of Little Bay Road

Figure 18: Option 2 Site Visit Observation 2d – 900mm Culvert at Highway Sign Embankment

Figure 19: Option 2 Site Visit Observation 2e – 900mm Accessway Culvert on Route 392

Figure 20: Option 2 Site Visit Observation 2f - 1600mm Cross Culvert on Route 390

Figure 21: Option 2 Site Visit Observation 3 - Poorly Graded Ditch

Figure 22: Option 2 Site Visit Observation 4 – Transmission Line Guy Wires Near Existing Ditch

Figure 23: Option 2 Site Visit Observation 5 - Ditch Deepens Near Route 390

Figure 24: Option 2 Site Visit Observation 6 - Erosion Between Route 390 and Indian River

Figure 25: Option 2 Site Visit Observation 7 – Sediment Embankment Near Indian River Discharge Point

Figure 26: Option 2 Site Visit Observation 8 – Pole and Guy Wire at Ditch Near Intersection of Route 390 and Route 392

Note that these observations pertain to existing conditions that need to be considered for the design of each option. If NL Hydro does not proceed with either remediation option modifying the properties of any of the existing infrastructure or conditions observed during the site visit is not expected to have a significant impact on the level of flooding that is predicted by the model.

4.0 TOPOGRAPHIC SURVEY AND DIGITAL ELEVATION MODEL DEVELOPMENT

The topographic survey was conducted by Red Indian Survey's based in Grand Falls' Windsor, NL during the week of August 20, 2018. The topographic survey collected elevation data between Davis Brook and Little Bay Road north of Route 392 as well as between Davis Brook and the Terminal Station South of Route 392. Information such as pipe size and invert elevation were also collected on the culverts observed during the site visit. The locations of potential infrastructure requiring relocation to affect the design of mitigation options (such as signs, driveways, power poles and guy wires) were also captured. A profile and cross sections of the existing roadside ditch along Route 392 was also picked up to refine the analysis of the ditch mitigation option. This information from the topographic survey was utilized to refine the Digital Elevation Model used in the 2017 flood study. Figure 27 below shows the difference between the 2017 and 2018 digital elevation models in the vicinity of Davis Brook.

Topographic survey and digital elevation model development

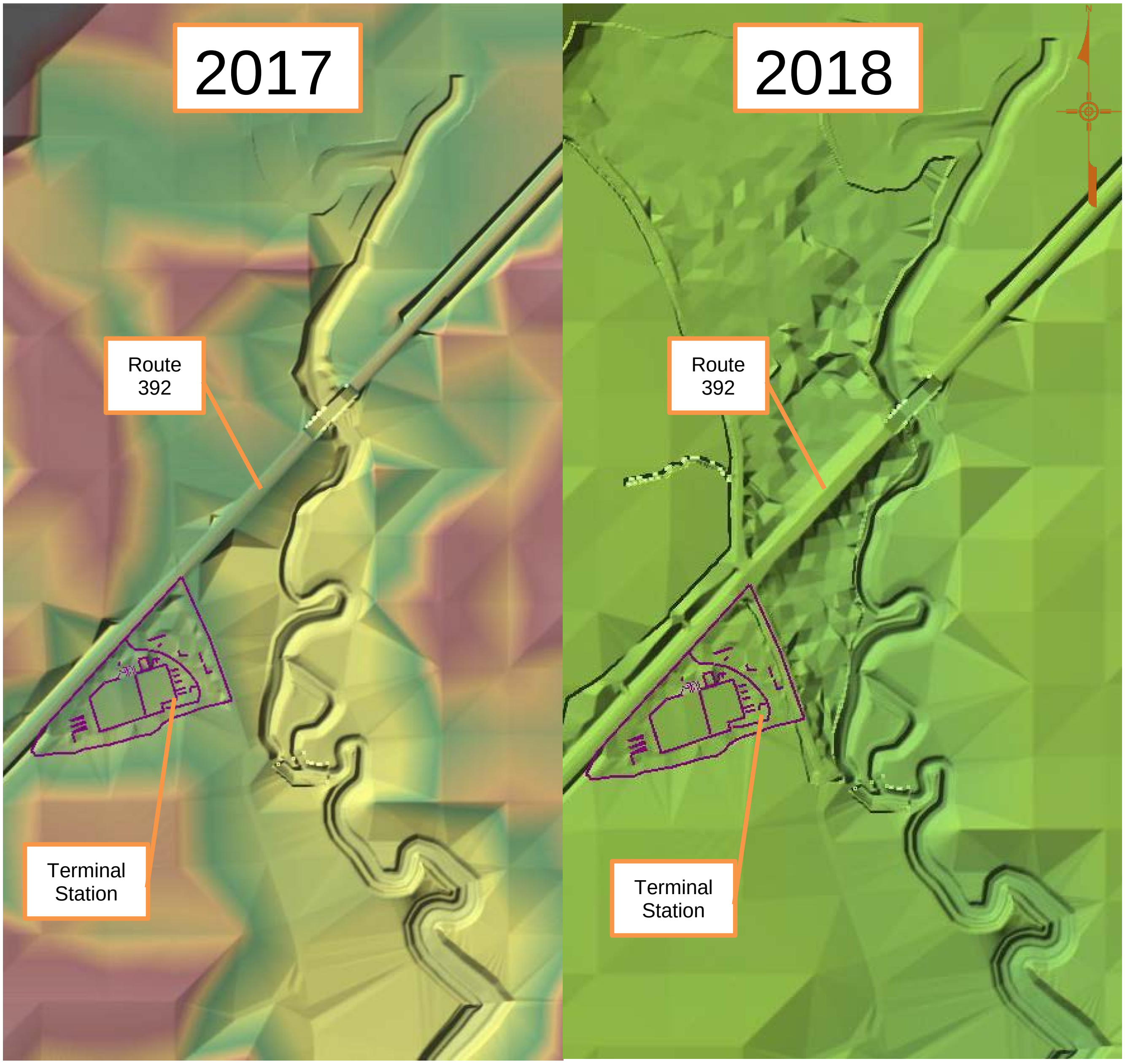

Figure 27: 2017 and 2018 Digital Elevation Models in Terminal Station Area

As shown in the figure there is significantly more detail in the area between Davis Brook and Little Bay road north of Route 392 and Between Davis Brook and the Terminal Station south of Route 392

In addition to the driveway and sign culverts in the ditch along Route 392, the topographic survey also identified an additional culvert that crosses Little Bay Road north of Route 392. This culvert drains a wetland area west of Little

Bay Road and directs water to the culvert that crosses Route 392 between Little bay Road and the Davis Brook. Figure 28 below shows the location of this culvert.

Figure 28: Location of Additional Culvert on Little Bay Road

The drainage area for this culvert was delineated and an inflow sequence was added to the hydraulic model to account for the additional flow. The Hydrograph was prorated from that of Davis Brook utilizing a proration factor based on drainage area. This yielded a peak flow of 0.21m^3/s for this culvert. For the hydraulic model an additional inflow boundary condition was added to account for this flow.

5.0 OPTION ANALYSIS

The two options were analyzed in a hydraulic model utilizing HEC RAS 5.03 software. HEC- RAS is a non-proprietary river analysis software developed by the US Army Core of Engineers. The 2D functionality of HEC-RAS makes it ideally suited for this project as it allows for the addition of berms and ditches and other drainage features to the digital elevation model to assess how the water flow is affected by such features.

5.1 EXISTING CONDITIONS

Prior to analyzing the flood mitigation options with HEC-RAS, an existing conditions model was run using the DEM from the 2017 study supplemented/modified with the new topographic data collected as part of this study. This simulation was carried out to assess if the updated DEM produced the expected result and to verify that the terminal station still floods under the 60% culvert blockage scenario identified in the 2017 flood study with the 100-year flow event. Figure 29 below shows the inundation for the 100-year event with the 2017 elevation data and the 2018 elevation data.

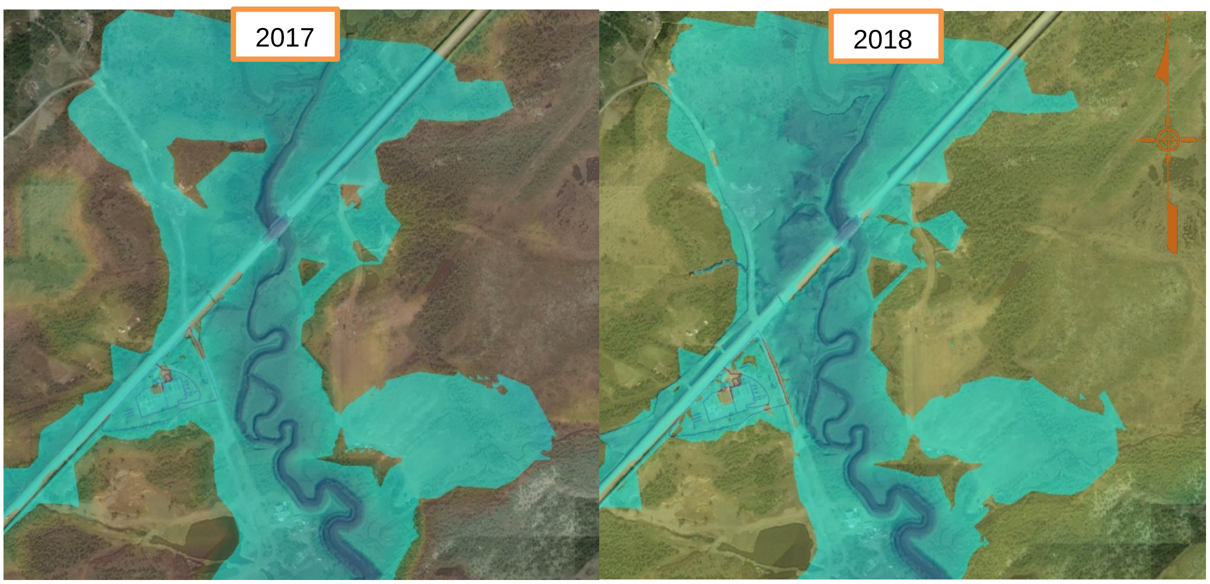

Figure 29: 2017 vs 2018 Existing Conditions Models with Culvert Blockage

As shown in the figure the inundation between the existing conditions models from the 2017 and current model is not appreciably different. Therefore, recalibration of the model to the April 2015 flood event was not required. The 2018 Water levels are slightly lower than the 2017 by 0.09m values from both studies are shown in Table 1 in Section 5.2.5 below. This is likely due to the lower elevations allowing more water to be retained north of the road.

Additional model inputs and considerations for the existing conditions model include:

- Additional lateral inflow at additional culvert identified at Little Bay Road during the topographic survey.

- Additional lateral inflow near intersection of Route 390 and 392 to account for roadside drainage in roadside ditch of Route 390 estimated by drainage area proration.
- Existing driveway and sign embankment culverts along Route 392 were accounted for.

Note the existing roadside ditch of Route has a very flat slope toward Davis Brook from approximately 300m southwest of Davis Brook when flood waters get high some of the water will flow the opposite direction toward Route 390. As such the terminal station in not reliant on the side ditch to prevent flooding. Since the ditch grades are very flat it is the ability of the Route 392 embankment to retain water on the north side is the road that is more critical to flooding.

5.2 OPTION 1 FLOOD RETENTION BERMS

5.2.1 Design Parameters

Based on the site visit observations and new topographic data, the berm alignment and configuration was modified from that presented in the 2017 flood study. Instead of 2 berms upstream of Route 392 a single berm 336m long was placed in the digital elevation model between Route 392 and high elevation which the water does not naturally cross. Height of this berm ranges from 2.5m at its highest point to 0.0m where it ties into existing elevations. Figure 30 below shows the locations of the proposed berms in the 2017 study and current study.

