JUNE 2017

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CFAS

Mud Bay Infrastructure Flood Vulnerability Assessment PIEVC Workshop: Summary and Outcomes

REPORT

Professional Engineers and Geoscientists of BC

Delta

epi

nhc
northwest hydraulic consultants

BRITISH COLUMBIA
Ministry of Transportation and Infrastructure

engineerscanada
ingénieurscanada

ASSOCIATED ENGINEERING
QUALITY MANAGEMENT SIGN-OFF
Signature
Date 15/6/2017
#04-17-037

DISCLAIMER

The workshop and this report shall not be construed as any acceptance or assumption of risk, responsibility, or liability by or on behalf of the City of Surrey for ongoing safe construction, operation, use, and maintenance of infrastructure in the floodplain. The full and complete responsibility and liability to ensure the ongoing safe construction, operation, use, and maintenance of infrastructure has been and continues to remain with the infrastructure owners.

Executive Summary

The City of Surrey is in the process of developing a comprehensive strategy to address coastal flooding risks in the Mud Bay area. The area has the potential to be affected by coastal flooding (king tides and storm surge), as well as riverine flooding from the Serpentine and Nicomekl Rivers. The risk of flooding by either mechanism is anticipated to greatly increase with climate change and sea level rise.

In support of Phase 1 of the **Coastal Flood Adaptation Strategy (CFAS)** process, the City engaged Associated Engineering (AE) to plan and deliver a workshop targeted at infrastructure owners and emergency service providers. This workshop was held on March 28, 2017, and was attended by 66 participants representing 28 organizations.

The workshop used the **Engineers Canada Public Infrastructure Engineering Vulnerability Committee (PIEVC) High Level Screening Tool** to assess the infrastructure in the Mud bay study area. The use of the procedure allows for a systematic process of assessing flood vulnerability of the various infrastructure types affected by flooding in the lowlands. The procedure was selected to capture the various infrastructure owners' wealth of information, including system knowledge and risk management expertise.

Workshop Attendee Organizations	
Associated Engineering	FortisBC
BC Ambulance Service	Metro Vancouver
BC Rail Consultant	Ministry of Agriculture
BNSF	Ministry of Community, Sport and Cultural Development
Canadian Coast Guard	Ministry of Environment
CFAS Consulting Team	Ministry of Transportation and Infrastructure
City of Surrey	Mud Bay Dyking District
City of Vancouver	Northwest Hydraulic Consultants
Corporation of Delta	Royal Canadian Mounted Police
Cowichan Valley Regional District	SNC Lavalin
Ducks Unlimited Canada	Southern Railway of BC
Emergency Management BC	Surrey Operations
Engineers Canada	Telus / Shaw

The workshop focused on identifying vulnerabilities to, and interactions between, transportation infrastructure (rail, roads, trails, and runways), utilities (power, gas, sanitary sewers and lift stations), and flood control / marine infrastructure (marinas, private docks, drainage pump stations, sea dams, and dykes) and assessing the consequences of the impacts from flooding.

Flood / Marine	TRANSPORTATION	TRANSPORTATION	UTILITIES
Flood Control Infrastructure	**Local Government Arterial and Collector Roads**	**Regional / International Transportation Infrastructure**	**Sanitary Lift Stations**
City of Surrey Sea Dams (2)	King George Boulevard	4 km of four-lane arterial roadway	City of Surrey: Elgin
15 km of dyking, including ditches and floodboxes	152nd Street	7 km section of Highway 99 linking Peace Arch Border	City of Surrey: South Port
Colebrook Pump Station	Colebrook Road	Highway 91 and 99 Interchange	City of Surrey: Winter Crescent
Maple Pump Station	Corporation of Delta: Ladner Trunk Road	4 km section of Highway 91	City of Surrey: Stewart Farm
Corporation of Delta: Oliver Pump Station	112 Street	6 km dyke trail connecting to parks	Metro Vancouver: Crescent Beach
Ducks Unlimited Canada Serpentine Fen Nature Reserve	**Class 1 Railways**	Delta-Surrey Greenway	**Underground infrastructure**
Water control and irrigation	Class 1 Railways Originating at Port Metro Vancouver (general)	**Runway**	5 km of Metro Vancouver 750 mm diameter Water Transmission Main
Screw pump stations (added)	BNSF Swing Bridge and Trestles	Surrey/King George Airpark Turf Runway	10 km of Metro Vancouver Sanitary Sewer Forcemains (500 mm to 1050 mm diameter)
Marine Facilities	6 km of BNSF Railway		>10 km of FortisBC Gas Mains
Crescent Beach Marina	Roberts Bank Railway Corridor (BC Railway Co. ownership with usage by CN, CP and BNSF)		**Overhead Utility Infrastructure**
Wards Marina			BC Hydro Twin 500kV bulk transmission line providing Intertie between BC Hydro and Bonneville Power
Private docks	Connection to Southern Railway of British Columbia		BC Hydro local overhead distribution lines
Farms			Shaw and Telus telecom lines
Private dairy facilities for more than 1,000 head of Cattle			Green Infrastructure

The flooding scenarios used in the risk assessment are based on the outcome of several floodplain studies developed in the CFAS project. The workshop focused on the following two scenarios:

- **Scenario A:** Coastal dyke breach causing progressive inundation of the coastal floodplain by the ocean.
- **Scenario B:** 200-year return period riverine flooding, with releases to Mud Bay via the sea dams restricted by tidal cycles.

Both scenarios were assessed under both **present-day and year 2100 time horizons**. Climate change is affecting both the intensity and frequency of storms and flood events, causing today's extreme floods to become more frequent in the future. Sea level rise will restrict the amount of time the sea dams and floodboxes can drain. The land in Mud Bay is also subsiding, which will exacerbate the effects of sea level rise.

Risk Assessment Summary

Using the PIEVC process, risk scores were developed for each interaction between infrastructure component and flood scenario. To determine the risk score (R) for each interaction, a probability score (P) was established for each flood scenario and the participants selected a consequence score (C) for each interaction between flood scenarios and infrastructure.

The resulting risk **R = P x C,** is the product of the probability score (P) and the consequence score (C).

- R = >10 — Low Risk — Risk requiring minimal action
- R = 10 – 19 — Medium Risk — Risks that may require future action
- R = 20 – 25 — High Risk — Risks that require action

Flood Scenario A – Coastal Flood with Dyke Breach

- 40 assets assessed per scenario
- Current risks are mostly low and medium
- Future risks increase to medium and high

	Number of Assets in Each Category							
	Flood Scenario A Current				Flood Scenario A Future			
	Transportation	Utilities	Flood Control / Marine	Total: Scenario A Current	Transportation	Utilities	Flood Control / Marine	Total: Scenario A Future
Low Risk	9	3	5	**17**	3	0	0	**3**
Medium Risk	7	9	5	**21**	2	7	6	**15**
High Risk	0	0	2	**2**	11	5	6	**22**

Flood Scenario B – Riverine Flood

- 40 assets assessed per scenario
- All assets are currently at low risk
- The number of assets subject to medium risk increases to 23 (>50% of the number of assets assessed), while 7 assets (~20%) are at high risk.

