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NHC Reference 3008460
May 10, 2024

Metro Vancouver Regional District
4515 Central Boulevard
Burnaby, BC V5H 0C6

Attention: Marcin Pachcinski, Division Manager, Electoral Area and Implementation Services
Via email: marcin.pachcinski@metrovancouver.org

Re: **Barnston Island Dike Assessment Update 2023**
Preliminary Report, Final

1 Introduction

Metro Vancouver received a $5.25M grant from the Province of British Columbia (the Province) to improve flood protection at Barnston Island. Projects implemented under this grant must be complete by March 2026. As an initial step, Metro Vancouver retained Northwest Hydraulic Consultants Ltd. (NHC) to review the *Barnston Island Dike Assessment 2012* report ("The 2012 Assessment"; NHC, 2013), with the intent of identifying changes that have taken place over the past eleven years; updating previously estimated costs of recommended improvements; and re-evaluating priority ratings. The 2012 Assessment was prepared for Ministry of Forests, Lands and Natural Resource Operations (MFLNRO) by NHC and issued in 2013.

The 2012 Assessment estimated that the Barnston perimeter dike protects to about the 40-year Fraser River return period flood (2.5% Annual Exceedance Probability or AEP). Due to climate change, future flood flows are expected to increase and sea levels rise; over time reducing the level of protection provided by the dike.

To re-estimate dike design levels and corresponding fill volumes, the current work utilizes an updated dike crest survey and flood profiles based on recent Fraser River two-dimensional (2D) hydraulic modelling, which has superseded earlier one-dimensional (1D) modelling. Other material quantity estimates apply similar assumptions as the previous work, but costs are updated for inflation. A qualitative prioritization of the various upgrades is provided to assist Metro Vancouver with initial stakeholder discussions on the type of improvements to implement using the grant funding.

Over the course of this assessment, NHC and Metro Vancouver received input from Katzie First Nation, local residents and various stakeholders, through a series of virtual meetings and at a public open house on Barnston Island on February 28, 2024.

2 2012 Assessment

The 2012 Assessment rated the dike to be in less than fair condition, with failure potential from overtopping, erosion and geotechnical deficiencies. Overly steep dike side slopes and active bank erosion were observed in some locations. Internal drainage behind the dike was found to be poor in low-lying areas, with some ditches on private property not maintained by landowners. The island pumpstation and flood-box were identified as sub-standard; the pump station nearing its end-of-life, at a minimum requiring urgent safety upgrades, and the floodbox needing replacement. During high flows, access to the ferry on the Surrey side is cut-off due to the low approach-road elevations.

At the time, upgrading the diking system and other flood mitigation components to withstand a Fraser River 50-year (2% AEP) flood was considered achievable for a cost of $4.1 M. The following priority measures were recommended:

1. Address bank erosion
    - Maintain trees in the strip of land between the dike and the river bank
    - Dissipate shore waves with log booms and enforce vessel speeds
    - Stockpile riprap for emergency repairs
2. Upgrade internal drainage
    - Replace pump station and floodbox
    - Maintain internal drainage network connected to the pump station and floodbox
3. Prepare flood protection O&M manual; revise livestock evacuation procedures
4. Upgrade dike
    - Raise crest to consistent level of 50-year flood + freeboard
    - Re-pave perimeter road
    - Install seepage prevention barriers as needed

3 2023 Site Conditions

To understand current site conditions and document any changes since the 2012 Assessment, NHC conducted site inspections and reviewed available flood protection upgrade information provided by Metro Vancouver, the Barnston Island Diking District (BIDD), and BC Ministry of Transportation and Infrastructure (MoTI). For information on Barnston IR3 lands, NHC relied on previous project work for Katzie First Nation (KFN).

3.1 Initial Site Inspection and Information Review

A site inspection was completed on October 17, 2023 by Daniel Maldoff (Project Engineer) and Monica Mannerström (Principal). The inspection was done by car along the perimeter road, allowing for an

overview-level assessment of the dike. The dike is generally set back from the riverbank and stops were made at all previously identified locations of concern. Due to heavy vegetation, the condition of the shoreline could only be viewed in select locations; a more detailed inspection of the bank condition was recommended. This additional inspection was completed on March 14, 2024 (see Section 3.2).

Figure 1 provides a location map of Barnston Island and shows the existing dike alignment and stationing referred to in this report. It matches the stationing in the 2012 Assessment; with Station 0+000 at the ferry landing and stations increasing in the counterclockwise direction.

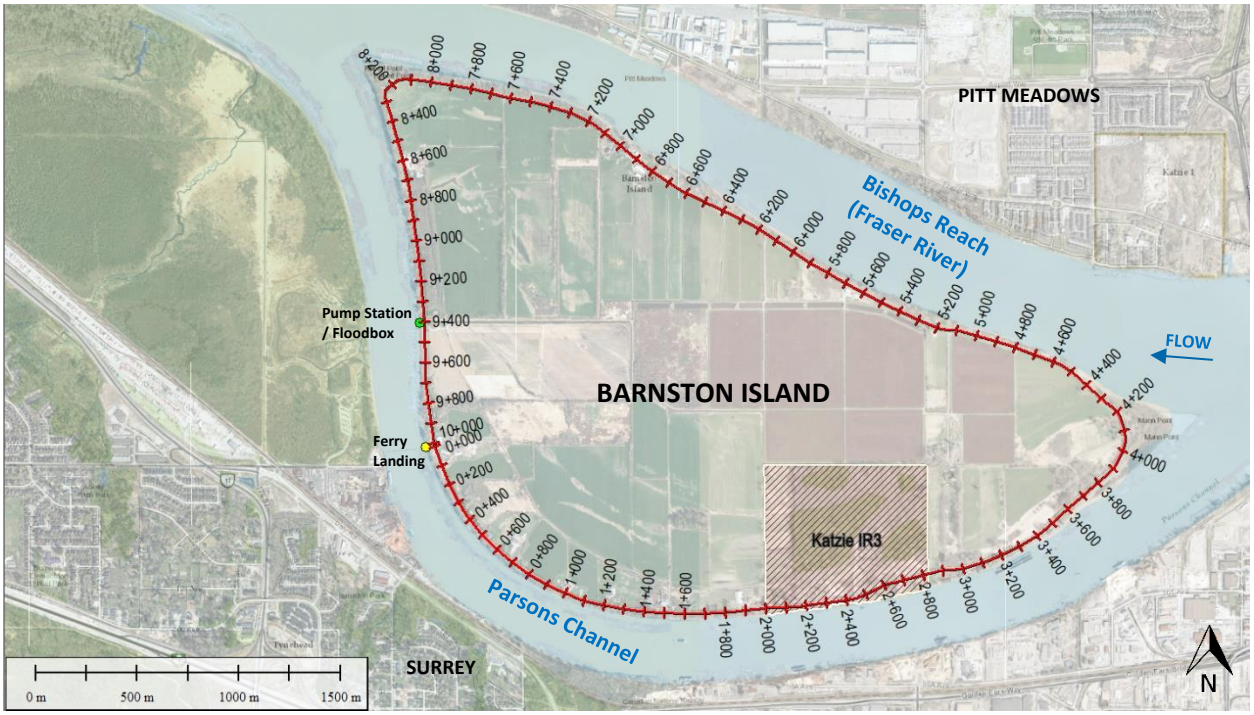

Figure 1 Barnston Island location map and dike stationing

Based on the information review and October 17, 2023 site inspection, the conditions of the road/dike, riverbank and drainage works were found to be similar to those in 2012, with the following variations:

- The perimeter road has been re-paved between the ferry landing and approximately Station 1+100. The road width in the re-paved stretch, which was previously identified as narrow, is now approximately 5 m, consistent with the prevailing road width on the remainder of the dike crest. Following the site inspection, MoTI confirmed that the road was widened as much as possible during re-paving. However, side slopes remain overly steep. While the widened road increases the allowance for vehicles to meet and pass, hazards remain due to the steep embankments and minimal road shoulders.
- The road surface between approximately 4+300 and 4+350 is rutted and in poor condition. In this area, the road embankment shows some signs of erosion, possibly due to ATV traffic.

- Based on qualitative observations, there appears to be some progression of erosion and launching of riprap along the top of bank at Station 4+390, evidenced by exposed geotextile since the 2012 Assessment. Riprap on the lower bank slope remains in place.
- Trees are leaning into the channel along Bishops Reach, indicative of bank erosion. However, the existing dense vegetation between the riverbank and the dike is expected to slow erosion and potentially provide some protection to the dike.
- The 2012 Assessment noted that the riprap placed in 2007 in a trench, set back from the bank between Stations 9+420 and 9+625, had started to launch. Monitoring was recommended. In the current inspection, the bank line was observed to be steep, with the riverside toe of the buried riprap exposed in some locations. A more detailed analysis is required to quantify bank retreat; however, the bank line appears to remain at a distance from the dike, with the riprap continuing to protect the dike. Based on these observations, ongoing monitoring of this bank erosion remains a recommendation.
- The pump station at Station 9+420 underwent electrical upgrades in 2021 to facilitate emergency generator hook-up. Fencing has been installed to improve safety and restrict public access to the structure.
- Some logs have been anchored on the water side of the floodbox to reduce the risk of debris preventing the gates from closing.
- Approximately 10 truckloads[1] of riprap and 6 truckloads of sand for sandbag have been stored at Katzie IR3 for emergency response.