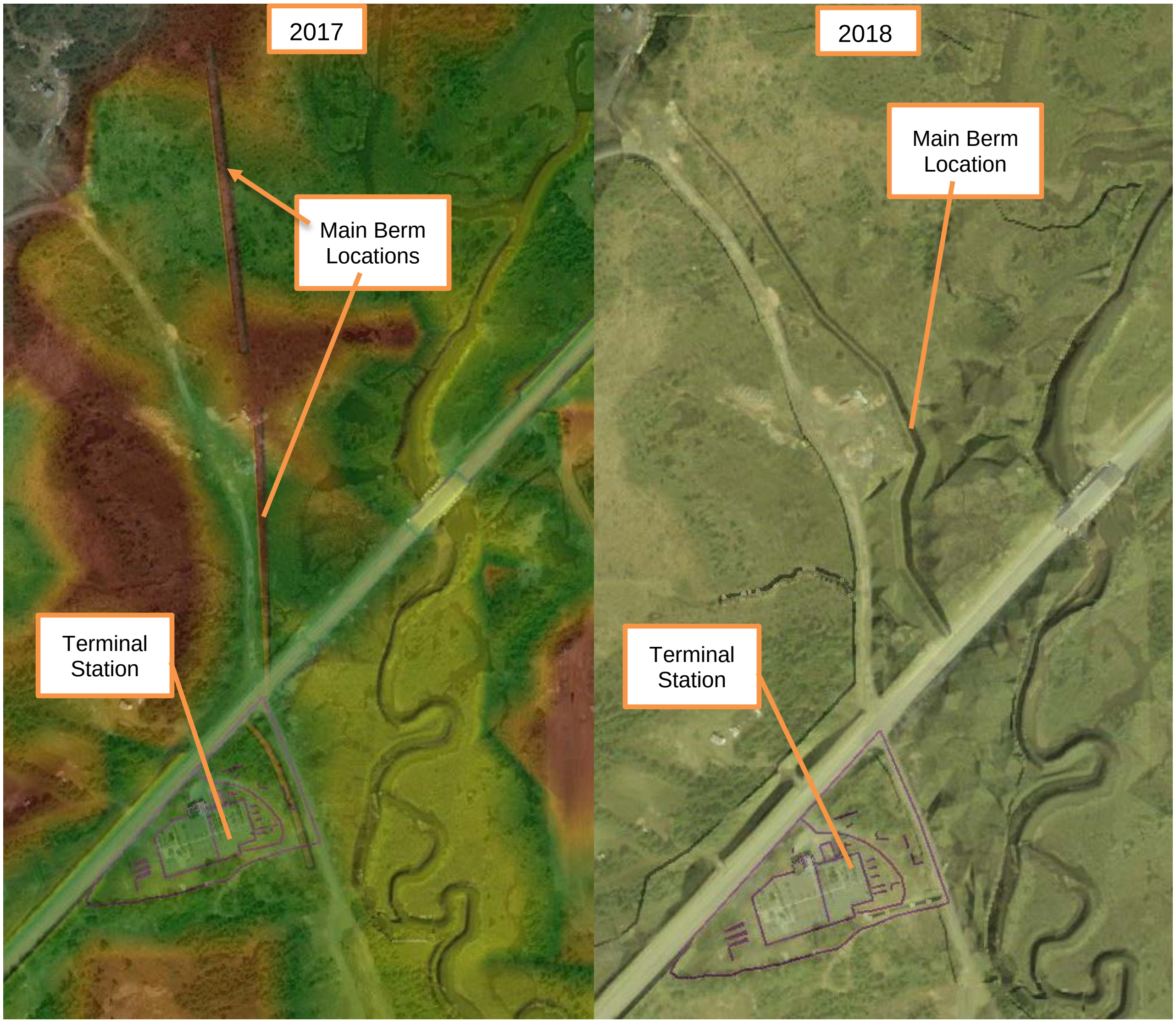

Figure 30: Location of Proposed Berms for 2017 Study and 2018 Study

Upon analysis of the existing conditions hydraulic model, it was determined that the maximum water surface elevation along the alignment ranged from 22.51m near Route 392 to 22.61m at the upstream end of the berm. Therefore, a top berm elevation 23.0m was modeled in the hydraulic model validation exercise for this option except for the area in which the berm is to tie into the shoulder of Route 392. In this area the modeled elevation ramps down to 22.8m. This elevation will require some adjustment of the existing grade of Route 392 during construction of the berm by raising the road approximately 0.5m during construction of the berm. This will be accomplished by introducing gentle grade changes between Little bay road and the Davis Brook crossing by introducing a grade of approximately 1.0%. Due to the culvert crossing Little Bay Road noted above in Section 4.0, a significant portion of the berm's length will have water on both sides for approximately 200m of its length. Therefore rip-rap for erosion protection will be required on both sides of the berm for approximately 200m of its length. This additional rip-rap increases the construction cost of the berm. However, it will decrease maintenance related repairs due to erosion or snow or ice damage. Figure 31 below shows a typical berm section.

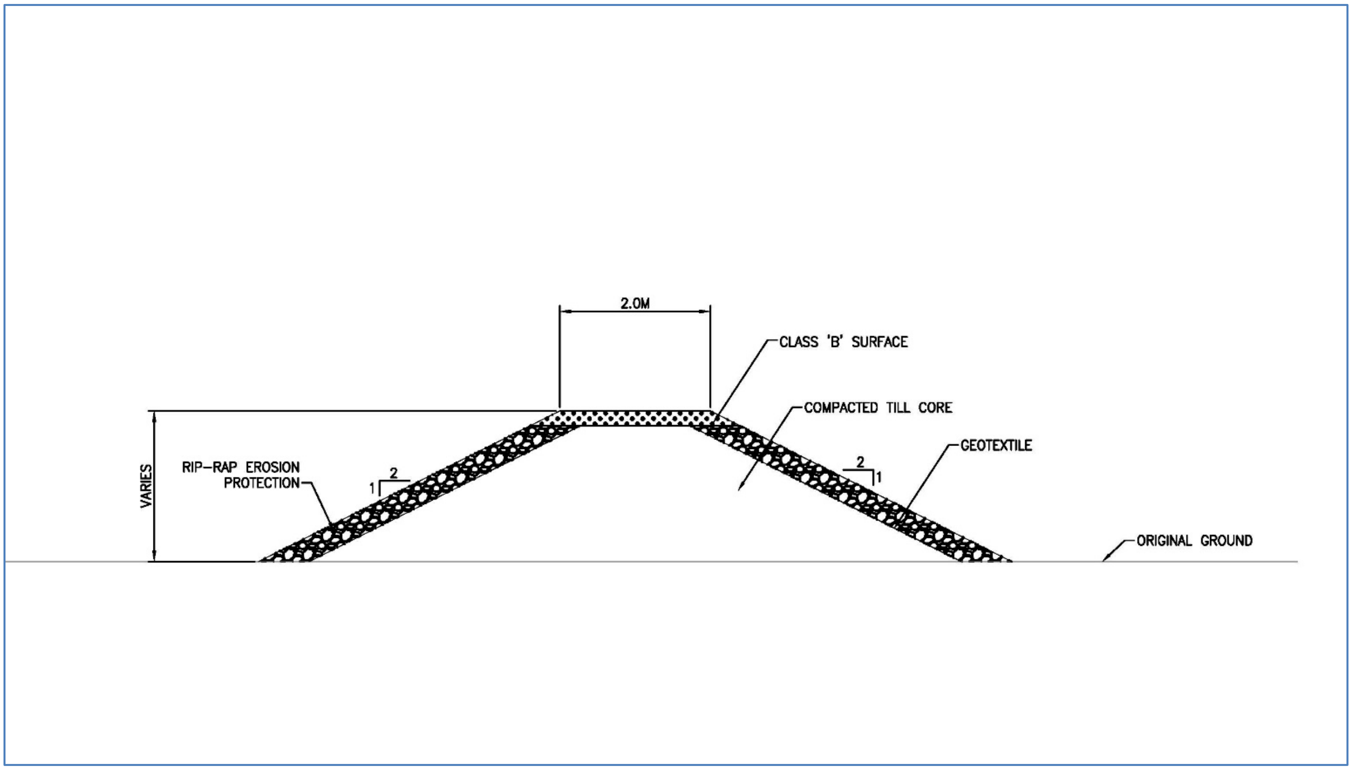

Figure 31: Typical Berm Section

In addition to the main berm North of Route 392, a second (smaller) berm is required at the southeast corner of the Terminal Station. This second berm is a shorter, having a maximum height of 0.75m and length of 20m. The locations of the proposed berms are shown in Figure 32 below:

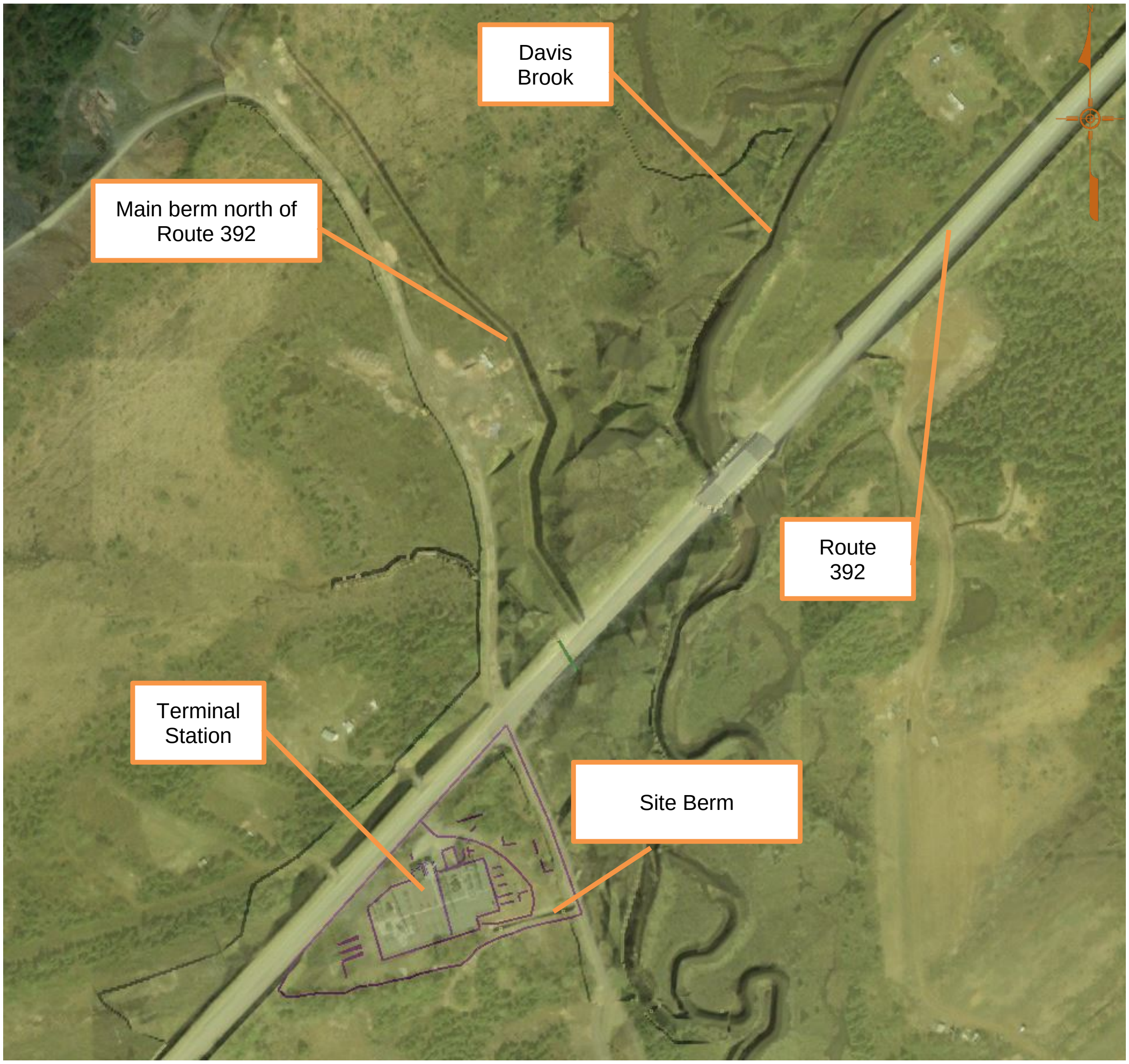

Figure 32: Location of Flood Mitigation Berms

Design parameters for Option 1.0 are summarized below:

Main Berm:

- Berm Length: 336m
- Berm Top Width: 2.0m
- Berm Bottom Width: 2.0 to 12.0m
- Berm Top Elevation: 22.8m to 23.0m
- Berm Height: 0 to 2.5m

- Berm Side Slopes: 2:1
- Rip-Rap erosion protection on both sides for approximately 200m

Site Berm:

- Berm Length: 20m
- Berm Top Width: 2.0m
- Berm Bottom Width: 2.0 to 10.0m
- Berm Top Elevation: 22.0m
- Berm Side Slopes: 2:1
- Berm Height: 0 to 0.75m

Berms are to be constructed of compacted till with geotextile and erosion protection stone placed on the outer faces. Please note some design parameters for the berms are subject to change during the detailed design depending on the results of the geotechnical investigation or CDA freeboard requirements analyzed in Phase 2 of this study

5.2.2 Hydraulic Model Validation

The berms at the locations shown in Figure 32 and per the design parameters noted in Section 5.2.1 were hydraulically modeled in HEC-RAS to validate their effectiveness as a flood mitigating measure. The model was run using the 100 year flow event with 60% culvert blockage, per the design criteria selected by NL Hydro for flood mitigation design. Figure 33 below shows the model result with berms installed as per the design parameters note above in Section 5.2.1 above.