	Number of Assets in Each Category							
	Flood Scenario B Current				Flood Scenario B Future			
	Transportation	Utilities	Flood Control / Marine	Total: Scenario B Current	Transportation	Utilities	Flood Control / Marine	Total: Scenario B Future
Low Risk	16	12	12	**40**	5	3	2	**10**
Medium Risk	0	0	0	**0**	9	6	8	**23**
High Risk	0	0	0	**0**	2	3	2	**7**

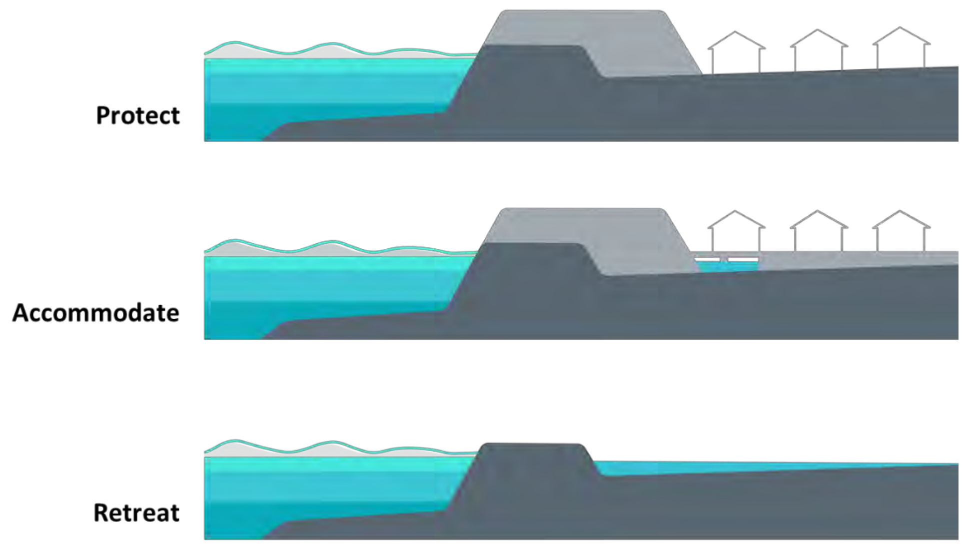
A **summary of flood risk** for the infrastructure is listed below.

Infrastructure		Flood Scenario A Current	Flood Scenario A Future	Flood Scenario B Current	Flood Scenario B Future
Transportation	**Runway**				
	Surrey/King George Airpark Turn Runway	4	5	3	5
	Regional / International Transportation Infrastructure				
	4 km of four-lane arterial roadway	12	25	3	10
	7 km section of Highway 99 linking Peace Arch Border	16	25	3	10
	Highway 91 and 99 Interchange	12	20	3	10
	4 km section of Highway 91	8	20	3	10
	6 km dyke trail connecting to parks	4	5	3	10
	Delta-Surrey Greenway	4	5	3	10
	Local Government Arterial and Collector Roads				
	King George Boulevard (City of Surrey)	12	25	3	10
	152nd Street (City of Surrey)	4	20	3	5
	112 Street (City of Surrey)	8	15	6	15
	Colebrook Road (City of Surrey)	8	15	6	15
	Ladner Trunk Road (Corporation of Delta)	12	20	9	20
	Class 1 Railways Originating at Port Metro Vancouver				
	Burlington Northern Santa Fe (BNSF) Nicomekl Swing Bridge and Trestles	16	20		
	6 km of BNSF Railway (Freight frequencies ~ 20 trains daily and up to 4 daily Amtrak Cascades trains)	16	25		
	Roberts Bank Railway Corridor (BC Railway Co. ownership with usage by CN, CP and BNSF) ~ 18 trains daily	8	20		
	Connection to Southern Railway of British Columbia	4	20	9	20

Infrastructure		Flood Scenario			
		A Current	A Future	B Current	B Future
Utilities	**Sanitary Lift Stations**				
	City of Surrey: Elgin	12	15		
	City of Surrey: South Port	16	20		
	City of Surrey: Winter Crescent	12	15		
	City of Surrey: Stewart Farm	16	20	6	20
	Metro Vancouver: Crescent Beach	16	20		
	Underground Infrastructure				
	5 km of Metro Vancouver 750 mm diameter Water Transmission Main	16	20	6	10
	10 km of Metro Vancouver Sanitary Sewer Forcemains (500 mm to 1050 mm diameter)	12	15	6	10
	>10 km of FortisBC Gas Mains	8	10	9	15
	Overhead Utility Infrastructure				
	BC Hydro Twin 500kV bulk transmission line providing Intertie between BC Hydro and Bonneville Power	12	15		20
	BC Hydro local overhead distribution lines	16	20		20
	Shaw and Telus telecom lines	8	10	6	10
	Green Infrastructure (Added)	8	15		15

Infrastructure		Flood Scenario			
		A Current	A Future	B Current	B Future
Flood Control / Marine	City of Surrey Sea Dams (2)	20	20	6	25
	15 km of dyking, including ditches and floodboxes	20	25	9	20
	City of Surrey: Colebrook Pump Station	16	20	6	15
	City of Surrey: Maple Pump Station	16	20	3	15
	Corporation of Delta: Oliver Pump Station	16	25	6	15
	Ducks Unlimited Canada Serpentine Fen Nature Reserve	8	10	3	5
	Water control features to maintain environmentally sensitive area including freshwater irrigation system	12	15		
	Screw Pump Stations (Added)	4	10	3	10
	Marine Facilities				
	Crescent Beach Marina	8	15	6	10
	Wards Marina	8	15	6	10
	Private docks	8	15	9	10
	Farms				
	Private dairy facilities for over 1,000 head of Cattle	16	25	3	10

Following the risk assessment, **adaptation scenarios and strategies** were discussed with an emphasis on high risk interactions on the Mud Bay infrastructure. Three adaptions approaches were discussed; Protect, Accommodate, and Retreat.



Results from the discussions and a follow-up survey were documented and will be used to inform the next phases of the CFAS project.