3.2 Additional Bank Inspection

Riverbanks were inspected on March 14, 2024 by Daniel Maldoff (Project Engineer), Jordan Morgenstern (Field Technician/Boat Operator), and James Ellis (Field/GIS Technician). The inspection was carried out using NHC's jetboat, with georeferenced observations and photos collected from the boat using the ESRI ArcGIS Field Maps application. Observation locations generally corresponded to those in 2012, with additional observations made at locations of interest. All observations were made from the boat. In some locations, tied up log booms limited the boat's proximity to the bank.

During the inspection, the Fraser River flow at Hope was approximately 850 m^3/s. Water levels at New Westminster were approximately El. 2.5 m Chart Datum, or El. 0.9 m CGVD2013, at the start of the inspection, and dropped to approximately El. 0.5 m Chart Datum, or El. -1.1 m CGVD2013, by the end.

The bank inspection was intended to document visible erosion along the upper bank at low tide/ flow. The inspection does not provide insight on potential larger-scale bank retreat due to channel migration and scour. A more detailed bank erosion study is recommended.

[1] Quantity was provided in truckloads by Metro Vancouver. A typical truckload corresponds to a material volume ranging from 6 m^3 to 12 m^3.

Field observations and photos are attached in Appendix A. Figure 2 includes locations where 2024 observations were made, shown as points and colour-classified by presence of active erosion. Erosion potential from the 2012 Assessment is included as a continuous line; for more information, refer to the 2012 Assessment. The figure indicates that the 2012 observed bank erosion has generally persisted to the present and that additional erosion has been initiated in some other locations.

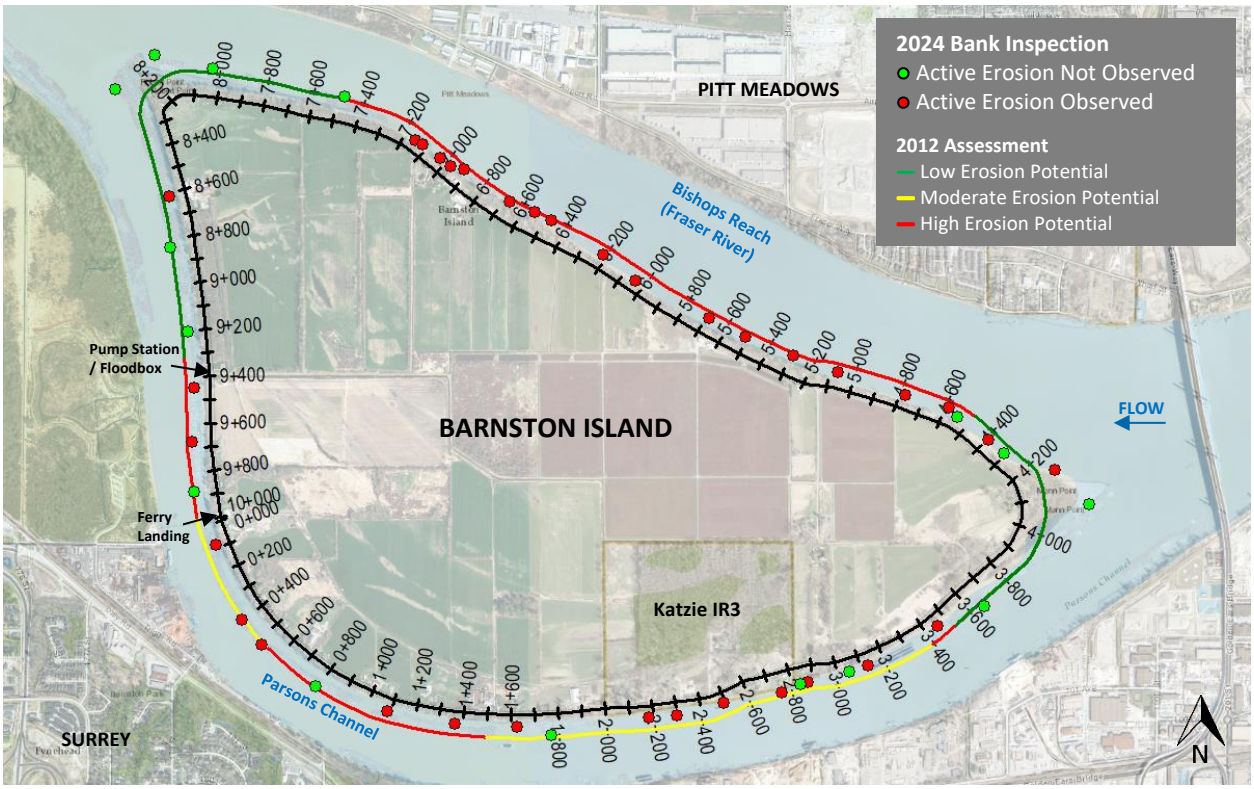

Figure 2 Summary of March 14, 2024 bank inspection observation locations, and erosion areas identified in the 2012 Assessment

Bank erosion observations are grouped separately under the Parsons Channel and Bishops Reach.

Parsons Channel (south side of Barnston Island from east to west)

Bank conditions along Parsons Channel were generally similar to that observed in 2012. Notable erosion sites are as follows:

- The riverbank is actively eroding in the vicinity of Station 3+495. This location was also noted in the 2012 Assessment. The dike centreline is 35 m from the bank, and there is minimal mature vegetation between the dike and bank.
- Near Station 2+850, a timber crib wall that supports the bank near a power pole has sustained some damage from a leaning tree.

- Along Katzie IR3 (Station 2+000 to Station 2+825), some locations are actively eroding, with failed riprap observed near Station 2+750. The dike centreline is 60 m to 70 m from bank upstream of Station 2+600, and generally within 30 m downstream of that.
- The area from roughly Station 0+500 to Station 1+500 is largely vegetated but still shows instability. A private residence is located on the water side of the dike near Station 1+375, with steep banks along the property and the structure located close to the channel.
- From Station 9+420 to 9+955, the bank is protected riprap installed in a trench, set back from the river. During construction of the riprap trench, a large number of trees were removed. The bank is steep, with the river-side toe of the buried riprap exposed in some locations, which indicates bank retreat since the 2012 Assessment. The dike centreline is about 20 m to 30 m from the bank.
- Other areas in Parsons Channel show moderate erosion. Log-booms are tied up along most of the shoreline which help reduce erosion from large waves, mainly caused by tugboats. Erosion from wind generated waves is, by comparison, minimal.

Bishops Reach (north side of Barnston Island from east to west)

Conditions along Bishops Reach have also generally persisted since the 2012 Assessment, with some areas of increased bank retreat. The riverbank along Bishops Reach is eroding at numerous locations, with mature vegetation being undercut. However, the bank materials, which are assumed to be firm to stiff silt (as noted in the 2012 Assessment), appear to be relatively erosion resistant and bank retreat appears to be gradual.

Notable bank observations are as follows:

- At Station 4+390 (also noted in the October 17, 2023 observations), the existing riprap protection has failed in some locations, which may be due to erosion from vessel generated waves and/or from foot access to the bank. This location also has limited vegetation along the bank, and the dike is within about 20 m to 30 m from the active channel.
- Riprap near Station 4+550 appeared to be in good condition. However, a 150-200 m long section of active erosion is present immediately downstream of this riprap.
- In some locations (e.g. Stations 5+500, 6+025, 6+450), tree roots are significantly exposed, creating hard points along the bank that are a mechanism for small erosion arcs forming upstream and downstream of individual trees.
- Riprap between Stations 6+900 and 7+025 is in poor condition, with missing/launched rock elements and active bank erosion present. There is limited vegetation between the bank and the dike at this site. Upstream of this riprap section, near Station 6+600, the bank is scalloped, with retreat of approximately 20 m relative to the surrounding bank line. The dike is generally 60 m to 70 m from the bank, but local erosion and bank retreat reduces this offset.

It should be noted that the intermittent period between 2012 and 2024 has not seen any significant Fraser River floods, and water levels have generally not reached the side slopes of the Barnston Island dike. In the event of a large freshet, bank erosion rates could substantially increase.

Local residents have observed bank retreat in select locations and have expressed concern regarding trees collapsing into the river and their roots damaging the bank when pulled up. There is significant evidence of active erosion, and, as recommended in the 2012 Assessment, bank monitoring continues to be a priority. However, imminent risk of dike destabilization was not observed during the 2024 bank inspection by boat.

3.3 Comparison of Dike Crest Survey and Updated Flood Levels

Figure 3 compares surveyed dike crest elevations and simulated flood levels. The dike crest elevations are based on a provincial survey of Lower Mainland dikes completed in 2019/2020. There is generally good agreement between the NHC 2012 dike survey and the more recent provincial survey, with no significant indication of dike settlement. Minor elevation differences are likely due to selected survey points.

The 2012 dike assessment used flood levels simulated using a one-dimensional (1D) MIKE11 hydraulic model (NHC and Triton, 2006; NHC, 2008). The updated flood profiles are based on a two-dimensional (2D) HEC-RAS model (NHC, 2019). The profiles shown in Figure 3 include a customary freeboard allowance of 0.6 m and are based on peak freshet flow conditions. The 2D simulated profiles are generally considered more accurate than the 1D results and give somewhat reduced flood levels. It is important to note that the 2D model also has a number of limitations (NHC, 2019) and should not be used for setting dike design levels without further refinement.

Flood levels at Barnston Island are influenced by the height and performance of upstream diking during flood events. For example, during the flood of 1948, large floodplain areas upstream of Barnston Island were inundated, providing flow storage and lowering peak flood levels at Barnston Island. However, the island dike still breached, likely due to a weakness at an abandoned floodbox on the north side of the island.