Figure 33: Option 1 Hydraulic Model Validation Results

As shown in the figure the Terminal Station is not expected to flood with the mitigation berms introduced and Route 392 raised as noted above in Section 5.2.1. Therefore, Option 1 appears to be a viable means of flood mitigation at the Terminal Station.

The site berm simple prevents water from entering the fenced yard of the Terminal Station. Figure 34 below shows a comparison of flooding inundation with and without the site berm installed:

Figure 34: Comparison of Terminal Station Inundation with and without the Site Berm Installed

Additional Model inputs and considerations for the Option 1 model include:

- Additional lateral inflow and additional culvert identified at Little Bay Road during the topographic survey
- Additional lateral inflow near Intersection of Route 390 and 392 to account for roadside drainage in Roadside ditch of Route 390
- Existing driveway and sign embankment culverts along Route 392 were accounted for.

5.2.3 Regulatory and Permitting Considerations

Some of the proposed berm is situated in a wet, boggy area to the east of Little Bay Road. This area may be considered environmentally sensitive as Davis Brook is a scheduled salmon river. The construction of berms in this area will require DFO approval as well as a permit to alter a body of water from the provincial Department of Municipal Affairs and Environment. There will also be a requirement for an environmental assessment to be conducted prior to construction of the berm. Elevation modifications to Route 392 where the berm ties in to the shoulder of the road will require approval from the Department of Transportation and Works.

5.2.4 Operation and Maintenance Considerations

Operation and maintenance of the berms will be a limited exercise. The berms should be inspected on an annual basis preferably in the spring time to identify any signs of erosion and damage due to snow cover or ice movement. In areas where the berm is not anticipated to be in contact with flowing water the presence of rip- rap will have little to no impact on the appearance of erosion damage as the slopes will be stabilized with vegetation. Any identified deficiencies should be repaired. They should also be inspected following any large flow event for which they are retaining water for any evidence of water or ice damage. These inspections should include walking both the upstream and downstream faces of the berm and photographing and noting the approximate location along the length of the berm of any deficiencies. Although unrelated to the berms, culvert blockage at Route 392 was identified in the 2017 report to be a major contributing factor to the flooding experienced at the terminal station. From an operational standpoint, these culverts should be inspected for blockage prior to forecasted heavy rainfall events. Flooding concerns in the area are governed by the very flat path of the watercourse of Davis Brook and are not expected to be significantly impacted by maintenance activities of infrastructure outside the jurisdiction of hydro.

5.2.5 Existing Infrastructure Considerations

The existing elevation of Route 392 at the proposed berm tie in location is approximately 22.3m. The hydraulic model indicates that if this elevation remains as existing, there is potential for water to exit the river channel and possibly enter the Terminal Station area. Therefore, the digital elevation model for this option includes raising Route 392 in this area by approximately 0.5m to an elevation of approximately 22.8m. The hydraulic model shows that this road modification will mitigate the risk of water getting over the road and entering the Terminal Station area. Note that the model shows that this water does not reach the Terminal station or have an impact on flooding level at the station. However, raising of the road will be required to prevent overtopping of the road where the berm ties into the road as well as to maintain freeboard at the road/berm junction.

The original 2017 flood study included a smaller berm at the east side of the Terminal station running parallel to Little Bay Road. This berm would have likely required the relocation of a pole or guy wire. The new topographic information obtained as part of this study between Little Bay Road and Davis Brook indicates that a berm in this location is not required. However, the hydraulic model shows that water will overtop Little Bay Road further downstream and head toward the terminal station. Therefore, a short site berm in the southeast corner of the terminal station is also included in this option. This berm does not interfere with any of the existing poles and guy wires at the Terminal Station. In should be noted that without the side berm in place the water does not reach the Terminal Station buildings which house the equipment that tripped during the 2015 flood. It simply reaches inside the fenced boundary of the terminal station. Should flows that exceed those modeled occur and the Terminal Station flood, the site berm would create an impedance to dewatering of the site worsening the flooding. Since the water does not reach the buildings the site berm should be considered optional if NL Hydro is willing to accept the above noted risk. The installation of the site berm is not a large component of less than 5% of the estimated cost of the berm construction cost estimate. However, there is little to no benefit to installing it and as noted above it may be a hinderance to site dewatering.

The location and alignment for the main berm north of Route 392 was selected with consideration for the existing culvert that crosses Little Bay Road, shown in Figure 28 above. Since this culvert drains to another existing culvert that crosses Route 392 (approximately 125m southwest of the main Davis Brook crossing), the berm at Route 392 must be located east of this culvert. The area between the downstream end of this culvert and Davis Brook could benefit from some improved channelization to convey the flow more effectively to Davis Brook. Improvements to this channel could be made as part of the berm construction project. These improvements would have to be approved by the Department of Transportation and Works. As this will not alter the flow path our ultimate destination of the runoff passing through this culvert it would have no impact on the requirement for a permit to alter a body of water. However, should NL Hydro proceed with the improved channelization the design should be included on any submittals associated with obtaining a permit to alter al body of water.

The 2017 flood study noted that a dwelling on Little bay Road south of the Terminal station was shown to be flood in both the existing conditions and berm models both with 60% blocked culverts. The 2017 study compared water levels at this dwelling for both scenarios. Table 1 below makes the same comparison utilizing results from the 2018 models and shows the 2017 results for comparison as well as the results without culvert blockage. Note that under existing conditions the 100 year event still floods the terminal station without culvert blockage. The 2017 study notes that event the notes that of the six storms analyzed during the 2017 study (2, 5, 10, 20, 50 and 100 year) study only the 50 and 100 year storms flood the station without culvert blockage while all six storms produced some inundation at the station with the 60% culvert blockage parameter. The dwelling location is also shown in Figure 35 below:

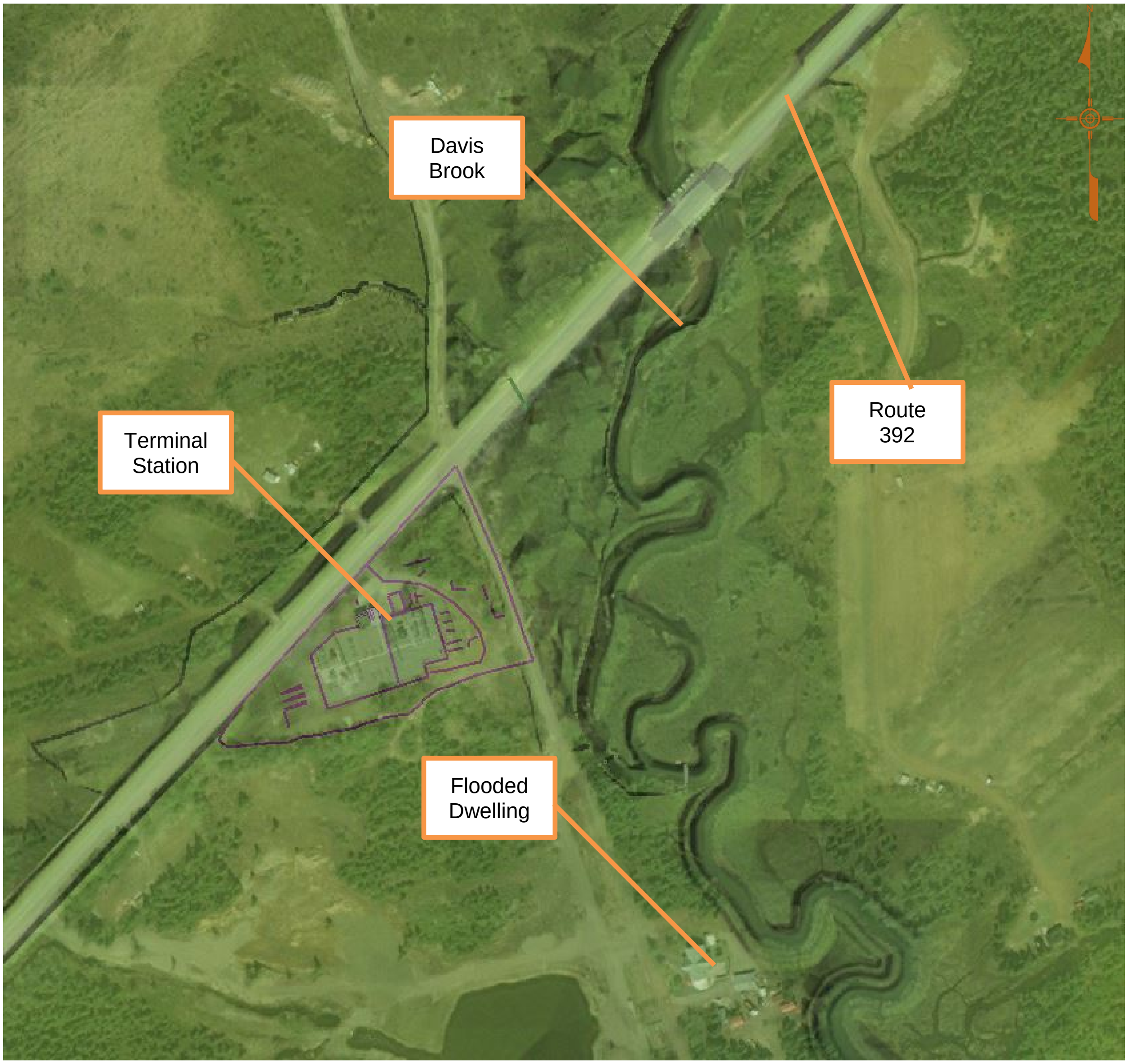

Figure 35: Location of Flooded Dwelling

Table 1: Pre and Post Mitigation Water Level Comparison at Flooded Dwelling and Terminal Station

Scenario	Maximum Water Depth at Dwelling	Maximum Water Depth at Terminal Station Building
100 Year No Mitigation- Culverts Blocked (2018)	0.34m	0.14m
100 Year No Mitigation- Culverts Free (2017)	0.36m	0.11m
100 Year Berm Culverts Blocked (2018)	0.36m	0.00m
100 Year No Mitigation- Culverts Blocked (2017)	0.86m	0.23m
100 Year No Mitigation- Culverts Free (2017)	0.54m	0.18m
100 Year Berm Culverts Blocked (2017)	0.54m	0.00m

As shown in the table the installation of the berm slightly increases the water level by 2cm at the previously flooded dwelling. This is likely due to the berm increasing the head at the culverts upstream of Route 392 allowing more water to pass to the main channel of Davis Brook. This slight increase in water level of 2cm can be considered within the tolerance of the model as errors of approximately 5cm were reported during the unsteady flow simulations. These error values are reported during the unsteady flow simulations as is model specific depending on the convergence of the flow equations. It should be noted that the presence of the site berm has no impact on the water levels at this dwelling. When unsteady flow performs unsteady flow simulations when more iterations are required to compute a convergent water surface elevation solution than the program maximum the water surface elevation error at the location which required additional iterations is reported.