Representative **adaptation stakeholder comments** include:

- *Accommodate and do incremental upgrades.*
- *Rock groin / breakwater (offshore 7 km long extending from beyond Crescent Beach to Highway 91) complete with tide gate (Stage construction with barrier raised over time, add gate later, upgrade dyke and pump station as required). Create better habitat internally.*
- *Retreat was not looked upon favorably since it will significantly impact transportation corridors. However, partial retreat was not explored (and it should be).*
- *Without offshore improvements, dyke upgrades will be challenging and will take a long time.*
- *Retreat for highways not considered feasible.*
- *Incremental adaptations are needed to meet changing needs of climate change.*
- *If we retreat, how will be transportation corridors be maintained? Could a long bridge be an option spanning the retreated area? Would the public be okay with intermittent road closures during high tide?*
- *Build a sea wall across Mud Bay.*
- *Dyking is a good option. Offshore islands are a no-go for Crescent Beach.*
- *Benefits of offshore islands on reducing flood vulnerability to infrastructure in Mud Bay.*
- *Raise the dykes - build a barrier wall.*

- *BC Hydro may implement protect or accommodate adaptation features for its infrastructure.*
- *No single approach but rather a combination of different options will need to be employed with input and support of all stakeholders in the Lower Mainland.*
- *What would be a global approach to adopt options to develop strategies against coastal flood risks?*
- *Sea level rise and subsidence are long term processes that will continue indefinitely. Protect options buy time, rather than permanent protection. You might consider how long protect options would be effective for.*
- *Look at options and evaluate problems they solve instead of vice versa.*
- *Incremental adaptations.*
- *Engage the whole Lower Mainland area.*
- *Yes, engagement with neighbouring municipalities should be needed for this type of workshop.*
- *Focus on people, infrastructure, ALR lands over Mud Bay environmental impacts (i.e. if a sea wall was constructed).*

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1 Introduction

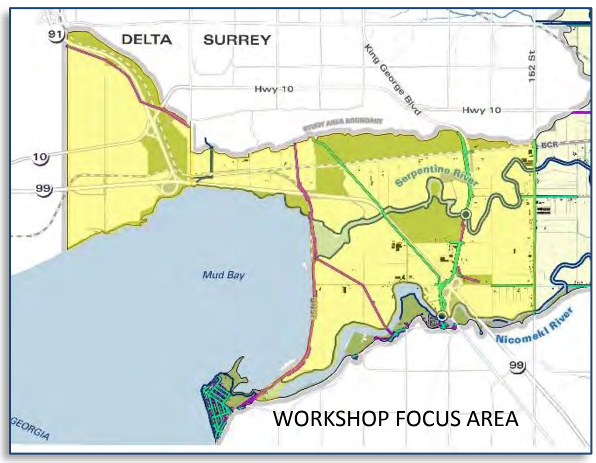
1.1 COASTAL FLOOD ADAPTATION STRATEGY

The City of Surrey is in the process of developing a comprehensive strategy to address coastal flooding risks in the Mud Bay area. The area has the potential to be affected by coastal flooding (king tides and storm surge), as well as riverine flooding from the Serpentine and Nicomekl Rivers. The risk of flooding by either mechanism is anticipated to greatly increase with climate change and sea level rise.

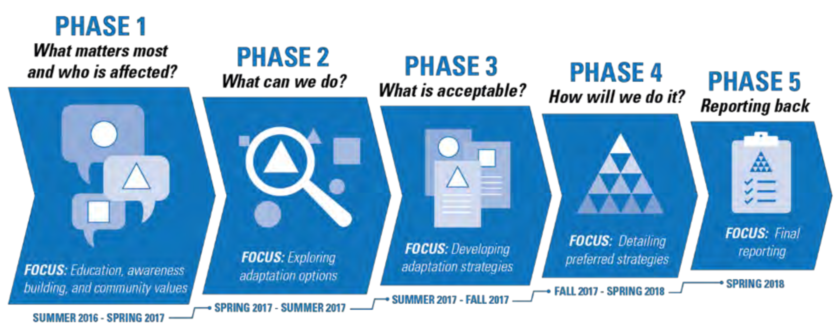
The City's prime consultant responsible for the overall Coastal Flood Adaptation Strategy (CFAS) is Northwest Hydraulic Consultants (NHC) with EcoPlan International, Diamond Head Consulting, and KM Consulting as subconsultants.

The current phase (Phase 1) focuses on education and increasing awareness of the flood hazards faced, and gathering input on the values and needs of various stakeholder groups, including:

- Farmers and the agricultural community;
- Residents, businesses, and community groups;
- Environmental and recreational groups;
- Semiahmoo First Nation; and
- Infrastructure operators, owners, and emergency service providers.

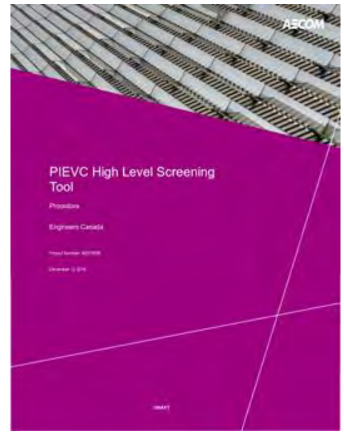


In support of Phase 1 of the CFAS, the City engaged Associated Engineering (AE) to plan and deliver a workshop targeted at the infrastructure owners and emergency service providers. This workshop was held on March 28, 2017, and was attended by 66 participants representing 28 organizations.



This report summarizes the process and outcomes of the workshop. The information collected during the workshop will be used to help inform flood mitigation approaches in later phases of the CFAS.

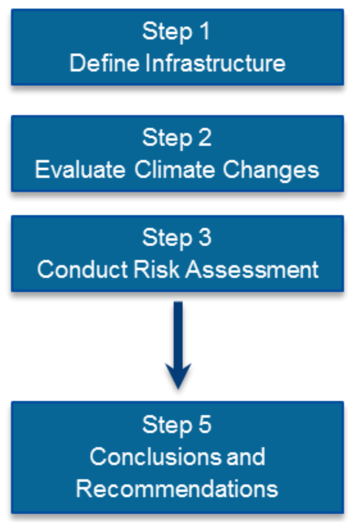
1.2 INFRASTRUCTURE FLOOD VULNERABILITY ASSESSMENT



The infrastructure vulnerability workshop was formulated around the Engineers Canada Public Infrastructure Engineering Vulnerability Committee (PIEVC) High Level Screening Tool. The use of this procedure allows for a systematic process for assessing flood vulnerability of the various infrastructure types affected by flooding in the lowlands. The procedure was selected to capture the various infrastructure owners' wealth of information, including system knowledge and risk management expertise. Engineers Canada licensed the PIEVC Tool to the City of Surrey for use on this project.