The 2012 Assessment concluded that the crest level along most of the dike was above the 40-year return period (2.5% annual exceedance probability, or AEP) flood level plus 0.6 m freeboard, based on the 1D hydraulic model. The 2D model suggests the dike is largely above the 100-year (1% AEP) design profile including 0.6 m freeboard, except for a distance of about 2,500 m along the Bishops Reach (Figure 2).

As a result of climate change, sea levels are rising and Fraser River flood flows are projected to increase by end-of-century, the future time span typically adopted for current flood protection design. Figure 3 also includes a preliminary profile for the end-of-century 50-year (2% AEP) flood plus 0.6 m freeboard, assuming a 10% increase in Fraser River discharge due to impacts of climate change (NHC, 2023) and 1 m of sea level rise (SLR). Simulated future 50-year water levels at Barnston Island were approximately 0.5 m to 0.6 m higher than present-day, roughly corresponding to the current 200-year flood levels. If these climate change effects are realized, the standard of protection of Barnston Island's existing dike can be expected to significantly decrease over time.

NHC is currently updating Fraser River flood flow projections for Fraser Basin Council and revising the 2D model upstream of Mission. The most recent information available should be used when the dike upgrade plans proceed to the next phase of preliminary design.

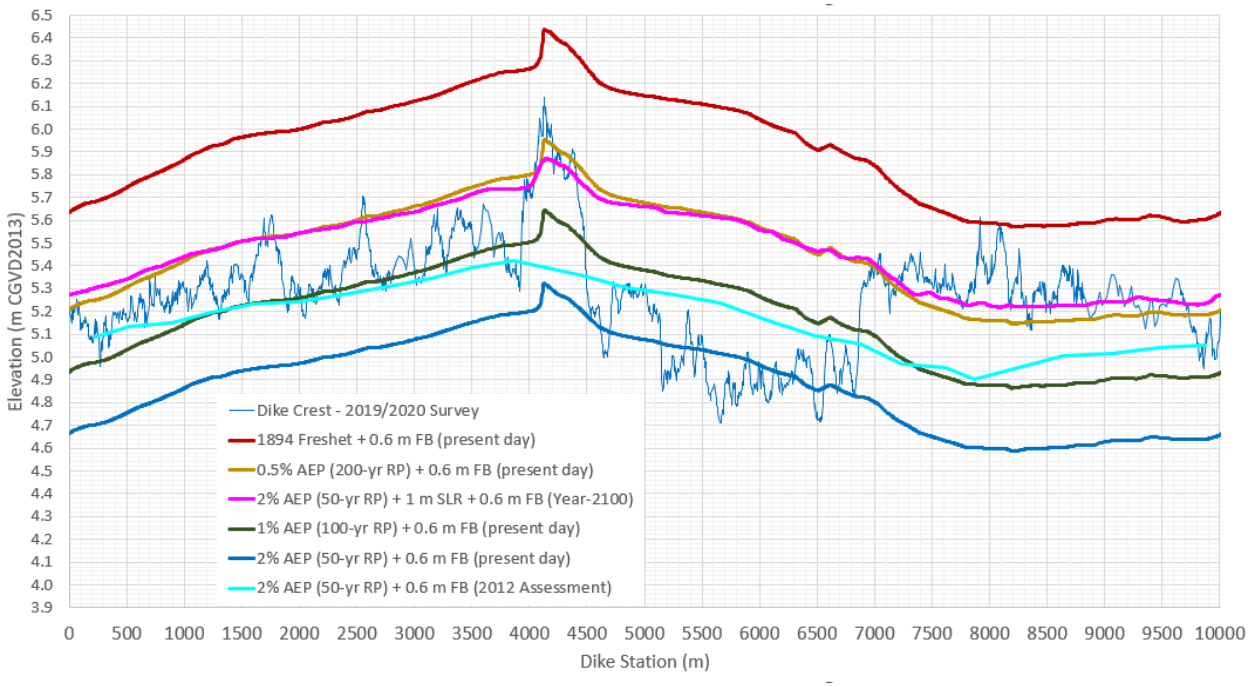

Figure 3 Existing dike crest profile and simulated design flood elevations including 0.6 m freeboard

3.4 Bathymetric Changes and Bank Erosion Potential

The 2012 dike assessment noted active bank erosion at several locations around the island. Based on historical bathymetric comparisons, the channel bed has shown some general lowering, indicative of potential future bank retreat. The recommended protection strategy was for monitoring the retreat using georeferenced stakes in select locations and stockpiling riprap for emergency placement.

The current site inspections identified continued bank erosion at several locations along the shores of Barnston Island, though with no apparent largescale bank retreat. However, the river has only experienced moderate freshet floods in the past 50 years and a larger, long-duration freshet could lead to a rapidly changing bank line.

Based on Public Services and Procurement Canada's (PSPC's) multibeam data, Figure 4 shows bed level changes in Bishops Reach from August 2015 to October 2021. A blue colour indicates bed lowering (degradation) and red a build up of material (aggradation). The channel lowering, roughly off-set from Station 4+600 to 5+000 indicates there could be some future undermining of the bank, raising concern as the dike is set back from the bank by only a relatively short distance (less than 20 m). This type of

bank erosion has been observed elsewhere along the lower Fraser River, where the bank line was previously stable for decades but then suddenly retreated.

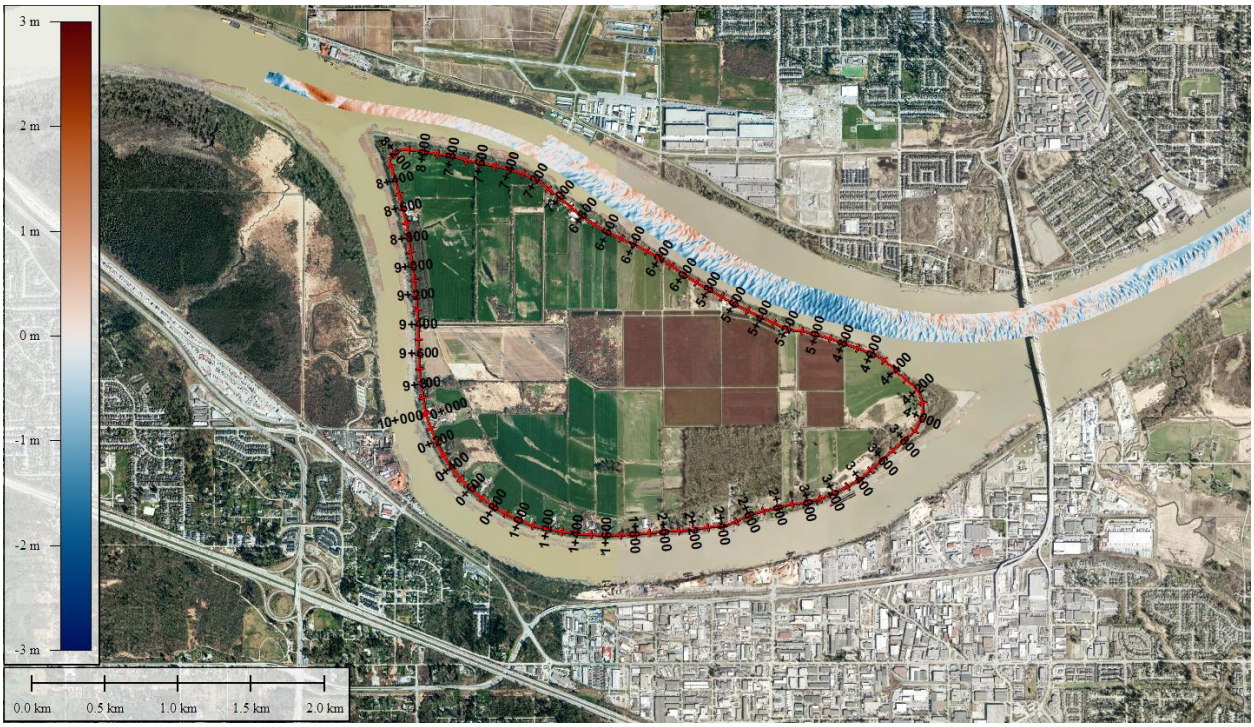

Figure 4 Bathymetry changes in Bishops Reach from 2015 to 2021 (PSPC data)

Erosion hazard for the existing dike was assessed through a simplified analysis, which classified the distance from the dike centreline to the bank of the active channel. Results are shown in Figure 5, along with locations where riprap (of varying condition) is present, as mapped in 2012. Most of the dike has a centreline within 50 m of the channel, vulnerable to dike erosion hazard. About 2.5 km of the dike has its centreline within 30 m of the channel, and most of these locations have no existing riprap along banks. Mature vegetation is important for arresting upper bank retreat that could encroach upon the dike.

A more detailed bank erosion study involving bathymetric surveys is recommended to identify bank protection requirements in more detail. The objective of such a study would be to better understand erosion hazard at Barnston Island, to identify potential threats to the dike in its current alignment, and to develop recommendations for erosion mitigation measures. This study is particularly important if new fill is to be placed on the riverside of the dike along Bishops Reach, disturbing existing vegetation.