5.2.6 Option 1 Summary

In summary, Option 1 appears to be a viable Option for flood mitigation at the Springdale Terminal Station. The advantages of this option are as follows:

- It does not interfere with any of NL Hydro's existing infrastructure at the terminal station.
- Operation and Maintenance activities are reasonable.
- There is a potential source of berm construction material nearby the site.

Disadvantages of Option 1 include:

- It requires modification to an existing road owned and operated by the Department of Transportation and Works.
- It will require permitting and approval from 3 regulatory authorities.
- It will require an environmental assessment
- It will potentially increase flood levels at a dwelling downstream of the terminal station
- Construction will require significant dewatering of excavations in boggy areas.
- It increases the head upstream of Route 392.
- It carries the risk of being and impedance to site dewatering should flooding of the terminal station occur.

5.3 OPTION 2 FLOOD DIVERSION DITCH

5.3.1 Design Parameters

Based on the site visit, a geotextile and rip-rap lined ditch would be the best option to minimize maintenance and the potential for overgrowth. The topographic survey shows that there is very little elevation in the ditch difference between the intersection of Route 392 and Little Bay Road. As such ad 0.2% would be the maximum achievable slope of the proposed diversion ditch along Route 392. As part of the hydraulic model validation process, ditch widths ranging from 1.0 to 3.0 m were tested. Culvert sizes ranging from 900mm to 1200mm were also tested at Little bay road and the numerous driveway crossings. The maximum culvert size tested along the ditch alignment was 1200mm as this was the maximum size achievable without significantly altering the grades of the accessways off Route 392.

5.3.2 Hydraulic Model Validation

Option 2 was unable to be validated as an effective mitigation measure by the hydraulic model. Figure 36 below shows the 100-year inundation assuming a 3.0m wide, 1.0m deep ditch and 1200mm culverts at locations noted above in Section 5.3.1.

Figure 36: Option 2: 3.0m wide Ditch with 1200mm Culverts

Table 2 below shows that water depths at the terminal station actually increased with the ditch installed.

Table 2: Existing Conditions and Option 2 Water Depths at Terminal Station

Scenario	Maximum water Level at Terminal Station
100 Year No Mitigation	0.14m
100 Year Option 2 with 3.0m wide ditch and 1200mm culverts	0.18m

Note that both the scenarios in the above table include 60% blockage of the culverts at route 392.

As shown in Figure 34 above, the Terminal Station is expected to flood under this scenario. The likely reason for this option not being viable is the very flat grade along Route 392 rendering the conveyance capacity of a ditch along this alignment insufficient to prevent overtopping of Route 392. This flat grade also limits the culvert size that is reasonably practical to install at the driveway crossings with significantly altering the road and driveways.

Additional model inputs and considerations for the Option 2 model include:

- Additional lateral inflow and additional culvert identified at Little Bay Road during the topographic survey
- Additional lateral inflow near Intersection of Route 390 and 392 to account for roadside drainage in Roadside ditch of Route 390
- Existing driveway and sign embankment culverts along Route 392 were accounted for.

5.3.3 Regulatory and Permitting Considerations

Since the ditch is proposed the be constructed in the existing ROW of a road owned and operated by the Department of Transportation and Works it will require review and approval from this entity. Also, since the proposed ditch will be removing some flow from Davis Brook and directing it toward the Indian River it may require review by the Provincial Department of Municipal Affairs and Environment as well as the Federal Department of Fisheries and Oceans.

5.3.4 Operation and Maintenance Considerations

Although this option could not be validated as a viable option with the hydraulic model, the ditch in its existing condition is heavily overgrown and as such has limited conveyance capacity. This condition should be brought to the attention of the Department of Transportation and Works such that they can make future improvements. It is possible that the overgrown condition of the existing ditch could be a contributing factor to Terminal Station flooding due to decreased conveyance capacity of the ditch.

Should this option be constructed it will consist of a geotextile and riprap lined ditch with intermediate culverts to accommodate, driveways, accessways and sign embankments at various points along its length. Therefore, operation and maintenance activities will include inspection and removal of debris from the ditch and culverts to create a clear path for water conveyance.

5.3.5 Existing Infrastructure Considerations

The construction of diversion ditch along Route 392 has several existing infrastructure considerations noted below:

- An existing 450mm culvert at Little Bay Road the would require upgrading.

- Two existing 450mm culverts at driveways along Route 392 that require upgrading.
- An existing sign embankment that protrudes into the ditch that would require relocation of the sign and removal of the embankment.
- An existing 900mm culvert at a directional highway sign embankment that would require upgrading
- An existing 900mm culvert at a driveway near the intersection of Route 390 and Route 392 that would require upgrading
- An existing 1600mm culvert that cross Route 390 and discharges to a ditch that leads to Indian River that would need to be assessed for ability to convey additional flow that the ditch diversion would introduce.
- Several existing guy wires would extend into the side slope of the proposed ditch and have to be adjusted or relocated.

In addition to these considerations, the proposed ditch would be constructed or partially constructed in the existing right-of-way for Route 392 owned by the Department of Transportation and Works. The existing grade of the road is such that the ditch would be sloping in the opposite direction in places making the roadside ditch deeper than is typical for provincial roads. This may be an undesirable condition as it may be considered a hazard to pedestrians or vehicles that may veer off the road. These conditions will not affect the constructability of the ditch. However, they may impact the approval process.

5.3.6 Option 2 Summary

In summary, Option 2 does not appear to be a viable Option for flood mitigation at the Springdale Terminal Station. The advantages of this option are as follows:

- It does not interfere with any of NL Hydro's existing infrastructure at the terminal station.
- Operation and Maintenance activities are reasonable.
- It is the lower cost option.

Disadvantages of Option 2 include:

- It does not alleviate flooding at the Terminal Station
- It requires modification to an existing road ROW owned and operated by the Department of Transportation and Works.
- It will require permitting and approval from 3 regulatory authorities.

6.0 OPINION OF PROBABLE COST

Based on the refined design parameters developed in the option analysis detailed above, Stantec has developed an Opinion of Probable Cost for the each option shown in Table 3 below. The 2017 conceptual opinions of probable cost are also shown for comparison purposes

Table 3: Opinion of Probable Cost

Mitigation Strategy Description	Estimated Cost (HST EXTRA)	Estimated Cost (HST EXTRA) (2017 Study
Option 1 – Installation of Retention Berms	$902,864.55	$380,000.00
Option 2 - Flood Diversion Ditch	$423,570.00	$410,000.00

The variance in the cost for Option 1 from the 2017 study is largely due to an increase in until prices in earthwork material handling. These variances are due to the requirement to remove and dispose of unsuitable bog materials well as the importing of and compaction of berm material. Also, the quantity of required berm material increased due to the updated topographic information. The cost for Option 2 is similar to the 2017 study. The ditch has a larger cross-sectional area than the 2017 and there are more driveway culverts to upgrade include. However, there is no longer a requirement to install a new culvert across Route 390 as the existing 1600mm culvert can convey the flow from the ditch. Al the refined topographic information in the existing ditch significantly reduced the ditch excavation quantity

Note that the above opinions of probable cost have an accuracy of +/- 25%, schedules of quantities and prices that Stantec for each option are included in **Appendix A.** The accuracy noted above is based on the design parameters noted in this report should three be some design alterations during the detailed the Opinion of Probable Cost will be adjusted accordingly based on the approved design. It is not anticipated that the alterations in the design parameters will exceed the 25% opinion of probable cost variance. Note that the opinion probable cost is construction cost only and does note include costs such as an environmental assessment or land acquisition.

7.0 ASSUMPTIONS AND EXCLUSIONS

This study is based on the following assumptions and exclusions:

- Hydraulic modeling of flood mitigation measures is based on the 100 year event with 60% culvert blockage at Route 392.

- Hydrological inputs are based on the 2017 flood study. Additional lateral inflows introduced in this study were prorated from the Hydrographs developed in the 2017 study.
- Manning’s roughness for the hydraulic modeling was the same as utilized in the 2017 Flood Study.
- Existing corrugated metal culverts were assumed to have a Manning’s roughness of 0.015.
- Opinion of Probable Cost assumes 1.5m depth of USM (Unsuitable Material) removal for the main berm and 0.5m for the site berm. This is to be verified during the geotechnical investigation in Phase 2 of the project. This can only be determined by the subsurface investigation USM depth of less than 1.5 m will reduce the cost of installation of the berm while greater depth will increase the cost.

8.0 CONCLUSIONS AND RECOMMENDATIONS

The engineering flood mitigation analysis conducted for this study was able to eliminate Option 2, the diversion ditch, as a mitigation strategy. However, Option 1 was found to be a valid mitigation strategy to prevent flooding at the Terminal Station. As such it is recommended that NL Hydro proceed with the detailed design of Option 1, flood mitigation berms. To first step this process is to undertake a geotechnical investigation to determine appropriate berm foundation design, as well as a suitable source of berm construction material. This geotechnical investigation has been included and will be undertaken in Phase 2 of the project. Once the geotechnical investigation in complete, it is recommended that the preliminary design drawings including plan, profile and sections be produced and sent to the appropriate regulatory authorities for review and approval. Operation and maintenance related recommendations once the berms are constructed are as follows:

- Conduct berm inspections on an annual basis and following heavy flow events. Correct identified deficiencies.
- Inspect culverts at Route 392 for blockages prior to high inflow events.

Appendix A

OPINION OF PROBABLE COST SCHEDULE OF QUANTITIES

Option 1 Flood Retention Berms Opinion of Probable Cost

Item/Description	Quantity	Unit	Unit Price	Total
Mobilizatin/ Demobilization	1	LS	$ 50,000.00	$50,000
Clearing and Grubbing				
Clearing and Grubbing	0.3	HA	$ 12,000.00	$ 3,600.00
Excavation and Erosion Protection				
USM Removal	5515	CM	$ 45.00	$ 248,175.00
Imported Structural Fill for Berms(Placed and Compacted)	7645	CM	$ 40.00	$ 305,800.00
200mm minus erosion protection	1790	CM	$ 50.00	$ 89,500.00
Geotextile	4220	SM	$ 7.00	$ 29,540.00
Reinstatement of Existing Ditches	250	LM	$ 20.00	$ 5,000.00
Ditching	45	LM	$ 50.00	$ 2,250.00
Dewatering	1	LS	$ 30,000.00	$ 30,000.00
Street Excavation				
Asphalt Removal	80	CM	$ 20.00	$ 1,600.00
OM	450	CM	$ 20.00	$ 9,000.00
Borrow	100	CM	$ 25.00	$ 2,500.00
Scarify and Reshape Subgrade	1500	SM	$ 5.00	$ 7,500.00
Gravel for Streets				
Class B	462	tonne	$ 28.00	$ 12,936.00
Class A	398	tonne	$ 30.00	$ 11,940.00
Hot Mix Asphalt Concrete Paving				
1. Base Course	98	tonne	$ 180.00	$ 17,640.00
2. Surface Course	98	tonne	$ 180.00	$ 17,640.00
Reshaping and Replacement of Asphalt Pavement				
1. Cutting of Asphalt Pavement	14	LM	$ 25.00	$ 350.00
2.Reinstatment of Pavement Markings	1	LS	$ 5,000.00	$ 5,000.00
Asphalt Tack Coat	1500	SM	$ 3.00	$ 4,500.00
Topsoiling, Sodding and/or Hydroseeding				
150mm topsoil and nursury sod	300	SM	$ 18.00	$ 5,400.00
Contengcy (5%)				$ 42,993.55
		Total(HST EXTRA)		**$ 902,864.55**