1.1.1 PIEVC High Level Screening Assessment

The High Level Screening Assessment is based upon four main steps:



In **Step 1**, the infrastructure under evaluation, and the hazards which it can face are scoped. In the case of the Mud Bay Assessment, this is the transportation, utility, flood control and marine infrastructure in the study area.

In **Step 2**, the assessment team determines the probability of future climate change events interacting with their infrastructure. In the Mud Bay Assessment, the two main flood scenarios were explored: Flood Scenario A: Coastal Flood with Dyke Breach; and Flood Scenario B: Riverine Flood.

In **Step 3**, the assessment team evaluates the consequences of the interaction between future climate changes and infrastructure. In the Mud Bay Assessment, this assessment was conducted in a one day workshop with infrastructure stakeholders in the Mud Bay area. The workshop focused on a subset of the overall CFAS project area extending from Mud Bay east to 152 Street.

In **Step 5**, the assessment team provides a portrait of the climate change risks for their infrastructure, and proposes recommended actions and areas of further study. In the case of the Mud Bay assessment, conclusion and recommendations were not developed, but rather, outcomes including **adaptation comments and strategies** were captured for further evaluation in the CFAS Project.

1.1.2 PIEVC Workshop

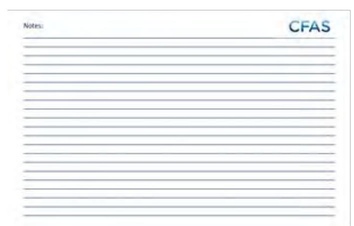
The workshop was held at Surrey City Hall on March 28, 2017. A total of 66 people representing 28 organizations participated in the workshop. The organizations in attendance were:

- Associated Engineering
- BC Ambulance Service
- BC Hydro
- BC Rail Consultant
- Burlington Northern Santa Fe Railway
- Canadian Coast Guard
- City of Surrey (Various Departments)
- City of Surrey Operations
- City of Surrey Fire
- City of Surrey RCMP
- City of Vancouver
- Corporation of Delta
- Cowichan Valley Regional District
- Ducks Unlimited Canada
- Emergency Management BC
- Engineers Canada
- FortisBC
- Metro Vancouver
- Ministry of Agriculture
- Ministry of Community, Sport and Cultural Development
- Ministry of Environment
- Ministry of Transportation and Infrastructure
- Mud Bay Dyking District
- Northwest Hydraulic Consultants
- Port of Vancouver
- SNC Lavalin
- Southern Railway of BC
- Telus

The workshop focused on identifying vulnerabilities to, and interactions between, transportation infrastructure (rail, roads, trails, and runways), utilities (power, gas, sanitary sewers and lift stations), and flood control / marine infrastructure (marinas, private docks, drainage pump stations, sea dams, and dykes) and assessing consequences of the impacts from flooding.

The day began with roundtable introductions and opening remarks on the CFAS Project and on the Engineers Canada PIEVC risk assessment process. A "History of Flooding" was then presented that outlined past flood impacts in the region and the flood infrastructure that was constructed in the Mud Bay area.

The next series of presentations provided background information on the Flood Scenarios (A and B) and an orientation on the PIEVC risk assessment process. Following this orientation, a series of group exercises were conducted.



These group exercises included facilitated discussions on **flood impacts** to each infrastructure component for each flood scenario and **risk analysis** to assess and quantify the consequence of each flood scenario to these infrastructure components. For the group exercises, workshop participants were provided a workshop workbook to write down comments and rationale. At the completion of each exercise, a group discussion took place to share comments from each individual table to all the workshop participants.

Following the risk assessment exercises, an “Adaptation Background” presentation was completed outlining the adaptation framework the CFAS project was exploring.

This was followed by a facilitated group exercise which asked participants to discuss and document **adaptation options** (protect, accommodate, retreat) for higher risk infrastructure identified in the previous exercises. At the completion of the exercise, a group discussion took place to share comments from each individual table with all the workshop participants.

The day concluded with a question and answer session and a brief presentation on the outcomes of the workshop and next steps of the CFAS project.

2 Step 1 - Infrastructure Definition

2.1 INFRASTRUCTURE DEFINITION

Step 1
Define Infrastructure

In advance of the workshop, potentially vulnerable infrastructure within the study area was identified, and was divided into three categories to assist in the assessment: 1) Transportation Infrastructure; 2) Utilities; and 3) Flood Control / Marine Infrastructure.

Tables were organized for each infrastructure category and workshop participants were assigned to one of the three categories to focus on for the day. Participants from emergency services organizations (City of Surrey Fire, RCMP, and BC Ambulance Service) were divided amongst the tables to provide their perspectives.

2.2 INFRASTRUCTURE IDENTIFICATION

The workshop study area encompasses the region from Mud Bay east to 152 Street. The infrastructure identified within the workshop study area is as follows:

Reference Figure 2-1, Transportation Infrastructure, Figure 2-2, Utilities Infrastructure, 2-3, Flood Control / Marine Infrastructure.

- **Transportation Infrastructure**
  - Runway
    - Surrey / King George Airpark Turf Runway
  - Regional / International Transportation Infrastructure
    - 4 km of four-lane arterial roadway
    - 7 km section of Highway 99 linking Peace Arch Border
    - Highway 91 and 99 interchange
    - 4 km section of Highway 91
    - 6 km dyke trail connecting to parks
    - Delta-Surrey Greenway
  - Local Government Arterial and Collector Roads
    - King George Boulevard (City of Surrey)
    - 152 Street (City of Surrey)
    - Colebrook Road (City of Surrey)
    - Ladner Trunk Road (Corporation of Delta)
  - Class 1 Railways Originating at Port Metro Vancouver
    - Burlington Northern Santa Fe (BNSF) Nicomekl swing bridge and trestles
    - 6 km of BNSF Railway (freight frequencies ~20 trains daily and up to 4 daily Amtrak Cascades trains)
    - Roberts Bank Railway Corridor (BC Railway Co. ownership with usage by CN, CP, and BNSF, ~18 trains daily)