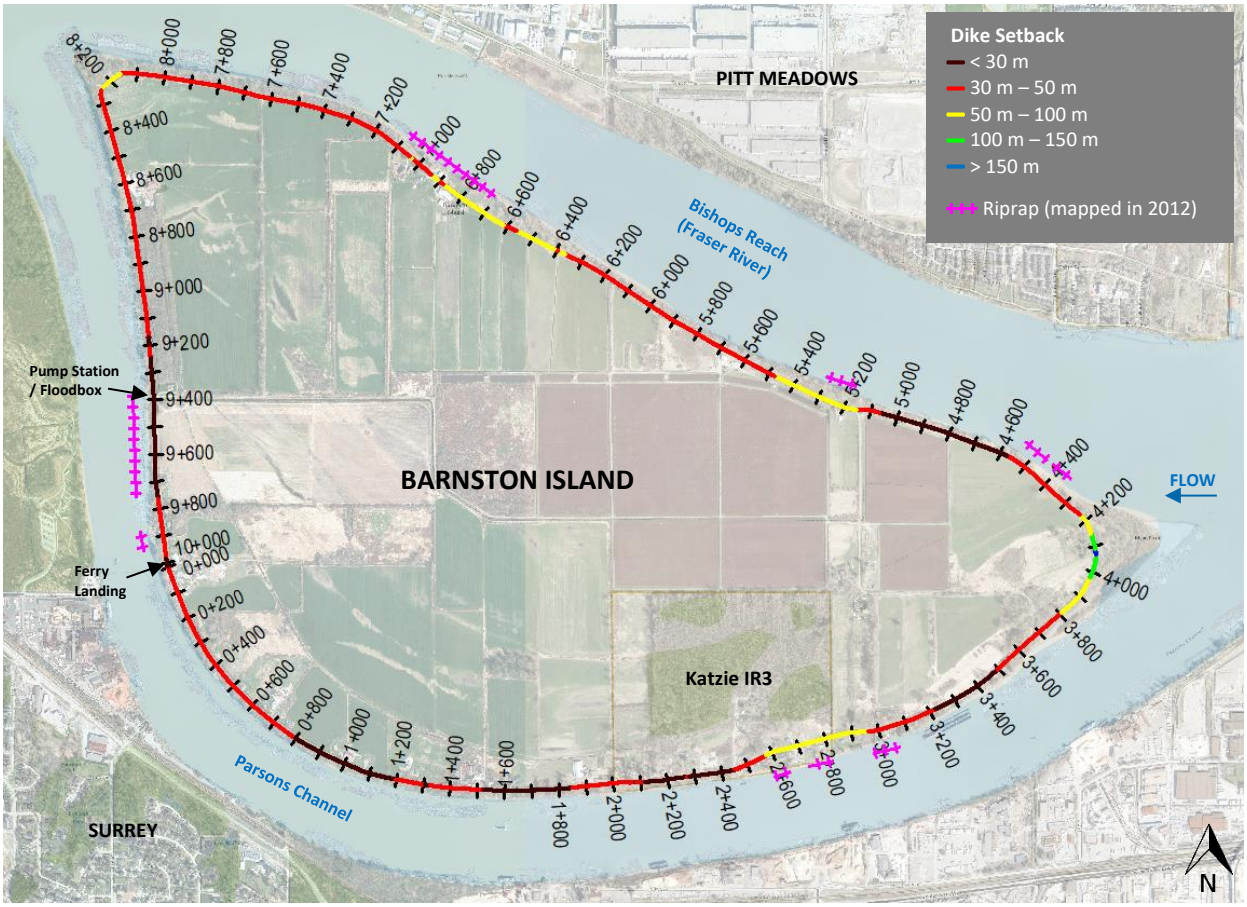

Figure 5 Dike centreline setback from the active channel (based on 2022 Google Earth imagery), and locations of existing riprap (mapped in the 2012 Assessment)

3.5 Internal Drainage

The Fraser River freshet is the main concern of flooding. However, heavy precipitation during the fall and winter can result in inundation of low-lying lands; the November 2021 atmospheric river led to extensive inundation at Katzie IR3. The 2012 Assessment noted that several drainage ditches were plugged and in poor condition, continuing to be so in 2023 (personal communication with BIDD). BIDD has confirmed that it maintains the central ditch conveying flow to the pump station and floodbox, but the internal drainage network is reliant on connecting ditches on private lands, which are not necessarily maintained by landowners. Drainage from Katzie IR3 is severely impeded due to infilling of ditches on adjacent lands.

Except for minor improvements, the pump station and floodbox remain in similar condition as noted in 2012. BIDD mentioned that the invert elevation of the floodbox is too high to allow for full drainage of the central ditch at low tide, implying the floodbox invert elevation could likely be optimized when the floodbox is replaced. Climate change impacts on river levels would need to be considered.

4 Updated Flood Protection Measures

Given the overall similar conditions as in 2012, the 2023 upgrade recommendations remain largely unchanged. However, estimated costs are now higher and additional prioritization may be needed to stay within the currently available grant funding. Grant-funded measures must also be complete by the March 2026 funding deadline, which may limit which recommended measures are achievable under the current grant.

4.1 Actions Summary and Approximate Updated Costs and Timelines

Approximate updated costs of various upgrade components are summarized in Table 1. Most of these components were identified and costed in the 2012 Assessment. The table also includes rough timelines for implementation. Projects requiring land acquisition and in-stream construction are subject to further timing uncertainty due to factors such as land negotiations, environmental permitting approval and appropriate construction timing; actions with these requirements are identified in the table. The costs and timeline estimates were developed for discussion and preliminary budgeting purposes and could vary significantly based on additional concept refinement and further identification of project considerations and constraints.

The updated costs are largely based on the 2012 estimates and adjusted for inflation, which may result in under-estimation. Additional cost adjustments were made for:

- The reassessed dike fill volumes (see Section 4.2)
- Recommended bathymetric surveys and protection needs assessment (this assessment should precede spending of the previously proposed bank protection contingency fund)

The actions recommended for immediate funding in 2012 had an estimated cost of $4.1 M. Implementing these previously recommended items plus the proposed additional work is estimated to cost a minimum of $8.4 M (present-day value). Additional prioritization will be necessary to stay within the current $5.25 M grant funding. Community and stakeholder input will need to be considered, as well as potential cost sharing arrangements with other organizations.

Table 1 Preliminary costs, timelines, and tentative priority rating of individual improvements

NOTE: Estimated costs and timelines are based on preliminary assumptions on scope of work and intended solely to assist with prioritizing projects under the current funding. Actual costs and timelines could substantially vary.

Improvement	2012 Assessment			2023 Update			Potential Implementation Challenges		Approximate Timeline	Comments/Assumptions
	Cost (2012)	Recommended for Funding (2012)	Priority (2012)	Cost (Updated)	Recommended for Funding (2023)	Priority (2023)	Land Acquisition	In-Stream Construction		
Conduct detailed bank erosion study	-		-	$150,000	x	High			6 months	Required to determine feasibility of dike upgrades in current location. Will provide recommendations for erosion mitigation.
Investigate and repair road surface rutting near dike STA 4+200 (MoTI cost sharing)	-		-	$60,000	x	High			1 year	Geotechnical investigation required to determine if rutting is a dike or road issue. Construction by MoTI; estimated cost does not include construction.
Safety upgrades to pump station	$23,000	x	Very High	($29,900)		High			1 year	Electrical upgrades completed. No further action required if pump station is to be replaced in near term.
Install and support water level monitoring equipment at pump station/floodbox (design inputs for upgrades)	$3,000	x	Very High	$2,000	x	High			3 months	Use Surrey water level data at 192nd Street for riverside and install pressure probe on landside.
Pump station replacement	$500,000	x	High	$650,000	x	High		x	6 months – detailed design; 1-2 years – construction (depending on permitting)	Cost could be significantly higher, particularly if seismic design is needed
Floodbox replacement	$300,000	x	High	$390,000	x	High		x	6 months – detailed design; 1-2 years – construction (depending on permitting)	Cost could be significantly higher, particularly if seismic design is needed
Drainage ditch upgrades	$100,000	x	High	$130,000	x	High	x		1 year (depending on land acquisition requirements)	Should include detailed drainage study with recommendations/strategy. Could include returning central ditch north of IR3 to original location and improvements to South Ditch. Cost likely higher as works more extensive than recommended in 2012
Drainage ditch network for Katzie FN. Assumed funding from AANDC, cost not included in total.	$75,000		High	($97,500)		High			N/A – separate project at Katzie IR3	
Develop and install erosion monitoring network. Conduct arborist assessment for bank tree removal. Remove trees as directed.	$3,000	x	High	$100,000	x	High			1 year	Trees about to fall into channel may need to be removed. Costs will vary depending on extent of required tree removal.
Introduce/ enforce boat traffic speed limit (discuss with Port Authority, improve signage, enforce)	Nominal		High	Nominal		High			N/A	Allowable vessel operations should consider erosion, and not just dike overtopping.
Prepare Operation and Maintenance Manual for dike	$30,000	x	High	$60,000	x	High			6 months	Scope guided by up-to-date dike o&m manual standards
Assess seepage during high freshet and prepare seepage barrier designs. (Installation extra.)	$15,000	x	High	$19,500	x	High			1 year (work must occur during freshet)	To be completed by geotechnical engineers
Review and improve island evacuation procedures	Nominal		High	Nominal		Medium			6 months	Main issue raised by some residents is evacuation orders issued too early.
Install permanent floating logs in specific areas / Encourage log-boom tie-up	$40,000	x	High	$52,000	x	Medium		x	1 year	Recommendation to be confirmed in bank erosion study
Relocate beavers etc. (Long term benefits to be determined. Cost not included in total.)	$2,000		Medium	($2,600)		Medium			N/A	Beavers are a factor in toppling trees and aggravating bank erosion.
Stockpile riprap for emergency bank protection	$75,000	x	Medium	$97,500	x	Medium			N/A	Estimated cost based on the previously recommended 1000 m^3; quantity to be refined following recommended bank erosion study