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Option 2 Flood Diversion Ditch Opinion of Probable Cost

Item/Description	Quantity	Unit	Unit Price	Total
Mobilizatin/ Demobilization	1	LS	$ 50,000.00	$50,000
Excavation and Erosion Protection				
Excavate and dispose of material for ditching	3390	CM	$ 30.00	$ 101,700.00
Imported common material	600	CM	$ 40.00	$ 24,000.00
200mm minus erosion protection	1518	CM	$ 50.00	$ 75,900.00
Culvert Trench Excavation	190	CM	$ 20.00	$ 3,800.00
Geotextile	5100	SM	$ 7.00	$ 35,700.00
Pipe Culverts				
1200mm CHDPE	16	LM	$ 1,200.00	$ 19,200.00
Class B Bedding	140	CM	$ 30.00	$ 4,200.00
Riprap End Treatment	10	EA	$ 1,500.00	$ 15,000.00
Scarify and Reshape Subgrade	1500	SM	$ 5.00	$ 7,500.00
Reinstatment				
Reinstatment of Road Signs	2	EA	$ 1,000.00	$ 2,000.00
Reinstatment of gravel Accessways	4	EA	$ 8,000.00	$ 32,000.00
Topsoiling, Sodding and/or Hydroseeding				
150mm topsoil and nursury sod	1800	SM	$ 18.00	$ 32,400.00
Contengcy (5%)				$ 20,170.00
		Total(HST EXTRA)		**$ 423,570.00**

Stantec Consulting Limited
141 Kelsey Drive
St. John's NL
A1B 0L2

February 12, 2019
File: 133348186

Attention: Mr. Troy Butler, P. Eng., PMP
Project Manager
Engineering Services
Project Execution (Regulated)

Dear Mr. Butler,

Reference: Engineering Flood Mitigation Analysis - Springdale Terminal Station

Pursuant to our meeting of February 1, 2019, as requested by NL Hydro, Stantec has conducted a hydraulic analysis and produced a +/- 25% opinion of probable cost to construct a perimeter berm around the Springdale Terminal Station as an additional option to mitigate flooding risk at the site. The construction of such a perimeter berm will also necessitate the provision of alternative vehicle access to the terminal station which has been included in our analysis. For the purpose of this memo the perimeter berm analyzed will be referred to as:

- **Option 3:** Construct a perimeter berm and relocate terminal station vehicular access

Note that during the 2017 study the option of a perimeter berm around the terminal station was not considered as the existing site access was to be maintained in its original location. However, due to the cost of the upstream retention berm identified in the 2018 study, NL Hydro requested that the perimeter berm option be analyzed in our meeting of February 1, 2019.

DESIGN PARAMETERS

The proposed perimeter berm that was analyzed has the following parameters:

- Berm Length: 270m
- Berm Top Width: 1.0m
- Berm Bottom Width: 4.0 to 6.0m
- Berm Top Elevation: 22.43m to 23.18m
- Berm Height: 1.0m
- Berm Side Slopes: 2:1
- Riprap erosion protection on the outward facing side

The proposed terminal station site access road is located on the northeast corner of the site. It ascends at grade of approximately 2.4% from Route 392 to pass over the berm where it descends at a grade of approximately 7.0% to tie into the existing gravel driving surface on the site. This access road location was selected to avoid interference with existing poles and guy wires that surround the terminal station. However, due to the close proximity of the station to Route 392, the proposed perimeter berm location is such that two guy wire anchors will have to be relocated or raised to the appropriate grade upon construction of the berm. The proposed accessway has the following dimensional parameters:

- Road Length: 46m
- Road Width: 6.0m
- Embankment Slopes: 2:1
- Surface treatment: gravel

Please note that the location of this access necessitates the installation of two culverts. One located at the access road and the other beneath Little Bay Road south of Route 392. An approximately 20m long ditch to convey water between these culverts is also required. These culverts are required such that the access road does not create a damming effect and runoff can freely drain to Davis Brook. The proposed perimeter berm and associated infrastructure are shown in Figure 1 below:

Reference: **Engineering Flood Mitigation Analysis - Springdale Terminal Station**

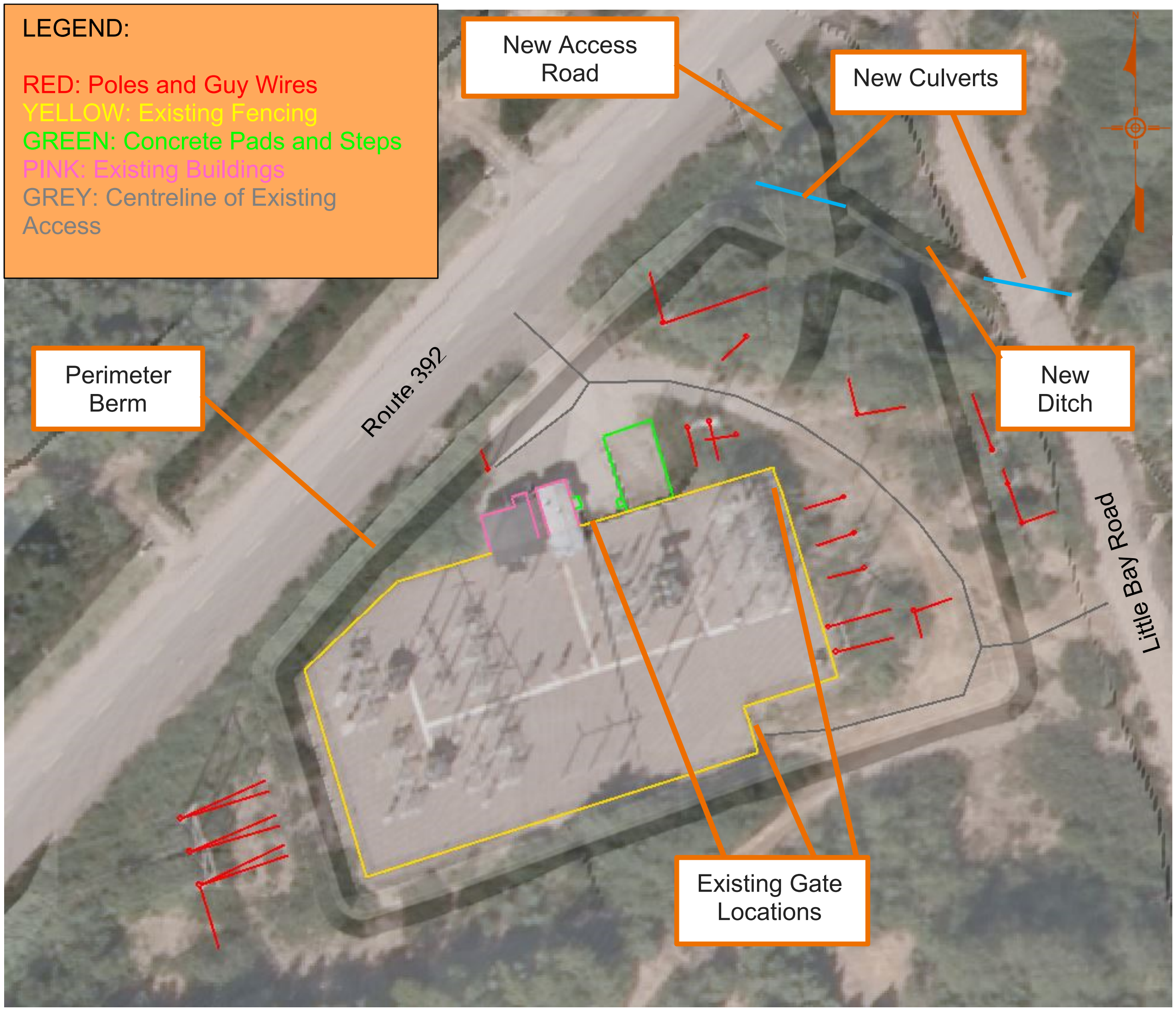

Figure 1: Proposed Perimeter Berm, Access Road and Existing Infrastructure

Please note that the encapsulation of the terminal station by a perimeter berm will likely necessitate some grading adjustments to the to allow for water to drain from the station. These adjustments may take the form of collection swales elevation adjustments and a sump structure with pump to remove the water from the site. Stantec has made allowances for this infrastructure in the opinion of probable cost. Some modification to the sites fencing and gate configuration may also be required.

Reference: **Engineering Flood Mitigation Analysis - Springdale Terminal Station**

HYDRAULIC ANALYSIS

The perimeter berm, accessway and culvert arrangement as described above was tested in the hydraulic model with the 100 year flood event with 60% culvert blockage at Route 392 as the design condition to test its effectiveness as a flood mitigation strategy. As shown in Figure 2 below the model shows that the proposed perimeter berm keeps the floodwater from entering the terminal station for the above noted design condition.

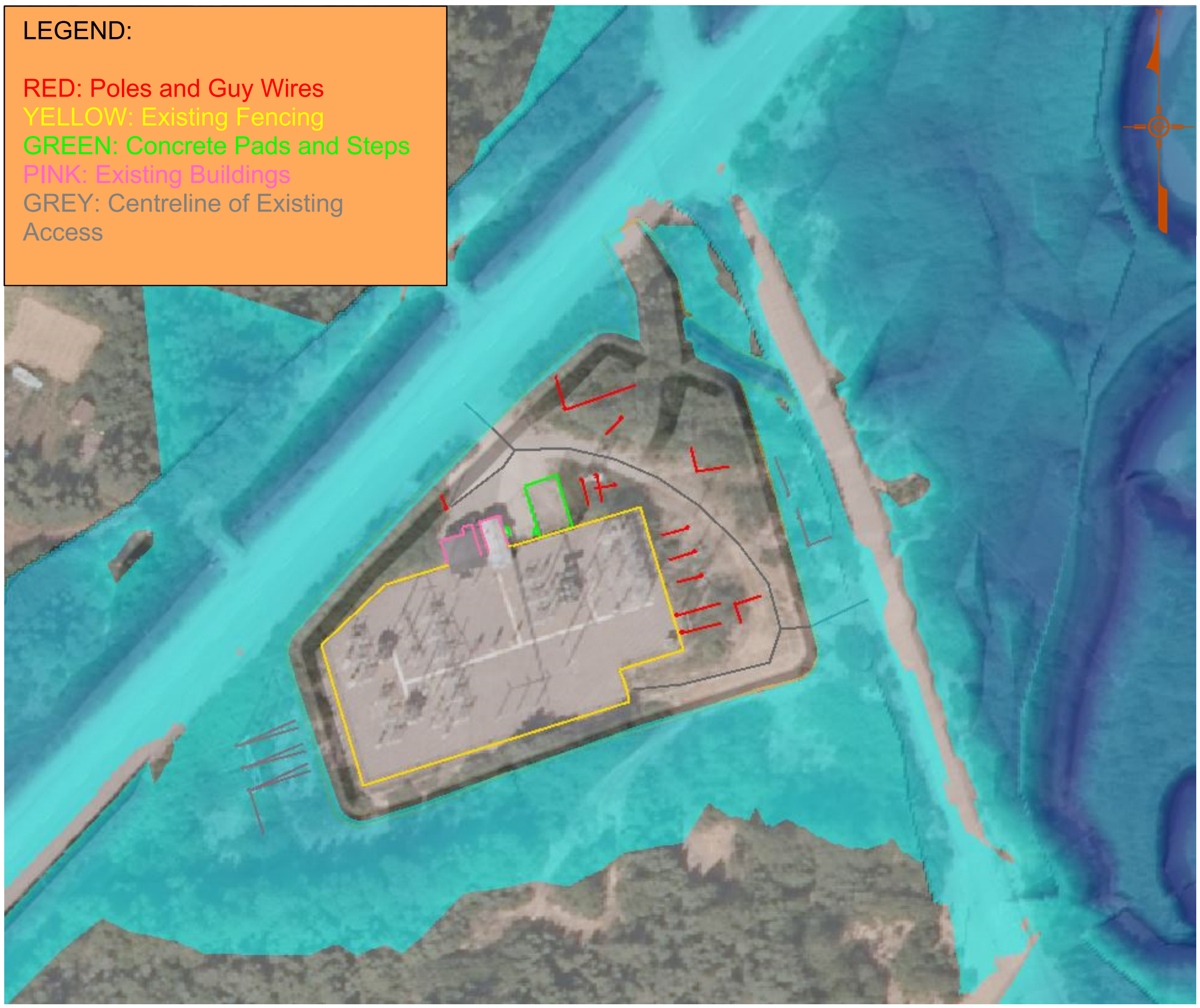

Figure 2: Flood Inundation at Terminal Station with perimeter berm and relocated access

EXISTING INFRASTRUCTURE CONSIDERATIONS

As noted above the proposed perimeter berm will require the relocation or raising to grade of two guy anchors associated with the terminal station infrastructure. Also, it will be necessary to install a culvert that passes under existing Little Bay Road South of Route 392. Stantec has endeavored to arrange the perimeter berm and new site access such that the modifications to the existing fencing and gate arrangement is minimized. The berm arrangement is such that the existing gates at the southeast and northeast sides of the site can be utilized in their current locations.