        - Connection to Southern Railway of British Columbia
- **Utilities**
    - Sanitary Lift Stations
        - Elgin (City of Surrey)
        - South Port (City of Surrey)
        - Winter Crescent (City of Surrey)
        - Stewart Farm (City of Surrey)
        - Crescent Beach (Metro Vancouver)
    - Underground Infrastructure
        - 5 km of Metro Vancouver 750 mm diameter water transmission main
        - 10 km of Metro Vancouver sanitary sewer forcemains (500 mm to 1050 mm diameter)
        - >10 km of FortisBC gas mains
    - Overhead Utility Infrastructure
        - BC Hydro Twin 500kV bulk transmission line providing intertie between BC Hydro and Bonneville Power
        - BC Hydro local overhead distribution lines
        - Shaw and Telus telecommunications lines
- **Flood Control / Marine Infrastructure**
    - Flood Control Infrastructure
        - Serpentine sea dam (City of Surrey)
        - Nicomekl sea dam (City of Surrey)
        - 15 km of dyking, including ditches and floodboxes
        - Colebrook Pump Station (City of Surrey)
        - Maple Pump Station (City of Surrey)
        - Oliver Pump Station (City of Surrey)
        - Ducks Unlimited Canada Serpentine Fen Nature Reserve
        - Water Control Features to maintain environmentally sensitive area, including freshwater irrigation system
    - Marine Facilities
        - Crescent Beach Marina
        - Wards Marina
        - Private docks
    - Farms
        - Private dairy facilities for over 1,000 head of cattle

In advance of the workshop, the **CFAS Primer, Backgrounder and Workshop Questionnaire** were sent to the invitees and twelve responses were received. Copies of these documents are included in Appendix A. Key responses from the questionnaires are summarized as follows:

- Metro Vancouver identified one pump station, a dozen valve chambers, and approximately ten kilometres of sewer main within the study area and noted that they have had minimal impacts from flooding to date, other than reduced access.

- The Ministry of Transportation and Infrastructure identified the following structures, but did not identify any known history of overtopping or damage to those structures due to flooding:
  - Peacock Brook culvert on Highway 99
  - Serpentine bridge on Highway 99
  - Nicomekl bridge on Highway 99
  - Bigslough culvert on Highway 99
  - Unknown culvert on Highway 99 west of Mud Bay overpass.
- Fortis identified the presence of high pressure and distribution pressure underground gas lines in the area, and noted that no significant impacts due to flooding have been experienced to date.
- Ducks Unlimited confirmed the presence of water control features at the Serpentine Fen to maintain the environmentally sensitive area.
- BNSF identified that storm surges have impacted the railway from White Rock to Mud Bay, and that they are continuously monitoring and fortifying their infrastructure through the area.

During the workshop, one additional infrastructure type ('green infrastructure') was identified and included in the assessment. Green infrastructure was generally defined as vegetation, and the rationale is that tree and vegetation mortality associated with flooding can be problematic and should be considered.

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Job Number 3001880
Date 24-MAR-2017
DRAFT
COASTAL FLOOD ADAPTATION STRATEGY
TRANSPORTATION INFRASTRUCTURE
PIEVC Workshop Extents
Municipal Boundary
First Nations Reserve Boundary
Infrastructure
Airpark
Railway
Provincial Highway
Arterial Road
Local Road Network
Greenway / Trail
Table 1
Transportation
Surrey/King George Airpark Turf Runway
Regional / International Transportation Infrastructure
• 4 km of four-lane arterial roadway
• 7 km section of Highway 99 linking Peace Arch Border
• Hwy 91 and 99 Interchange
• 4 km section of Highway 91
• 6 km dyke trail connecting to parks
• Delta-Surrey Greenway
Local Government Arterial and Collector Roads
• King George Boulevard (City of Surrey)
• 152nd Street (City of Surrey)
• Colebrook Road (City of Surrey)
• Ladner Trunk Road (Corporation of Delta)
Class 1 Railways Originating at Port Metro Vancouver
• Burlington Northern Santa Fe (BNSF) Nicomekl Swing Bridge and Trestles
• 6 km of BNSF Railway with freight frequencies between 16 and 20 trains daily and up to 4 daily Amtrak Cascades trains
• Roberts Bank Railway Corridor (BC Railway Company ownership with usage by CN, CP and BNSF) with up to 18 trains daily.
• Connection to Southern Railway of British Columbia.
DELTA
SURREY
Hwy 91
Hwy 10 (58 Ave)
King George Blvd
KING GEORGE AIRPARK
BNSF Rwy
Ladner Trunk Rd
Colebrook Rd
BC Rail
BC Rail
Hwy 99
152 St
King George Blvd
MUD BAY
Crescent Rd
DATA SOURCES: CITY OF SURREY, METROVAN, GEOBC, NRCAN. ORTHOPHOTO BASE IMAGE FROM CITY OF SURREY AND ESRI.

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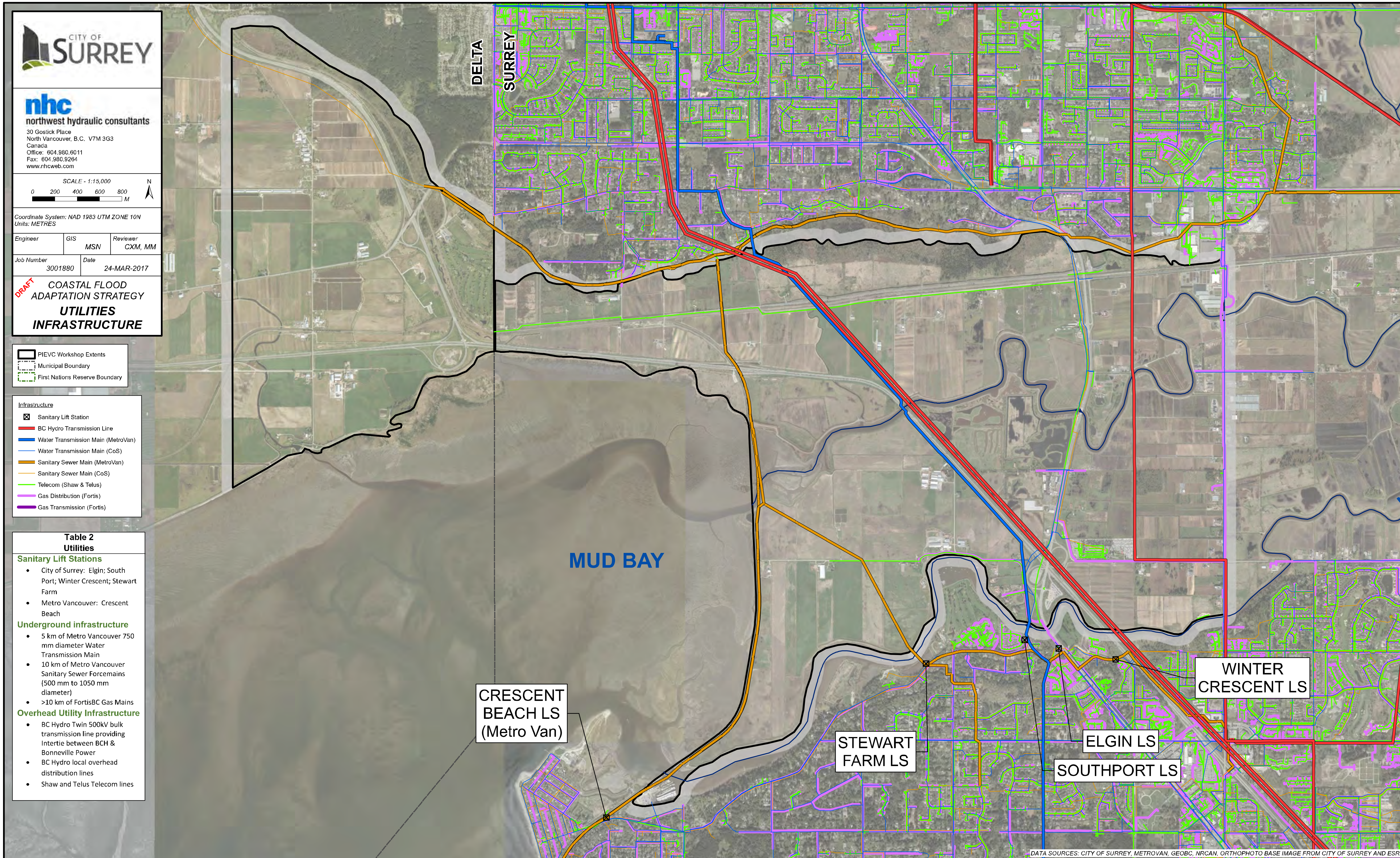