Improvement	2012 Assessment			2023 Update			Potential Implementation Challenges		Approximate Timeline	Comments/Assumptions
	Cost (2012)	Recommended for Funding (2012)	Priority (2012)	Cost (Updated)	Recommended for Funding (2023)	Priority (2023)	Land Acquisition	In-Stream Construction		
Establish bank protection contingency fund (apply following careful monitoring at critical sites) OR construct bank protection as per results of detailed bank erosion study. Cost to be determined.	$1,000,000	x	Medium	$1,300,000	x	Medium		x	1-2 years (if constructed; depending on permitting, and on type and extent of bank protection)	To be confirmed. Actual cost could be significantly different depending on erosion study recommendations.
Establish seepage prevention fund (apply following geotechnical assessment during high freshet). Install seepage barriers as required.	$500,000	x	Medium	$650,000	x	Medium			1-2 years	Requirements to be determined by seepage assessment.
Raise dike to consistent design crest level standard	$1,500,000	x	Medium	$4,700,000	x	Medium	x	x	6 months – detailed design; 1-2 years – construction (depending on permitting and land acquisition)	Raising on water side, per geotechnical seepage mitigation recommendations. Riprap needed in some locations. Paving by MoTI; estimated cost does not include paving
Prepare temporary flood protection to raise dike to forecasted level using gabions, floodbags, sandbags, etc. (resulting in one-way traffic only). Note that seepage issues are to be addressed first.	$1,500,000		Optional	$1,950,000		As needed			3 months-1 year	May be considered as funding deadline approaches
Provide livestock safe areas	$300,000		Optional	$390,000		Not recommended	x		2+ years	Not feasible, based on discussions with some residents (livestock must be evacuated)
Community fund for flood-proofing or raising buildings	$2,500,000		Optional	$3,250,000		Recommend for future funding			5+ years	New construction is currently required to meet flood construction level (FCL). Establishing a fund could be considered as funding deadline approaches
Repair and repave road (MoTI)	$3,000,000		Optional	$3,900,000		Optional			1-2 years	Repaving likely not a flood issue
Relocate/raise housing presently outside dike.	$1,200,000		Optional	$1,560,000		Optional	x		5+ years	
Repair dike following breach/overtopping	$300,000		As needed	$390,000		As needed			N/A – emergency works	Emergency funding could be available if/when needed
TOTAL COST of Items Recommended for Funding (x)	**$4,089,000**			**$8,361,000**						

4.2 Conceptual Dike Crest Raise

The 2012 Assessment recommended raising the dike to a consistent design crest level corresponding to the 50-year freshest flood, plus 0.6 m freeboard. The recommended crest level was based on 1D hydraulic modelling (NHC and Triton, 2006; NHC, 2008), and was consistent with the Province of British Columbia's crest level standard for agricultural land (MWLAP, 2003).

Comparing the existing dike profile against design profiles from updated 2D hydraulic modelling (NHC, 2019), the majority of the existing dike exceeds the 100-year flood profile with 0.6 m freeboard added. For this current study, it is assumed that locations along the dike that are low could be raised to the updated 100-year level with 0.6 m freeboard, to meet similar standards as the rest of the dike.

EGBC guidelines require that impacts of climate change be considered when assessing and mitigating flood hazards (EGBC, 2018). Based on hydraulic modelling of climate change scenarios, the end-of-century Fraser 50-year profile is expected to exceed the present-day 100-year profile (Figure 3). Designing for a standard greater than the present-day 50-year provides an allowance for future increases in water levels. Although the recommended crest profile would exceed the present Provincial standard for agricultural dikes, it is expected to be an efficient use of funding, considering the crest level of most of the dike. Ideally, the entire dike would be raised to withstand the end-of-century 50-year flood, to meet agricultural standards.

The main location requiring raising is an approximately 2.5 km-length along the north side of Barnston Island. This location is shown on the dike crest profile in Figure 6, and on the map in Figure 7. To meet the recommended height, the dike must be raised by approximately 0.2 m to 0.5 m.

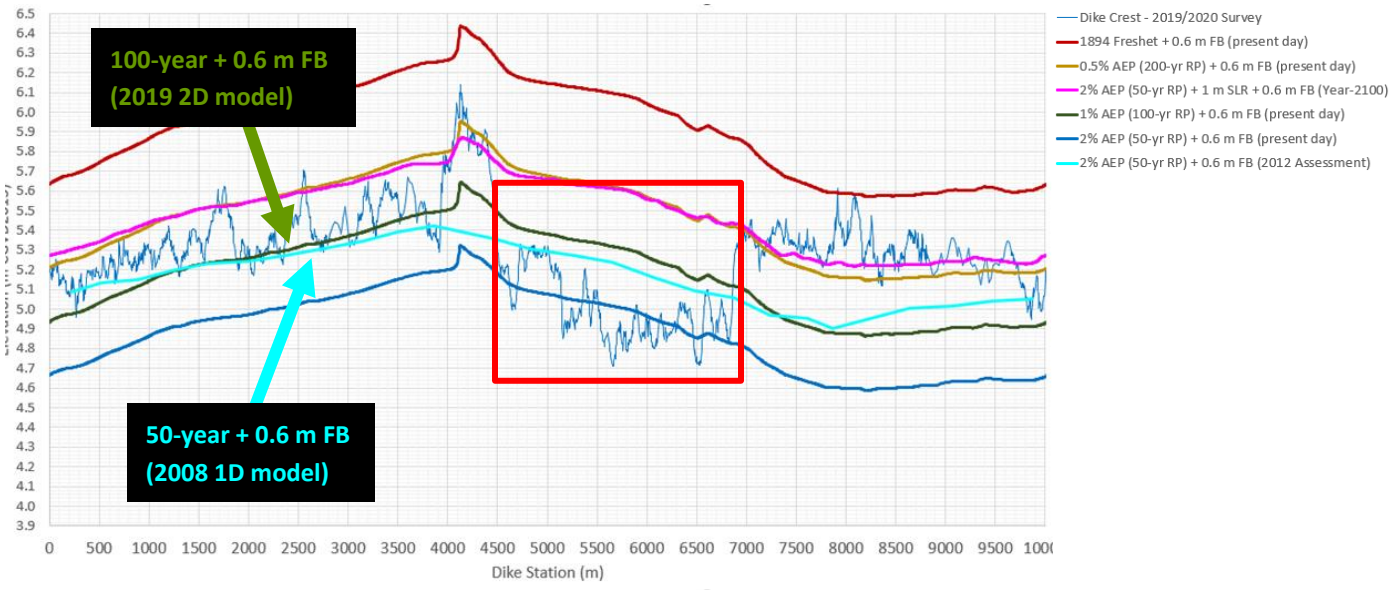

Figure 6 Existing dike crest profile and simulated design flood elevations for various return periods, showing approximate location where dike raise is recommended

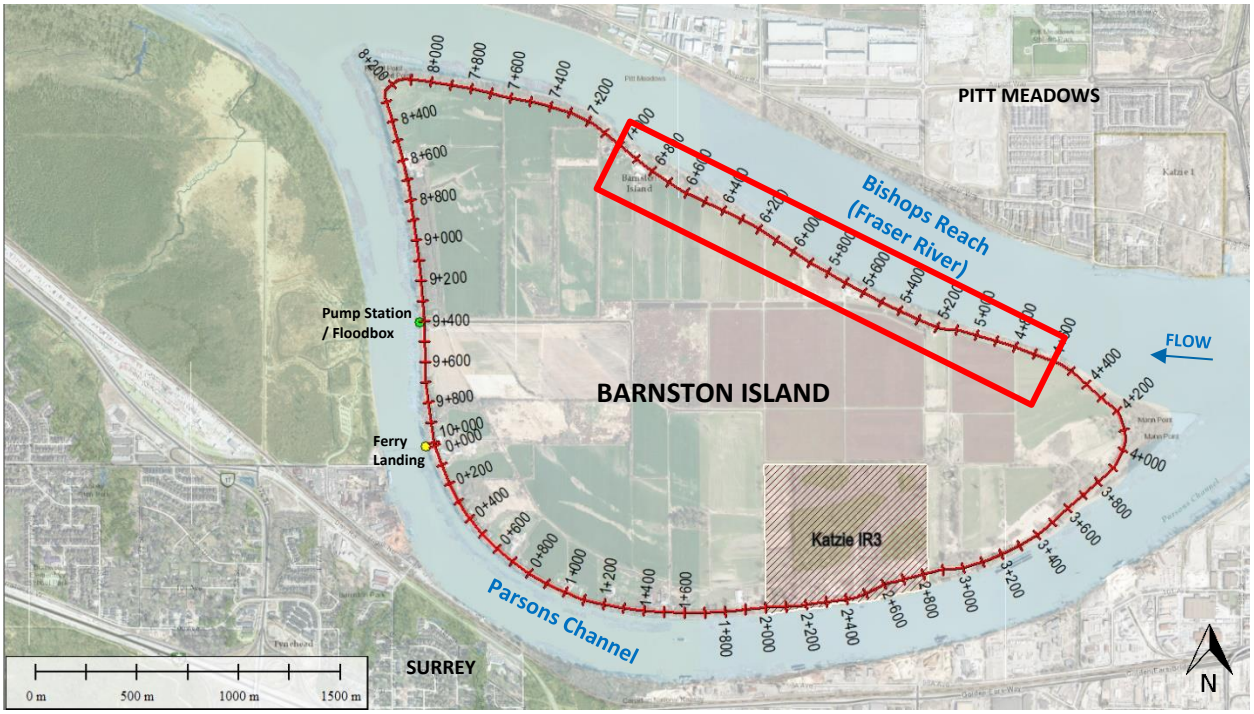

Figure 7 Plan view map of Barnston Island showing approximate location where dike raise is recommended

NHC estimated material quantities and costs for the recommended raise. The assumed upgrade design was based on recommendations in the Barnston Island Dike Assessment Preliminary Geotechnical Assessment Report (Thurber Engineering Ltd., 2013), part of the 2012 Assessment. To mitigate seepage, it was recommended that low-permeability fill be placed on the river side of existing dike fill down to a silt layer, located below existing grade at El. 2.6 m to 3.0 m +/-, based on available drill logs (Figure 8).