The 2017 flood study noted that a dwelling on Little Bay Road south of the Terminal station was shown to be flooded in both the existing conditions and upstream retention berm models for the 100 year event with 60% blocked culverts. The 2018 Engineering Flood Mitigation Analysis study updated the water depths at the dwelling as well as indicating flooding depth with the culverts at Route 392 flowing free and clear. Depths at the terminal station building were also provided. Table 1 below shows these depths with depths at the same locations for the perimeter berm scenario. Please note that the 2018 no mitigation model scenarios also serve as the base no mitigation models for the perimeter berm scenarios. Note that the 2017 and 2018 no mitigation values are different due to the updated topographic information obtained for the 2018 study. The perimeter berm option values are highlighted in the table.

Table 1: Pre and Post Mitigation Water Level Comparison at Flooded Dwelling and Terminal Station

Scenario	Maximum Water Depth at Dwelling	Maximum Water Depth at Terminal Station Building
100 Year No Mitigation- Culverts Blocked (2018)	0.34m	0.14m
100 Year No Mitigation- Culverts Free (2018)	0.36m	0.11m
100 Year Upstream Retention Berm Culverts Blocked (2018)	0.36m	0.00m
100 Year Upstream Retention Berm Culverts Free (2018)	0.36m	0.00m
100 Year Perimeter Berm Culverts Blocked (2019)	0.33m	0.00m
100 Year Perimeter Berm Culverts Free (2019)	0.34m	0.00m
100 Year No Mitigation- Culverts Blocked (2017)	0.86m	0.23m
100 Year No Mitigation- Culverts Free (2017)	0.54m	0.18m
100 Year Upstream Retention Berm Culverts Blocked (2017)	0.54m	0.00m

REGULATORY AND PERMITTING CONSIDERATIONS

Two elements of the proposed perimeter berm flood mitigation option will require review and approval of the Department of Transportation and Works. These include the location of the new site access where it ties into Route 392 and the perimeter berm along the northeast side of the site may encroach onto the right-of-way of Route 392 due to the proximity of the terminal station to the road. The Department of Transportation and Works will review the proposed access for appropriate site distances where it intersects Route 392. Due to the flat topography of the area Stantec does not anticipate any site distance issues with the proposed new access location. However, this is to be confirmed by the Department of Transportation and Works. The proposed culvert that crosses Little Bay Road will be subject to review and approval by the Town of Springdale. Because the proposed perimeter berm will be altering the flow path of Davis Brook floodwaters and it requires the installation of culverts, a permit to altar a body of water from the Department of Municipal affairs and Environment will be required. Also, Davis Brook is a scheduled salmon river and as such an environmental assessment and review of the proposed perimeter berm by DFO will be required.

OPERATION AND MAINTENANCE CONSIDERATIONS

The berms should be inspected on an annual basis preferably in the spring time to identify any signs of erosion and damage due to snow cover or ice movement. Any identified deficiencies should be repaired. They should also be inspected following any large flow event for which they are retaining water for any evidence of water or ice damage. In addition to inspection and repair of any berm damage the site grading following the installation of a perimeter berm may require the installation of a sump pit and pump arrangement to remove direct runoff from the site. From a maintenance perspective the flow paths from the site to the sump structure should be kept clear of debris such that water has a clear path to the sump and prior to forecasted heavy rainfall events the pump system should be verified to be in good working order.

OPINION OF PROBABLE COST

Based on the refined design parameters developed in the option analysis detailed above, Stantec has developed an Opinion of Probable Cost for each option in the 2018 Engineering Flood Mitigation Analysis Study and the additional perimeter berm option that are shown in Table 2 below. The 2017 conceptual opinions of probable cost are also shown for comparison purposes. The perimeter berm analyzed has been highlighted yellow. Please note that the 2018 study determined that Option 2 was not feasible.

Table 2: Opinion of Probable Cost

Mitigation Strategy Description	Estimated Cost (HST EXTRA)	Estimated Cost (HST EXTRA) (2017 Study
Option 1 – Installation of Retention Berms	$902,864.55	$380,000.00
Option 2 - Flood Diversion Ditch	$423,570.00	$410,000.00
Option 3 – Terminal Station Perimeter Berm	$384,917.40	N/A

ASSUMPTIONS AND EXCLUSIONS

Please note the above analysis is based on the following assumptions and exclusions:

- Hydraulic modeling of flood mitigation measures is based on the 100 year event with 60% culvert blockage at Route 392.
- Opinion of Probable Cost for the perimeter berm assumes the following:
    - 0.6m depth of USM (Unsuitable Material) removal beneath perimeter berm and access road. This can be verified via sub surface geotechnical investigation.
    - A full perimeter drainage swale system on the inside of the perimeter berm is to be installed to collect site runoff and direct it to the sump pit. Having not performed a detailed design exercise we have assumed that one sump pit structure will be sufficient to remove water from the site.
    - The interior fenced yard of the terminal station is free draining (allows water to flow toward the perimeter fencing)
    - Full resurfacing of the existing gravel driveways inside the berm is included to account for grading modifications.

Reference: Engineering Flood Mitigation Analysis - Springdale Terminal Station

- The berm will only be riprapped on the exterior side.
- Detailed design of the berm and access road will confirm the extent of the required grading modifications and interior runoff collection system.
- The opinion of probable cost is construction cost only and does not include any costs associated with regulatory approvals, subsurface investigations, quality control/quality assurance during construction, land acquisition, or environmental assessments.

Regards,

Stantec Consulting Limited

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Attachment: Option 3 Terminal Station Perimeter Berm Opinion of Probable Cost

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Option 3 Terminal Station Perimeter Berm Opinion of Probable Cost

Item/Description	Quantity	Unit	Unit Price	Total
Mobilization/ Demobilization	1	LS	$ 50,000.00	$50,000
Clearing and Grubbing				
Clearing and Grubbing	0.15	HA	$ 12,000.00	$ 1,800.00
Excavation and Erosion Protection				
USM Removal (Berm)	1176	CM	$ 30.00	$ 35,280.00
Imported Structural Fill Placed and Compacted (Berm)	2116	CM	$ 40.00	$ 84,640.00
USM Removal (Access Road)	320	CM	$ 30.00	$ 9,600.00
Imported Structural Fill Placed and Compacted (Access Road)	600	CM	$ 40.00	$ 24,000.00
200mm minus erosion protection	388	CM	$ 50.00	$ 19,400.00
Geotextile	1484	SM	$ 7.00	$ 10,388.00
Ditching	30	LM	$ 50.00	$ 1,500.00
Site Drainage Swales	540	LM	$ 10.00	$ 5,400.00
Culvert Trench Excavation	64	CM	$ 20.00	$ 1,280.00
Dewatering	1	LS	$ 5,000.00	$ 5,000.00
Pipe Culverts				
600mm CHDPE	22	LM	$ 800.00	$ 17,600.00
Class B Bedding	35	CM	$ 30.00	$ 1,050.00
Riprap End Treatment	4	EA	$ 1,500.00	$ 6,000.00
Gravel for Streets				
Class B	510	tonne	$ 28.00	$ 14,280.00
Class A	255	tonne	$ 30.00	$ 7,650.00
Regrading Site Accessways				
1. Regrading Site Accessways	1	LS	$ 15,000.00	$ 15,000.00
Sump Pit Structure				
1.Sump Pit Catch Basin	1	LS	$ 15,000.00	$ 15,000.00
2.Sump Pump and Associated discharge piping	1	LS	$ 10,000.00	$ 10,000.00
3. Sump Electrical Control Panel and Housing	1	LS	$ 10,000.00	$ 10,000.00
Relocate/Adjust Utilities to Grade				
Guy Wire Anchors	2	EA	$ 1,000.00	$ 2,000.00
Relocate/Adjust Utilities to Grade				
Fencing and Gate Adjustment Allowance	1	LS	$ 10,000.00	$ 10,000.00
Topsoiling, Sodding and/or Hydroseeding				
150mm topsoil and nursery sod	540	SM	$ 18.00	$ 9,720.00
Contingency (5%)				$ 18,329.40
			Total(HST EXTRA)	**$ 384,917.40**

Springdale Terminal Station Flood Mitigation

Construction of Flood Mitigation Berm

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Background Information

Springdale Terminal Station

- Located on the 138 kV transmission system between Stony Brook and Howley.
- Supplies power to Newfoundland Power customers in the Springdale area

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a nalcor energy company

Background Information

Flood Events

- Flooding occurs at the terminal station via overland flow across Route 392 and pooling downstream of site
- Flooding events have occurred in April 2006 and April 2015
- During 2015 flood event, water entered the building and infiltrated a control cabinet and damaged a protective relay, the damage caused a trip and resulted in a power outage to Newfoundland Power customers in the Springdale area

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a nalcor energy company

Background Information

Flood Events

Proposed Solution

Proposed Solution

Installation of Earthen Berm

- Several options assessed, most feasible option chosen
- Solution chosen: construct an earthen perimeter berm and relocate terminal station vehicle access

Modeled based on 100 year flood

Proposed Solution

Environmental Assessment

- As the construction of the berm is classified as prime contracting, and the berm is located within 200m of a schedule salmon river, an Environmental Assessment is required
- As such, the construction is subject to the approval of the Department of Municipal Affairs and Environment of the Government of Newfoundland and Labrador. No construction activities are permitted to take place prior to this approval
- As part of the Environmental Assessment process NL Hydro is consulting with impacted stakeholders to discuss the proposed project and address any concerns that may arise

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a nalcor energy company

Proposed Solution

Installation of Earthen Berm

Conceptual Design Parameters:

Aspect	**Conceptual Design**
Total Berm Length	maximum of 270 metres
Berm Top Width	1.0 metres
Berm Bottom Width	4.0 to 6.0 metres
Berm Top Elevation	22.43 to 23.18 metres
Berm Height	approximately 1.0 metre
Berm Side Slopes	2:1

- Till core with rip-rap or reinforced geofabric exterior for erosion protection

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Proposed Solution

Installation of Earthen Berm

Preliminary Construction Schedule:

- Construction to commence next summer (June/ July 2020)
- Construction activities are estimated to take approximately 4 weeks