Table 2
Utilities

Sanitary Lift Stations

- City of Surrey: Elgin; South Port; Winter Crescent; Stewart Farm
- Metro Vancouver: Crescent Beach

Underground infrastructure

- 5 km of Metro Vancouver 750 mm diameter Water Transmission Main
- 10 km of Metro Vancouver Sanitary Sewer Forcemains (500 mm to 1050 mm diameter)
- >10 km of FortisBC Gas Mains

Overhead Utility Infrastructure

- BC Hydro Twin 500kV bulk transmission line providing Intertie between BCH & Bonneville Power
- BC Hydro local overhead distribution lines
- Shaw and Telus Telecom lines

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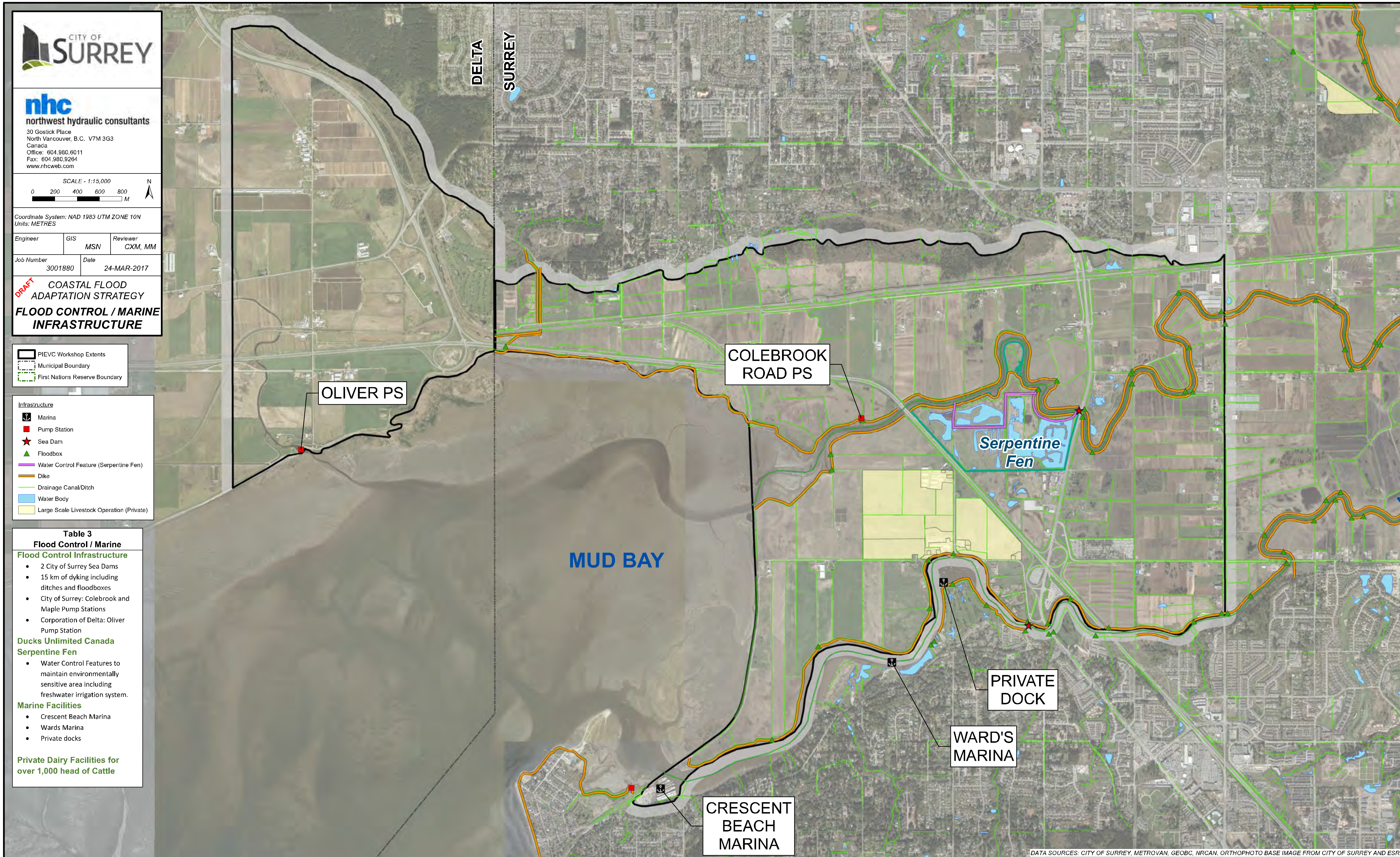

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Reviewer CXM, MM
Job Number 3001880
Date 24-MAR-2017
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COASTAL FLOOD ADAPTATION STRATEGY
FLOOD CONTROL / MARINE INFRASTRUCTURE
PIEVC Workshop Extents
Municipal Boundary
First Nations Reserve Boundary
Infrastructure
Marina
Pump Station
Sea Dam
Floodbox
Water Control Feature (Serpentine Fen)
Dike
Drainage Canal/Ditch
Water Body
Large Scale Livestock Operation (Private)
Table 3
Flood Control / Marine
Flood Control Infrastructure
• 2 City of Surrey Sea Dams
• 15 km of dyking including ditches and floodboxes
• City of Surrey: Colebrook and Maple Pump Stations
• Corporation of Delta: Oliver Pump Station
Ducks Unlimited Canada Serpentine Fen
• Water Control Features to maintain environmentally sensitive area including freshwater irrigation system.
Marine Facilities
• Crescent Beach Marina
• Wards Marina
• Private docks
Private Dairy Facilities for over 1,000 head of Cattle
DELTA
SURREY
OLIVER PS
COLEBROOK ROAD PS
Serpentine Fen
MUD BAY
PRIVATE DOCK
WARD'S MARINA
CRESCENT BEACH MARINA
DATA SOURCES: CITY OF SURREY, METROVAN, GEOBC, NRCAN. ORTHOPHOTO BASE IMAGE FROM CITY OF SURREY AND ESRI.