Mature trees between the dike and active channel stabilize the banks and arrest bank retreat, and placement of fill on the water side of the current dike will require tree removal, increasing dike erosion hazard. Bank protection will be needed in locations where the upgraded dike is close to the channel, and/or a strip of trees cannot be maintained between the dike and bank.

For the purposes of estimating an approximate cost, it was assumed that riprap would be required in all dike upgrade locations where the current dike centreline is within 50 m of the channel (Figure 5), with self-launching riprap buried in a trench along the water side dike toe (like what was constructed along Parsons Channel from Station 9+420 to 9+955). Such riprap would be intended to protect the dike from upper bank retreat, but not undermining of the bank toe due to bed lowering.

A 15% bulking factor was applied to the dike fill quantity to account for compaction and material losses during transport. It was also assumed that a 7.5 m wide ROW would need to be acquired along the land side toe of the upgraded dike, which is the recommended ROW width in Provincial dike design guidelines (MWLAP, 2003).

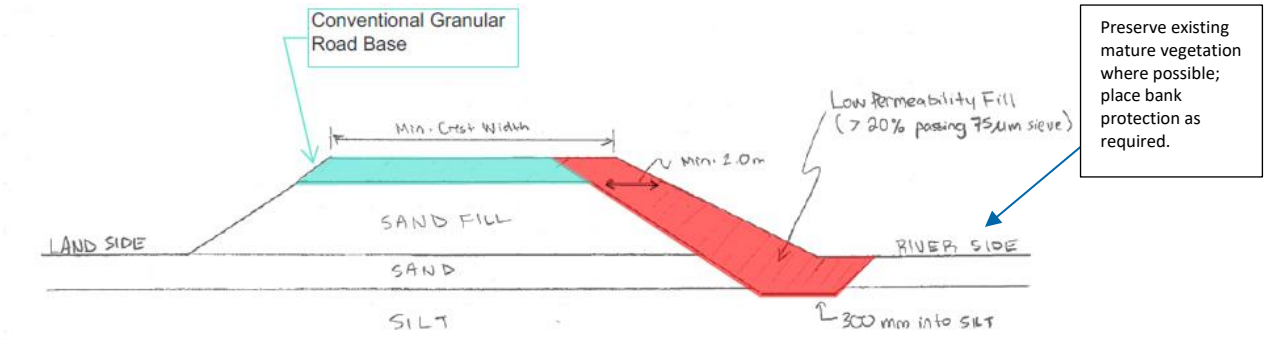

Figure 8 Typical section for conceptual dike raise, adapted from 2012 Assessment Preliminary Geotechnical Assessment Report (Thurber Engineering Ltd., 2013)

Table 2 provides a summary of estimated costs for the recommended dike raise. A 30% cost contingency has been applied. The total factored cost is provided without paving, assuming paving will be funded by MoTI, outside of the grant funding.

Table 2 Conceptual cost estimate for recommended dike raise

Item	Units	Unit Rate	Quantity	Cost
Mobilization/Demobilization (10% of total)				$294,000
Grubbing/stripping - (dike raise footprint on water side, 0.3 m deep)	m^3	$10	7200	$72,000
Low Permeability Dike Fill (suppy, haul and place; includes 15% volume increase for compaction and material loss)	m^3	$85	18000	$1,530,000
Road Base (includes 15% volume increase for compaction and material loss)	m^3	$40	4200	$168,000
Riprap (in trench along water side toe, sized to mitigate upper bank retreat)	m^3	$75	8400	$630,000
Land Acquisition (assume 7.5 m width required along length of upgraded dike)	m^2	$30	18000	$540,000
TOTAL, UNFACTORED				**$3,234,000**
30% Contingency				$970,200
Engineering and Environmental (15% of total)				$485,100
TOTAL, FACTORED (Without Paving)				**$4,689,300**

Note: Unit rates for Barnston Island may exceed assumed typical costs.

Preliminary cost was also estimated for an alternative dike raise concept with fill placed on the land side. Such a design would not meet geotechnical recommendations for seepage mitigation. This estimated cost came to $2.6 M, including 30% contingency and without road paving costs. The reduced estimated

cost relative to the concept in Table 2 is mainly due to reduced fill quantities (no tie-in to buried silt layer), and assumption that riprap would not be needed. Placement of fill on the land side would also increase land acquisition needs, which is subject to a high level of cost uncertainty and feasibility challenges.

Prior to upgrading the dike, erosion hazard should be studied in detail. If there is extensive need for erosion protection, increasing dike setback may be a more feasible option.

5 Conclusions and Recommendations

Based on evaluation of the current flood protection infrastructure and flood/ erosion hazards, the updated 2023 Barnston Island dike assessment resulted in similar findings as the 2012 Assessment. Potential upgrade recommendations were outlined for consideration under the current $5.25 M grant. Careful prioritization will be required as the grant funding will be insufficient for implementing all recommendations. Also, the March 2026 deadline to use this funding must be considered when prioritizing improvements. The current assessment forms a preliminary evaluation that Metro Vancouver can use for stakeholder engagement to initiate discussion of potential upgrades.

The following general recommendations are provided:

1. Following consultation with stakeholders, a preliminary prioritized implementation plan should be developed as soon as possible.
2. If the pump-station/flood-box replacement is to proceed, potential alterations to the internal drainage network must be considered, along with present/future design runoff volumes and river levels. The use of a standard design for the structures is likely to result in some cost savings over a more customized design.
3. To reduce bank erosion, regulation of vessel speeds, installing permanent log booms, removing problem trees and relocating beavers should be explored.
4. To assess bank erosion in more detail, completing a bathymetric survey is recommended to identify potential risks of the toe-of-bank being undermined. This study should occur before dike upgrade design, to evaluate dike erosion hazard under the current dike alignment and to identify erosion protection needs.
5. Road rutting near the northeast end of the dike should be investigated by a geotechnical engineer to evaluate potential dike structural issues, then repaired as required.
6. Any dike upgrades will need to be made on the water side of the dike, per geotechnical recommendations, which will result in disturbing of vegetation outside the dike. Erosion protection or increased dike setback may be required. Property lines and dike ROW requirements should be compared and an up-to-date Dike Operation & Maintenance Manual should be prepared.
7. A detailed ground-based dike survey and seepage assessment should take place prior to the preliminary dike upgrade design. Similarly, preliminary Inspector of Dikes' approvals must be obtained, and geotechnical requirements confirmed.
8. In the event of there being insufficient time or funding for raising the low dike segment, preparing for temporary flood mitigation measures could be considered.

9. Coordination with MoTI, BIDD, KFN, the Province, the Port Authority and other agencies/ stakeholders will be invaluable for prioritizing upgrades and developing cost sharing arrangements.
10. A review of Barnston Island evacuation procedures is recommended.
11. Estimated costs are approximate, and more detailed cost estimates will need to be prepared for final prioritization of mitigation measures.

6 Closure

We trust this report meets your current needs. If you have any questions or further requests, please feel free to contact the undersigned.

Sincerely,

Northwest Hydraulic Consultants Ltd.

Report prepared by:

2024-05-10

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Report reviewed by:

9 May 2024

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Principal

EGBC Permit to Practice Number: 1003221

DISCLAIMER

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Except as required by law, this report and the information and data contained herein are to be treated as confidential and may be used and relied upon only by **Metro Vancouver Regional District**, its officers and employees. **Northwest Hydraulic Consultants Ltd.** denies any liability whatsoever to other parties who may obtain access to this report for any injury, loss or damage suffered by such parties arising from their use of, or reliance upon, this report or any of its contents.

7 References

EGBC (2018). *Professional Practice Guidelines – Legislated Flood Assessments in a Changing Climate in BC*.