Mitigating Impacts to Public

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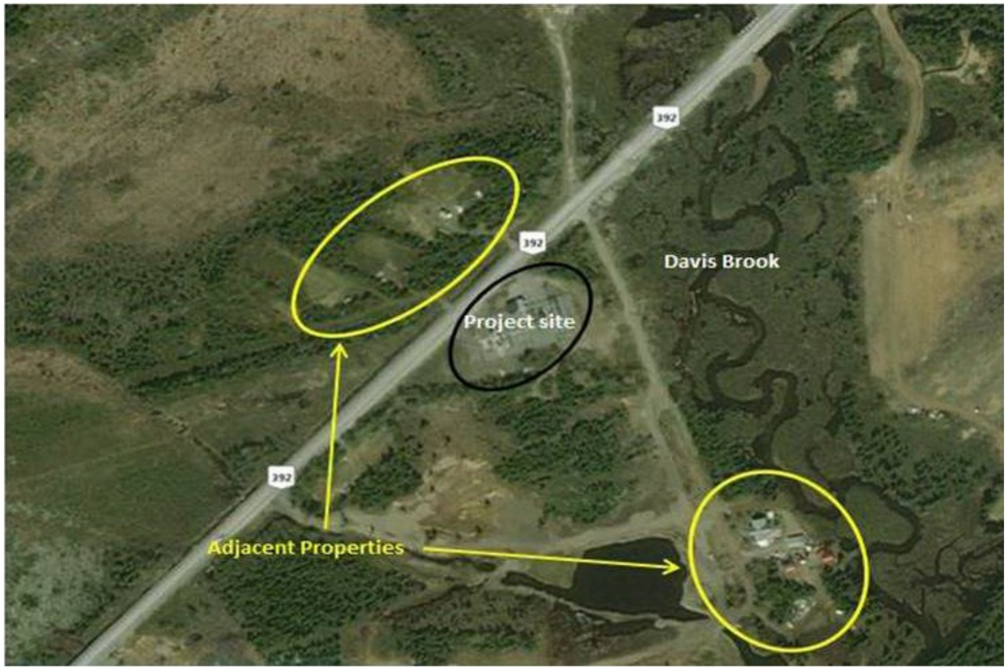
Mitigating Impacts to Public

Residents in Area



Access from Route 392 to resident properties will be maintained at all times

Mitigating Impacts to Public

Construction Activities

- ***Construction Noise and Dust:***
  - Construction activities will be limited to daylight hours to minimize the noise disruption
  - The site is located adjacent to a paved road so dust suppression may not be necessary. If required, standard and approved dust suppression methods will be employed
- ***Erosion and Sedimentation Control:***
  - A site specific erosion and sedimentation control plan has been developed to identify required areas for silt fencing to mitigate TSS (total suspended solids) in runoff.
  - Construction activities will not create erosion issues for the surrounding area.

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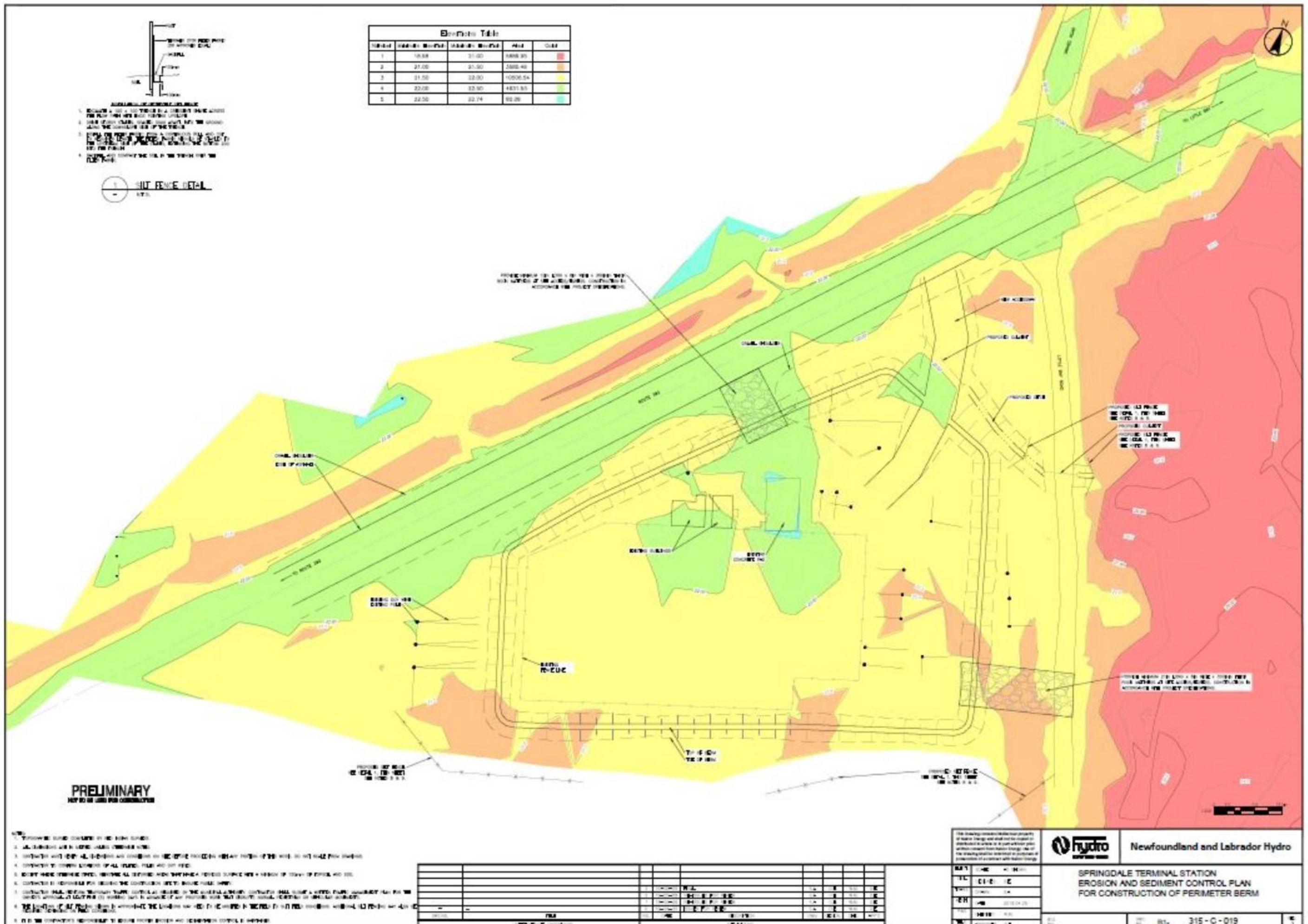
Mitigating Impacts to Public

Construction Activities



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Mitigating Impacts to Public

Construction Activities

- ***Construction Safety:***
  - Any open excavations will be barricaded before Contractor leaves the job site for the day
  - Spotters will be used as required
  - Signage will be installed identifying the construction zone and any hazards
- ***Impacts to Traffic:***
  - Route 392 will remain open, a lane closure may be required, traffic control will be provided to facilitate traffic during the lane closure

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Mitigating Impacts to Public

Impacts of Redirecting Water

- A hydrological model was created (using HEC-RAS) to simulate a 100 year flood, using collected survey data to create the surface
- The proposed berm was inputted into the model to assess the impacts
- Based on this modelling, no additionally adverse impacts are expected for any of the surrounding infrastructure due to the presence of the berm

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Questions?

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Project Fact Sheet

Springdale Terminal Station Flood Mitigation – Construction of Perimeter Berm

Background Information

The Springdale Terminal Station supplies power to the Newfoundland Power customers in the Springdale area. Past flooding events at the terminal station due to high volumes of runoff during storms, have caused damage to equipment, resulting in power outages. Past events occurred in April 2006 and April 2015.

Proposed Solution

In order to ensure Hydro maintains a reliable power supply, flood mitigation measures are required to prevent flooding at the terminal station. Hydro is proposing to install a perimeter earthen berm to prevent the infiltration of runoff in the terminal station. Construction activities will commence in June/July of 2020, and the estimated duration of construction is 4 weeks.

Mitigating Impacts to the Public

Construction activities may require lane closures on Route 392, however traffic control will be provided during these closures to ensure safe and organized traffic flow, and access to adjacent properties will be maintained at all times. Construction activities will be limited to daylight hours to minimize the noise disruption. A site specific erosion and sedimentation control plan has been developed to minimize environmental impacts. Appropriate construction signage and hazard identification markers will be present. Based on hydrological modelling, it has been determined that the redirection of runoff water due to the presence of the berm is not expected to have any additionally adverse impacts to the surrounding infrastructure.

Questions?

Should you have any questions please contact Chad Evans at 709-737-1938 or chad.evans@nlh.nl.ca by July 19, 2019.

Good Morning Chad,

I appreciate the feedback regarding my previous email.

As you have mentioned, the design has incorporated all the standard existing practices; I just wanted to ensure that you had the full story with regards to the emergency events witnessed in the last twelve (12) years within the community.

I understand that the this bridge is outside the zone of influence for design, but with the changing climatic conditions, I would suggest that in the future the zones being assessed for evaluation will be increased.

Regardless of this, the installation of a berm directing additional water downstream will have an effect on the water levels running under this bridge - but I understand that due diligence has been undertaken by your team and this is the best possible modeling available at this time.

Thanks for touching base and I hope that the information supplied was of some assistance.

Matthew Bowers, P.Eng
Public Works Superintendent
Office: 673-4292 Cell: 673-7650
publicworks@townofspringdale.ca
www.townofspringdale.ca

From: ChadEvans@nlh.nl.ca [mailto:ChadEvans@nlh.nl.ca]
Sent: Friday, July 26, 2019 3:52 PM
To: publicworks@townofspringdale.ca
Cc: TroyButler@nlh.nl.ca; MarkKing@nlh.nl.ca; AshleyHobbs@nlh.nl.ca
Subject: Re:RE: REQUEST FOR COMMENT BY JULY 19 - Springdale Terminal Station Flood Mitigation Project

Matthew,

I have met with the project team to review the items contained in your email below from July 15. I have numbered the responses as outlined in your email.

1. Detailed engineering on the berm to provide specifics on construction details are not available at this time. This activity will commence upon release of the undertaking from

Environmental Assessment.   The design parameters used for hydraulic modelling are as follows:

Aspect	Conceptual Design
Total Berm Length	maximum of 270 metres
Berm Top Width	1.0 metres
Berm Bottom Width	4.0 to 6.0 metres
Berm Top Elevation	22.43 to 23.18 metres
Berm Height	approximately 1.0 metre
Berm Side Slopes	2:1

2. The file size of the hydraulic model is very large and difficult to transmit. We understand the importance of ensuring there are no negative impacts on existing municipal infrastructure. We have assessed the impacts to municipal infrastructure within the zone of hydraulic influence of the berm using industry accepted methods (2D flood modeling in HEC RAS), and can confirm based on our modelling there are no negative impacts to existing infrastructure as a direct result of the presence of the berm (based on our design). In reference to the question as to whether the design criteria is conservative, we feel the 100yr flood is a conservative design condition, given that this is not a water retention dam. We have compared our design criteria with some of the storm water infrastructure design guidelines from the Department of Transportation and Works, and the City of St. John's, and our design meets, or exceeds in most cases, their criteria.

3. As indicated above, we have assessed municipal impacts within the zone of hydraulic influence. The TW bridge is outside of the zone where hydraulic influence from this project may be observed. The hydraulic model also examined potential impacts at the adjacent property. We have been in contact with this landowner (Perry Pelley, 431 Little Bay Road) and briefed him on the project to which he has no objection. Our modelling has predicted no adverse impact to the Pelley property. A small decrease in water level is predicted from 0.36m (assuming 100 yr flooding, no mitigation and no culvert blockage at Route 392) to 0.34 m under the same model conditions with the perimeter berm installed at the Hydro terminal station. The culverts to be installed under the access road will drain via overland flow.

Please review and let us know if you would like additional information. Hydro is planning to register this project under the Environmental Assessment Regulations by the end of next week.

Thanks

Chad Evans
Environmental Specialist
Environmental Services
Newfoundland and Labrador Hydro - a Nalcor Energy company
t. 709 737-1938 c. 709 691-4759 f. 709 737-1777
e. ChadEvans@nlh.nl.ca
w. www.nlh.nl.ca

From: Mark King/NLHydro
To: "Matthew Bowers" <publicworks@townofspringdale.ca>, Chad Evans/NLHydro@NLHYDRO
Cc: "'Jason Sparkes'" <cao@townofspringdale.ca>, <info@townofspringdale.ca>
Date: 07/16/2019 11:15 AM
Subject: Re:RE: REQUEST FOR COMMENT BY JULY 19 - Springdale Terminal Station Flood Mitigation Project

---

Thank you for this, Mr. Bowers. I'm passing your questions and feedback along to Chad Evans, with our Environmental Services team, for follow up.