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2.3 INFRASTRUCTURE VULNERABILITY

The functionality of infrastructure in the Mud Bay region is reliant on flood control infrastructure, including sea dams, sea dykes, floodboxes, pump stations, and ditches.

The coastal floodplain is subject to flooding from both coastal processes (high tide, storm surge, wind and wave setup) and riverine processes (heavy precipitation, rain on snow / snow melt, high tides). As time progresses, sea level rise, land subsidence, and upland development will contribute to increased risk of flooding from these processes.

A previous vulnerability assessment of the sea dams, dykes, bridges, roads, and railroads, conducted by NHC, indicated that at the present 200-year flood condition:

- Freeboard would be compromised at the Serpentine Sea Dam;
- The Serpentine left bank dyke downstream of the sea dam would be inundated and freeboard would be compromised at all of the lowland dykes;
- Bridge decks would be inundated at three of the bridges and the low chords submerged at nine other bridges;
- A portion of Highway 99 would be inundated and freeboard compromised at Colebrook Road, with a few sections of railroad having compromised freeboard as well.

In 2100 at the 200-year flood (ignoring potential precipitation increases):

- Both the Serpentine and Nicomekl Sea Dams would be inundated;
- The lowland dykes upstream and downstream of the sea dams would also be inundated and nearly all other dykes would have compromised freeboard;
- The bridge decks would be inundated at seven bridges and the low chords submerged at 10 other bridges;
- Major roads and railroads would have either compromised freeboard or some inundation. Even during moderate present floods, some damage to infrastructure can be expected. Consequences of inundation may include widespread power outages, damage to transportation routes, challenges for emergency services and loss of critical assets such as water and sewage transmission. These primary impacts are likely to lead to cascading impacts outside the floodplain and in neighbouring municipalities.

The workshop participants identified potential impacts due to flooding on each piece of infrastructure. These impacts are summarized in Tables 2-1, 2-2, and 2-3.

Table 2-1: Flood Impacts to Transportation Infrastructure

Infrastructure	Identified Potential Flood Impacts
Surrey / King George Airpark Turf Runway	• Environmental contamination from fuel stored on-site. • Damage to aircraft and facilities. • Loss of access to patients for emergency response.
4 km of Four-Lane Arterial Roadway (including King George Boulevard)	• Inundation or washout of bridges, culverts, and the road structure. • Loss of access for emergency services. • Disruption of potential evacuation route for the public. • Environmental contamination from fuel. • Economic losses due to disruption of commuter traffic movement, congestion. • Loss of access to sea dams and other critical infrastructure. • Public safety issues with people parking cars or equipment on the roadside.
7 km Section of Highway 99 Linking Peace Arch Border	• Inundation or washout of bridges, culverts, and the road structure. • Loss of access for emergency services and maintenance operations on damaged utilities. • Disruption of potential evacuation route for the public. • Environmental contamination from fuel, possible hazardous good transport. • Economic losses due to disruption of commuter traffic. • Economic losses due to disruption of commercial and public access to the Canada / USA border.
Highway 91 and 99 Interchange	• Economic losses due to disruption of commercial and public access to the Canada / USA border. • Potential structural damage to the interchange due to scour, inundation of the foundations.
6 km Dyke Trail Connecting to Parks	• Loss of use due to inundation or partial washout. • Impact to commuter cyclists. • Impeded access to flood control infrastructure for repairs or maintenance.
152 Street	• Loss of access to the region for emergency services, the public, and operations and maintenance staff.
Colebrook Road	• Bridge damage. • Disruption of access to trains.

Infrastructure	Identified Potential Flood Impacts
Ladner Trunk Road	• Disruption of access to airport and hospital.
BNSF Nicomekl Swing Bridge and Trestles	• Economic disruption to the national economy, including goods movement to the US and the Ports. • Damage to the rail line with long recovery time.
6 km of BNSF Railway	• *No specific comments*
Roberts Bank Railway Corridor	• Economic impacts due to the loss of the sole connection to Deltaport.
Connection to Southern Railway of British Columbia	• *No specific comments*

Table 2-2: Flood Impacts to Utilities

Infrastructure	Identified Potential Flood Impacts
Sanitary Lift Stations	• Loss of power to the stations. • Inundation of the controls, shutting the stations down and reducing their capability to function or to be restored. • Potential interactions within the system, where if one on-line pump station goes down the entire system cannot function. • Increased inflow and infiltration (I&I) exceeding the capacity of the pumps and leading to surcharge and potential release of raw sewage to the environment. • Compromised access to the utility to perform maintenance, inspection, or repair. • Flooding of backup generators affects recovery time.
5 km of Metro Vancouver 750 mm diameter water transmission main	• Exposure of the utilities due to scour, potentially triggering a break. • Possible break in the system if the Nicomekl sea dam is compromised and either shifts or fails (the transmission main goes through the dam). • Loss of drinking water supply for communities south of Mud Bay – some redundancy in the system but may be insufficient capacity for demand. • Lost availability of water for firefighting. • Release of chlorinated water into a potentially sensitive receiving environment. • Compromised access to the utility to perform maintenance, inspection, or repair.

Infrastructure	Identified Potential Flood Impacts
	• Flooding of PRVs in the lowlands. • Corrosion due to saltwater.
10 km of Metro Vancouver sanitary sewer forcemains (500 mm to 1050 mm diameter)	• Release of raw sewage if the capacity is overwhelmed due to increased I&I, or if upstream users do not adjust their behavior. • Loss of capability to convey sewage. • Exposure of the utilities due to scour, potentially triggering a break. • Corrosion due to saltwater. • Compromised access to the utility to perform maintenance, inspection, or repair.
>10 km of FortisBC gas mains	• Exposure of the gas mains due to scour, potentially triggering a break and release of gas into the environment. • Potential loss of up to five stations. • No backfeed. • Corrosion of the gas mains due to saltwater. • Compromised access to the utility to perform maintenance, inspection, or repair.
BC Hydro Twin 500kV bulk transmission line providing intertie between BC Hydro and Bonneville Power	• Scour along the base of the towers could lead to failure of this power transmission (internationally regulated) with a long recovery time. • Compromised access to the transmission lines to perform maintenance, inspection, or repair. • Economic loss to BC Hydro due to the inability to sell power to the USA. • Potential corrosion of the towers due to saltwater. • Widespread power loss to the region. • Reduction in overhead clearance.
BC Hydro local overhead distribution lines	• Failure of the poles due to scour or wood rot. • Loss of power to the public with a long restoration time. • Loss of power to drainage pump stations and sanitary lift stations, compromising those utility functions. • Loss of power to streetlights and traffic control, exacerbating congestion and disrupting traffic and evacuations. • Compromised access to the distribution system to perform maintenance, inspection, or repair.