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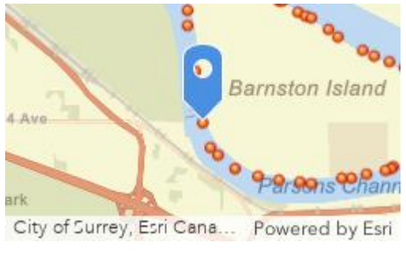
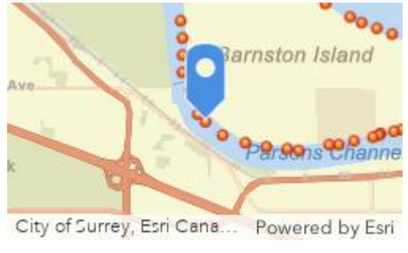
APPENDIX A

BANK INSPECTION OBSERVATIONS BY NHC, MARCH 14, 2024

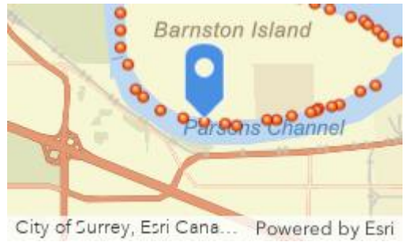
Dike Station	Inspection Location
0+100	
Active Erosion Yes	**Bank Protection** Yes
Notes Lower bank is sandy with grassy vegetation. Toe is over-steepened. Old riprap present above lower bank, protecting what appears to be a fill pad just east of ferry landing. Bank is covered with blackberry bushes and difficult to inspect.	

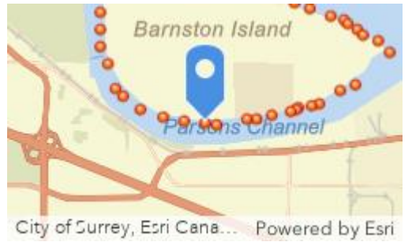
Dike Station	Inspection Location
0+400	
Active Erosion Yes	**Bank Protection** No
Notes Bank is generally steep and showing signs of erosion. Some mature trees are present between bank and dike.	

Dike Station	Inspection Location
0+525	
Active Erosion Yes	**Bank Protection** No
Notes Sandy bank covered with grassy vegetation, localized near-vertical banks. Mature vegetation grows between eroding bank and dike.	

Dike Station	Inspection Location
0+800	
Active Erosion No	**Bank Protection** No
Notes Bank is well-vegetated, no visible erosion	

Dike Station	Inspection Location
1+100	
Active Erosion Yes	**Bank Protection** No
Notes Undercut banks and leaning trees. Some trees along bank in 2012 photos are no longer present.	

Dike Station	Inspection Location
1+375	
Active Erosion Yes	**Bank Protection** No
Notes Trees leaning toward channel. House outside dike is close to channel with steep bank.	

Dike Station	Inspection Location
1+625	
Active Erosion Yes	**Bank Protection** No
Notes Localized erosion, evidenced by undercut trees and grassy vegetation at bottom of bank	

Dike Station	Inspection Location
1+775	
Active Erosion No	**Bank Protection** No
Notes Bank is well-vegetated and does not appear to have widespread erosion	

Dike Station	Inspection Location
2+175	
Active Erosion Yes	**Bank Protection** No
Notes Bank shows some signs of erosion, with some exposed tree roots. There is a sandy terrace at bottom of visible bank.	

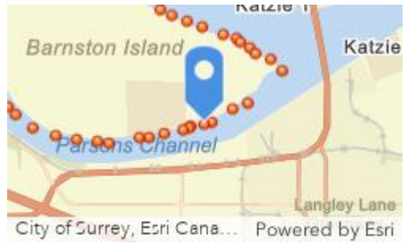
Dike Station	Inspection Location
2+300	
Active Erosion Yes	**Bank Protection** No
Notes Active erosion. Leaning trees.	

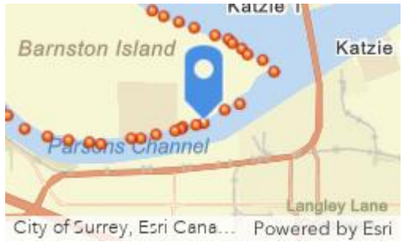
Dike Station	Inspection Location
2+500	
Active Erosion Yes	**Bank Protection** No
Notes Location of active erosion, potentially from foot access to the river.	

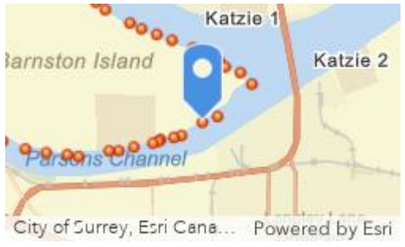
Dike Station	Inspection Location
2+750	
Active Erosion Yes	**Bank Protection** Yes
Notes Larger rock has been placed along bank. Some was either dumped in-channel or has launched. Local bank oversteepening.	

Dike Station	Inspection Location
2+850	
Active Erosion	**Bank Protection**
No	Yes
Notes	
Timber crib wall supports bank near power pole. Crib wall is damaged with overhanging trees.	

Dike Station	Inspection Location
2+875	
Active Erosion Yes	**Bank Protection** No
Notes Active bank erosion. Oversteepening at top of bank. Trees leaning with roots exposed.	

Dike Station	Inspection Location
3+050	
Active Erosion No	**Bank Protection** Yes
Notes Riprap consists of small rock but appears to be in good condition	

Dike Station	Inspection Location
3+125	
Active Erosion Yes	**Bank Protection** Yes
Notes Old riprap in poor condition. Leaning trees suggests active erosion, and bank is oversteepened in some locations. Steep bank at upstream end of riprap	

Dike Station	Inspection Location
3+450	
Active Erosion Yes	**Bank Protection** No
Notes Active erosion. Trees leaning toward channel, roots exposed. Sparse vegetation between bank and dike.	

Dike Station	Inspection Location
3+650	
Active Erosion No	**Bank Protection** No
Notes Side channel observed in 2012. No notable updates.	

Dike Station	Inspection Location
4+075	
Active Erosion No	**Bank Protection** No
Notes Point bar at eastern tip of island. No notable updates; photos taken for documentation.	

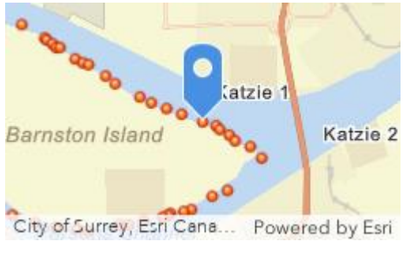
Dike Station	Inspection Location
4+175	
Active Erosion Yes	**Bank Protection** No
Notes Densely vegetated area. Bank is near-vertical with roots exposed. Sandy bar near upstream end of island.	

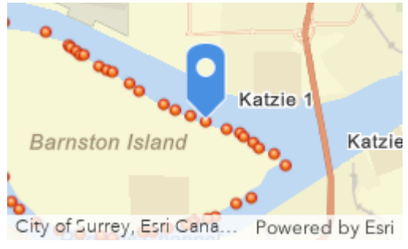
Dike Station	Inspection Location
4+300	
Active Erosion No	**Bank Protection** No
Notes Upper bank is near-vertical, indicating some erosion, but there is vegetation between bank and dike.	

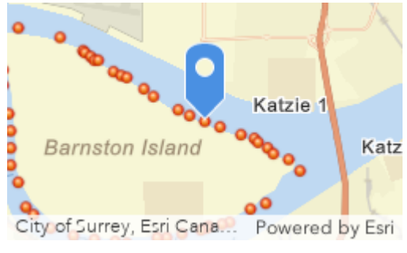
Dike Station	Inspection Location
4+390	
Active Erosion Yes	**Bank Protection** Yes
Notes Upstream end of riprap section. Some erosion near top of bank, potentially due to foot access down bank. This erosion was noted in the 2012 Assessment. There is minimal mature vegetation at top of bank.	

Dike Station	Inspection Location
4+550	
Active Erosion No	**Bank Protection** Yes
Notes Riprap is present, and appears to be in reasonably good condition.	

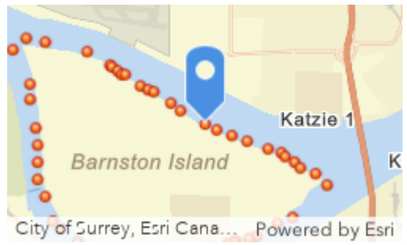
Dike Station	Inspection Location
4+575	
Active Erosion Yes	**Bank Protection** No
Notes Section of eroding bank (150-200 m long) downstream of riprap. A portion of this eroding bank lacks mature vegetation between the bank and dike.	

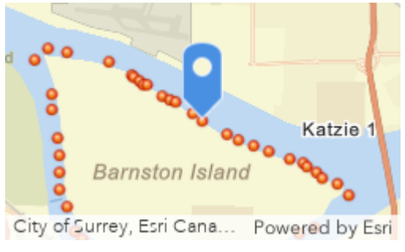
Dike Station	Inspection Location
4+775	
Active Erosion Yes	**Bank Protection** No
Notes Bank is steep and sandy, with roots exposed. Some mature trees and some grassy vegetation at top of bank. Bank drops off steeply below water, according to boat depth sounder	

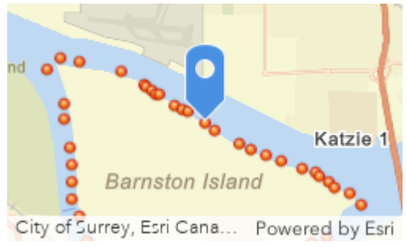
Dike Station	Inspection Location
5+075	
Active Erosion	**Bank Protection**
Yes	No
Notes	
Bank is steep and lacks mature vegetation between the bank and the dike. Sandy terrace is visible at bottom of upper bank.	

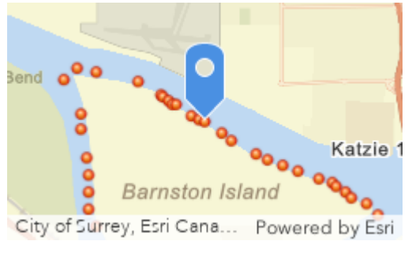
Dike Station	Inspection Location
5+275	
Active Erosion Yes	**Bank Protection** Yes
Notes Riprap is present at this location. Rock sizing is relatively small, and some launching was visible; however, the riprap appears to be mitigating the typical oversteepening seen elsewhere along the reach.	