Regards,
Mark

From: "Matthew Bowers" <publicworks@townofspringdale.ca>
To: <MarkKing@nalcorenergy.com>, "'Jason Sparkes'" <cao@townofspringdale.ca>
Cc: <info@townofspringdale.ca>, <ChadEvans@nlh.nl.ca>
Date: 07/15/2019 03:31 PM
Subject: [External] RE: REQUEST FOR COMMENT BY JULY 19 - Springdale Terminal Station Flood Mitigation Project

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Good Afternoon Mark,

I apologize for the late reply, but this is my first day back in the office from annual leave.

I appreciate the consultation regarding the flood mitigation plan as far as comments I have the following:

1. Is it possible to view the detail drawing of the berm structure (till core aggregate and reinforced berm)

2. Is it possible to obtain a copy of the HEC-RAS model that was generated for the surrounding impacts (see pictures regarding the flow at the bridge and 100 yr flood, is this conservative enough with climate change?)

3. The two most critical areas for the Town are the resident's adjacent to Davis brook and the TW bridge that acts as the gateway to the community:

- In the 2005 Flooding Event there was an excessive amount of water passing under this bridge to the point where it was nearly reaching the deck; we would just like to make sure that this is accounted for in the flood modeling
- You will also note from the pictures that the location of Northeast Well Drilling and Springdale Forest Resources were badly flooded as well; with the addition of this berm, there will be even more water surcharging Davis Brook. Will there be any additional measures taken downstream to help prevent this? And, what is the planned path for the water from the culverts to reach Davis Brook from the new access road? Will it be overland flow and filtration or piping directly to the brook?

I have more pictures from the 2006 flooding event if you require them, and feel free to contact me at any time is you want to discuss further.

Thanks,

Matthew Bowers, P.Eng
Public Works Superintendent
Office: 673-4292 Cell: 673-7650
publicworks@townofspringdale.ca
www.townofspringdale.ca

THE TOWN OF Springdale

From: MarkKing@nalcorenergy.com [mailto:MarkKing@nalcorenergy.com]
Sent: Friday, July 05, 2019 11:15 AM
To: Jason Sparkes
Cc: publicworks@townofspringdale.ca; info@townofspringdale.ca; ChadEvans@nlh.nl.ca
Subject: REQUEST FOR COMMENT BY JULY 19 - Springdale Terminal Station Flood Mitigation Project

Good morning,

Newfoundland and Labrador Hydro is planning a project to construct a flood mitigation berm at the Springdale terminal station. Following provincial environmental assessment regulations, we are providing the following project information for the Town's review and inviting any feedback or questions you may have, prior to Hydro filing its EA registration.

I am forwarding this information on behalf of our project team and Environmental Services division. Your questions and comments are requested by **July 19, 2019**.

Attached is a project overview with background and a description of the work, as well as a fact sheet.

Please direct any questions or comments that you may have regarding the project to Chad Evans with Hydro's Environmental Services at 709-737-1938 or chad.evans@nlh.nl.ca by July 19.

Given the difficulty in summer meeting schedules, we felt it was most effective to send you this information package and ask for your review and feedback. Thank you for your attention to this matter.

Regards,

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Mark King
Sr Communications Advisor
Corporate Communications
Regulatory Affairs & Corporate Services
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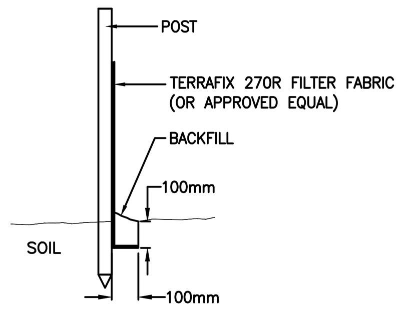
w. **www.nlhydro.com**



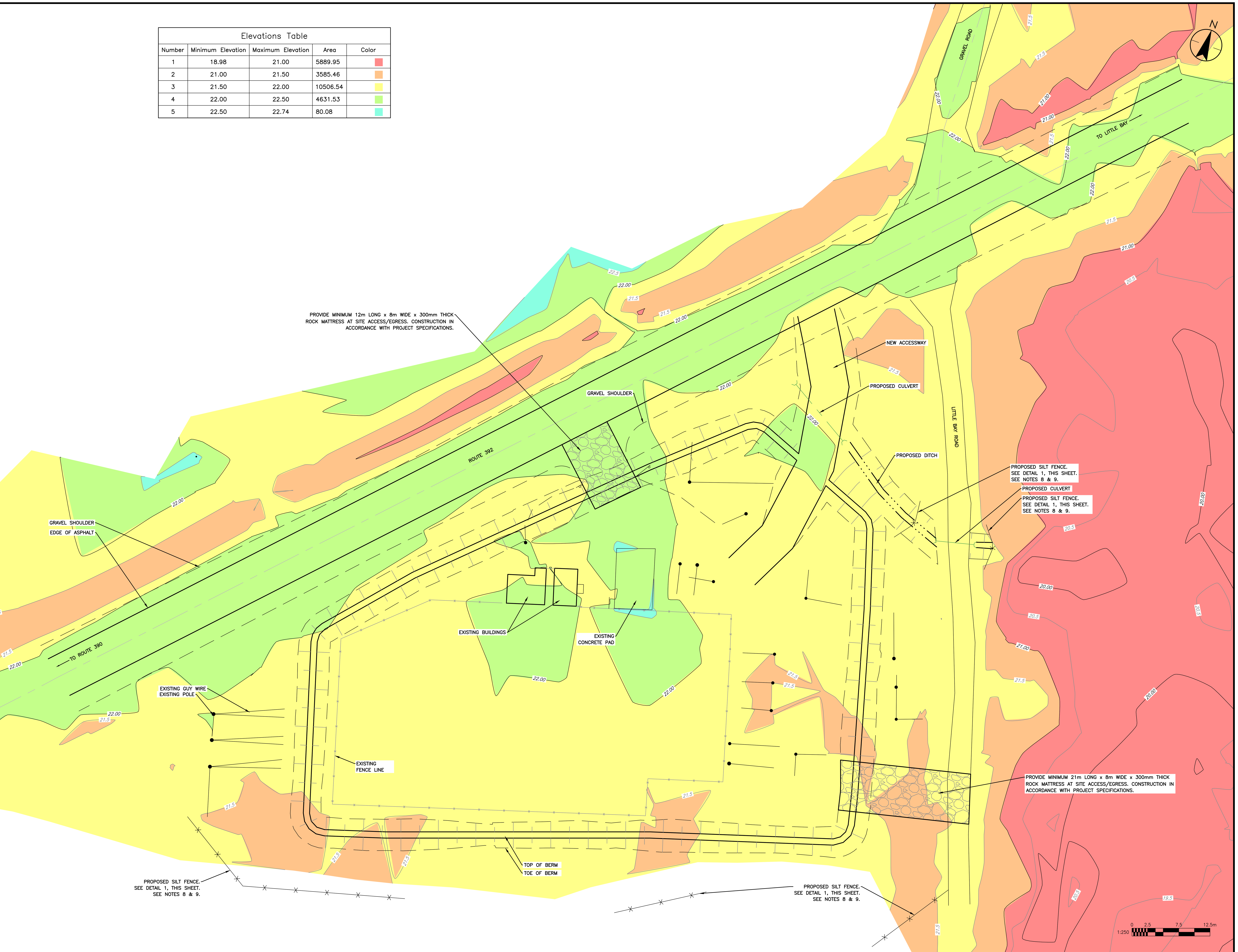
INSTALLATION OF GEOTEXTILE SILT FENCE

1. EXCAVATE A 100 x 100 TRENCH IN A CRESCENT SHAPE ACROSS THE FLOW PATH WITH ENDS POINTING UPSLOPE.
2. DRIVE STURDY STAKES, SPACED 3000 APART, INTO THE GROUND ALONG THE DOWNSLOPE SIDE OF THE TRENCH.
3. INSTALL THE FILTER FABRIC FROM A CONTINUOUS ROLL AND CUT TO REQUIRED LENGTH. THE FILTER FABRIC SHOULD BE STAPLED TO THE UPSTREAM SIDE OF THE STAKES, EXTENDING THE BOTTOM 200 INTO THE TRENCH.
4. BACKFILL AND COMPACT THE SOIL IN THE TRENCH OVER THE FILTER FABRIC.

1 / – SILT FENCE DETAIL
N.T.S.

Elevations Table

Number	Minimum Elevation	Maximum Elevation	Area	Color
1	18.98	21.00	5889.95	
2	21.00	21.50	3585.46	
3	21.50	22.00	10506.54	
4	22.00	22.50	4631.53	
5	22.50	22.74	80.08	



PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

NOTES:
1. TOPOGRAPHIC SURVEY COMPLETED BY RED INDIAN SURVEYS.
2. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
3. CONTRACTOR MUST VERIFY ALL DIMENSIONS AND CONDITIONS ON SITE BEFORE PROCEEDING WITH ANY PORTION OF THIS WORK. DO NOT SCALE FROM DRAWINGS.
4. CONTRACTOR TO CONFIRM LOCATIONS OF ALL UTILITIES, POLES AND GUY WIRES.
5. EXCEPT WHERE OTHERWISE STATED, REINSTATE ALL DISTURBED AREAS THAT HAVE A PERVIOUS SURFACE WITH A MINIMUM OF 150mm OF TOPSOIL AND SOD.
6. CONTRACTOR IS RESPONSIBLE FOR SECURING THE CONSTRUCTION SITE TO ENSURE PUBLIC SAFETY.
7. CONTRACTOR SHALL PERFORM TEMPORARY TRAFFIC CONTROL AS REQUIRED BY THE MUNICIPAL AUTHORITY. CONTRACTOR SHALL SUBMIT A WRITTEN TRAFFIC MANAGEMENT PLAN FOR THE OWNER'S APPROVAL AT LEAST FIVE (5) WORKING DAYS IN ADVANCE OF ANY PROPOSED WORK THAT DISRUPTS NORMAL PEDESTRIAN OR VEHICULAR MOVEMENTS.
8. THE LOCATIONS OF SILT FENCING SHOWN IS APPROXIMATE. THE LOCATIONS MAY NEED TO BE MODIFIED IN THE FIELD TO SUIT FIELD CONDITIONS. ADDITIONAL SILT FENCING MAY ALSO BE REQUIRED DEPENDING ON FIELD CONDITIONS.
9. IT IS THE CONTRACTOR'S RESPONSIBILITY TO ENSURE PROPER EROSION AND SEDIMENTATION CONTROL IS MAINTAINED.

REFERENCE DRAWINGS

DWG.NO.	TITLE
–	–

REVISIONS

NO.	DATE	DESCRIPTION	DWN.	DESIGN.	CHK.	APP'D
3	19–05–09	ISSUED FOR USE	S.A.	D.E.	W.M.	D.E.
2	19–05–08	RE–ISSUED FOR REVIEW	S.A.	D.E.	W.M.	D.E.
1	19–05–06	RE–ISSUED FOR REVIEW	S.A.	D.E.	W.M.	D.E.
0	19–04–25	ISSUED FOR REVIEW	S.A.	D.E.	W.M.	D.E.

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Newfoundland and Labrador Hydro

ELECT.	SCALE:	AS SHOWN
CIVIL	DESIGNED:	D.E.
TRANS.	DRAWN:	S.A.
MECH.	DATE:	2019.04.25
P&C	CHECKED:	W.M.
TELC.	APPROVED:	D.E.

SPRINGDALE TERMINAL STATION
EROSION AND SEDIMENT CONTROL PLAN
FOR CONSTRUCTION OF PERIMETER BERM

W.O. NO.

DWG. NO. B1- 315 - C - 019

REV. 3

PLOT SCALE 1:1 C.A.D.