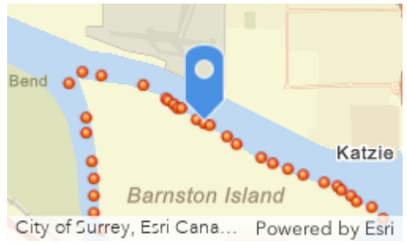
Dike Station	Inspection Location
5+500	
Active Erosion Yes	**Bank Protection** No
Notes Bank retreat has exposed the roots of mature trees. Root structures have created hard points that have resulted in small erosion arcs forming upstream and downstream of mature trees.	

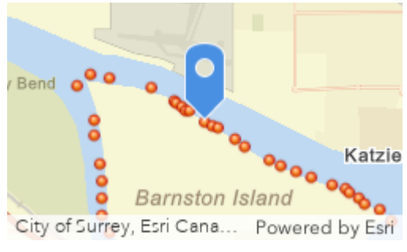
Dike Station	Inspection Location
5+675	
Active Erosion Yes	**Bank Protection** Yes
Notes Riprap is present near an intake structure. Bank is actively eroding upstream and downstream of the limits of the riprap.	

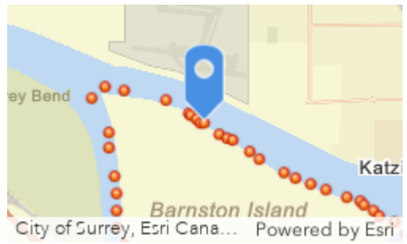
Dike Station	Inspection Location
6+025	
Active Erosion Yes	**Bank Protection** No
Notes Typical undercut banks. Small erosion arcs are present downstream of some exposed mature tree root structures.	

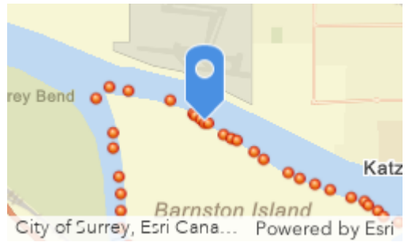
Dike Station	Inspection Location
6+200	
Active Erosion Yes	**Bank Protection** No
Notes Bank is near-vertical with leaning trees and roots exposed.	

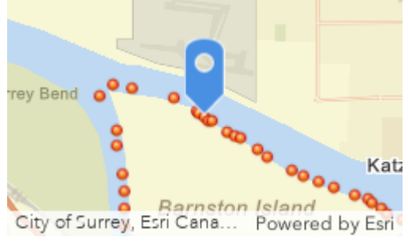
Dike Station	Inspection Location
6+450	
Active Erosion Yes	**Bank Protection** No
Notes Bank is actively eroding. Near-vertical bank slope, with loss of support to mature trees at top of bank. Some root structures have flow passing inland of them, resulting in increased scour along the bank behind these trees.	

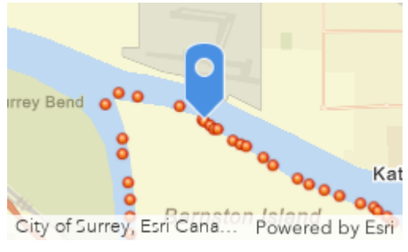
Dike Station	Inspection Location
6+550	
Active Erosion Yes	**Bank Protection** Yes
Notes Localized riprap (10 m long section), which appears to be launching. This riprap has created a hard point along the bank that has resulted in a small erosion arc downstream of it.	

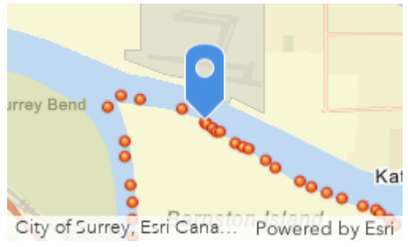
Dike Station	Inspection Location
6+675	
Active Erosion Yes	**Bank Protection** No
Notes Upstream end of riprap section. Bank is actively eroding, overly steep and unsupported. Bankline is retreating upstream of riprap.	

Dike Station	Inspection Location
6+900	
Active Erosion Yes	**Bank Protection** Yes
Notes Riprap has been placed on the upper bank following localized bank retreat. This location is directly adjacent to a developed property, with no mature trees along top of bank. The bank is generally steep and undercut in the vicinity of this riprap.	

Dike Station	Inspection Location
6+975	
Active Erosion Yes	**Bank Protection** Yes
Notes Riprap is present, except along a 5 m long section. At this location without riprap, the bank has retreated relative to the armoured banks. There is sparse mature vegetation at top of bank.	

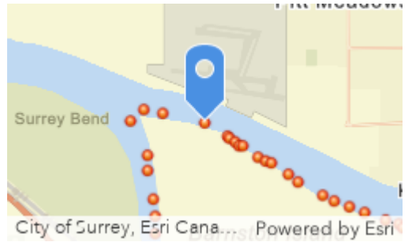
Dike Station	Inspection Location
7+025	
Active Erosion Yes	**Bank Protection** Yes
Notes Some riprap is present, but is launching, which has resulted in inconsistent bank coverage. The bank is actively eroding at locations where the riprap is absent. There is little vegetation between the bank and the dike here.	

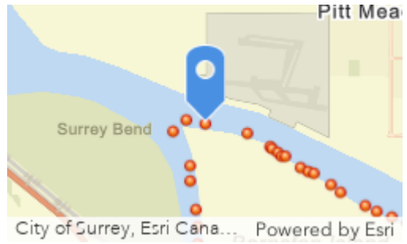
Dike Station	Inspection Location
7+125	
Active Erosion Yes	**Bank Protection** Yes
Notes Riprap is present but has launched in some locations, leaving sections of the bank unprotected. The bank is oversteepened at these locations. There is minimal vegetation between the bank and the dike.	

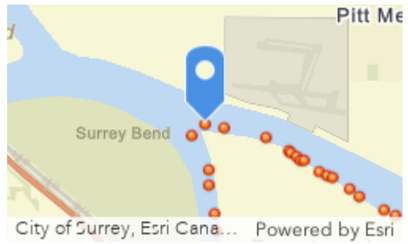
Dike Station	Inspection Location
7+150	
Active Erosion	**Bank Protection**
Yes	No

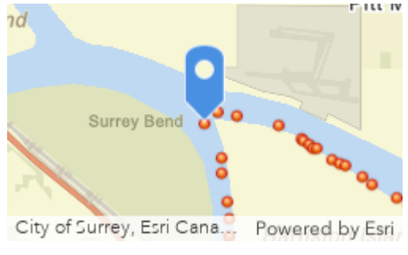
Notes

Location of downstream end of riprap section. There is active erosion downstream of where the riprap ends, with undercut banks and exposed tree roots.

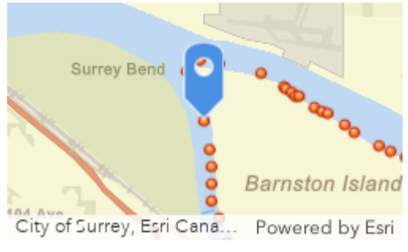
Dike Station	Inspection Location
7+475	
Active Erosion No	**Bank Protection** No
Notes Sandy beach at bottom of upper bank. Widespread erosion not observed here. Dense mature vegetation is present at top of bank.	

Dike Station	Inspection Location
8+025	
Active Erosion No	**Bank Protection** No
Notes A sandy terrace is visible at bottom of bank. Mature trees are present at top of bank. Erosion does not appear to be progressing here.	

Dike Station	Inspection Location
8+175	
Active Erosion No	**Bank Protection** No
Notes Sandy terrace present at bottom of upper bank. Upper bank is steep with mature trees that have some roots exposed, but trees are not leaning toward the channel. Bank line appears more stable than farther upstream along Bishops Reach.	

Dike Station	Inspection Location
8+250	
Active Erosion No	**Bank Protection** No
Notes West end of Barnston Island. No evidence of erosion. Thick mature vegetation is present at top of bank.	

Dike Station	Inspection Location
8+625	
Active Erosion Yes	**Bank Protection** No
Notes Mature trees have roots exposed by erosion, but are not leaning into channel	

Dike Station	Inspection Location
8+850	
Active Erosion No	**Bank Protection** Yes
Notes Localized minor bank erosion, evidenced by leaning trees and exposed roots	

Dike Station	Inspection Location
9+200	
Active Erosion No	**Bank Protection** No
Notes Minor localized erosion, but bank is well vegetated	

Dike Station	Inspection Location
9+450	
Active Erosion Yes	**Bank Protection** Yes
Notes Location of pump station. There is localized riprap upstream of pump station. Bank upstream of pump station is steep and not well vegetated. Dike is close to bank.	

Dike Station	Inspection Location
9+675	
Active Erosion Yes	**Bank Protection** No

Notes

Bank is quite close to dike, with minimal mature vegetation providing protection against erosion. Exposed tree roots indicate active erosion. This is the location of self-launching riprap that is buried in a trench on land. It was observed during the October 2023 inspection by car that the riprap was exposed/imminently launching in some locations, indicating bank retreat since 2012.

Dike Station	Inspection Location
9+875	
Active Erosion No	**Bank Protection** Yes
Notes Riprap placed along bank in front of house. Structures are located close to top of bank. Bank does not appear to be actively eroding.