Infrastructure	Identified Potential Flood Impacts
Shaw and Telus telecom lines	• Failure of the poles due to scour or wood rot (poles are shared with BC Hydro). • Loss of routine and emergency communication capabilities. • Compromised access to the lines to perform maintenance, inspection, or repair. • Potential loss of SCADA control communication to pump stations.
Green infrastructure	• Loss of root stability leading to damage of above-ground utilities, and reduction in available leaf-area for rainwater interception.

Table 2-3: Impacts to Flood Control / Marine Infrastructure

Infrastructure	Identified Potential Flood Impacts
Sea dams	• Potential failure due to scour, destabilization, overtopping, and an inability to inspect or repair because of access and/or inundation. • Damage to utilities passing through the sea dam including Metro Vancouver water transmission main. • Inability for the dams to open and release water to relieve upstream flooding. • Seepage and saltwater intrusion affecting agricultural land and sensitive utilities upstream of the dam.
15 km of dyking, including ditches and floodboxes	• Potential scour and erosion of the dykes, or overtopping contributing to failure and cascading increases to flood magnitudes. • Inability to drain fields for an extended period of time, impacting agricultural lands and property upstream. • Compromised ability to access pump stations and dykes to conduct inspection and repair.
Drainage pump stations	• Potential for pumps to operate on a near-continuous basis for an extended period, resulting in excess wear, increased maintenance, and / or shortened service life. • Loss of power to the pump stations, limiting the ability to drain the upstream lands and contributing to cascading increases in flood impacts. • Inundation of stations damaging controls or flooding backup generators and resulting in long recommissioning timelines.
Ducks Unlimited Canada	• Shift to less productive brackish marsh due to saltwater intrusion.

Infrastructure	Identified Potential Flood Impacts
	• Potential for environmental contamination and loss of filtration capability of the system, resulting in degraded water quality. • Damage to critical habitat for Canada's largest wintering waterfowl populations.
Water Control Features to maintain environmentally sensitive area including freshwater irrigation system	• Loss of ability to manage water levels in the environmentally sensitive area. • Damage to electrical pumps and erosion or failure of flood culverts. • Saltwater intrusion into freshwater system.
Crescent Beach Marina	• Potential loss of secondary emergency responder access by the Coast Guard. • Public safety for people on the docks. • Potentially severe damage to infrastructure.
Wards Marina	• Public safety for people on the docks. • Potentially severe damage to infrastructure.
Private docks	• Significant damage and loss of the docks, potentially contributing to debris hazards elsewhere in the system.
Private dairy facilities for over 1,000 head of cattle	• Interruption of feed production with effects on long-term sustainability of the facility. • Death of livestock (estimated 2,400).

General notes:

- Transportation corridors severely impacted, affecting access to the various utilities for repairs, access by emergency responders, and access to repair critical flood control infrastructure. Detours, evacuations, and congestion likely to be a major problem. Impacts are similar for all of the roads, magnitude of the problem depends in part on which roads are affected and whether alternate routes are available.
- Coastal breach scenario is most likely to occur around Christmas to New Years (the time when king tides typically occur), delayed response by utility operators.

3 Step 2 - Climate Parameters

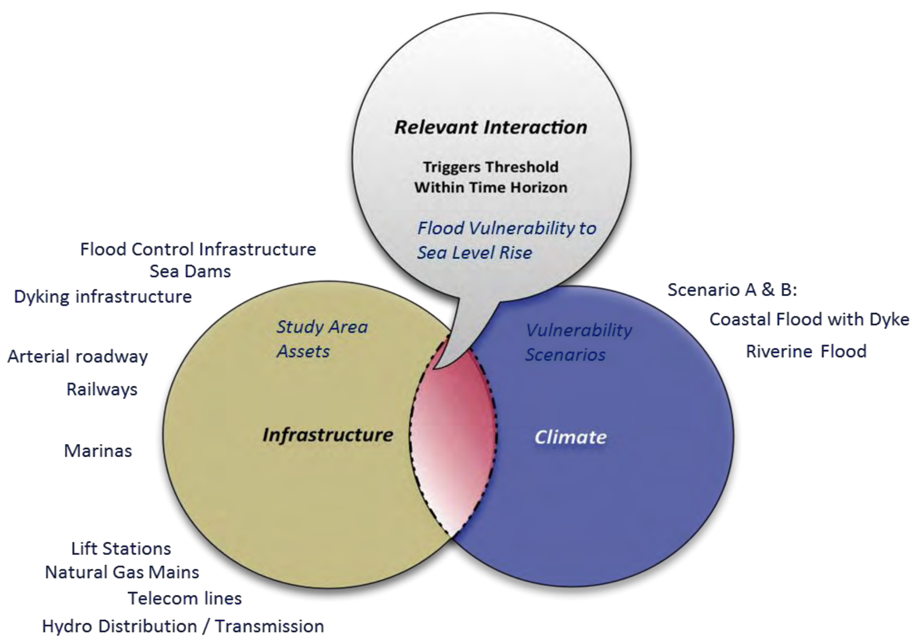
Step 2
Evaluate Climate Changes

The flooding scenarios used in the risk assessment are based on the outcome of several floodplain studies developed by NHC. The workshop focused on the following two scenarios:

- **Scenario A:** Coastal dyke breach causing progressive inundation of the coastal floodplain by the ocean.
- **Scenario B:** 200-Year return period riverine flooding, with releases to Mud Bay via the sea dams restricted by tidal cycles.

Both scenarios were assessed for both the present-day and the year 2100 time horizons. Climate change is affecting both the intensity and frequency of storms and flood events, causing today's extreme floods to become more frequent in the future. Sea level rise will restrict the amount of time the sea dams and floodboxes can drain by gravity. The land in Mud Bay is also subsiding, which will exacerbate the effects of sea level rise.

Reference Figure 3-1, Scenario A – Current, Figure 3-2, Scenario A – Future, Figure 3-3, Scenario B – Current, Figure 3-4, Scenario B – Future.



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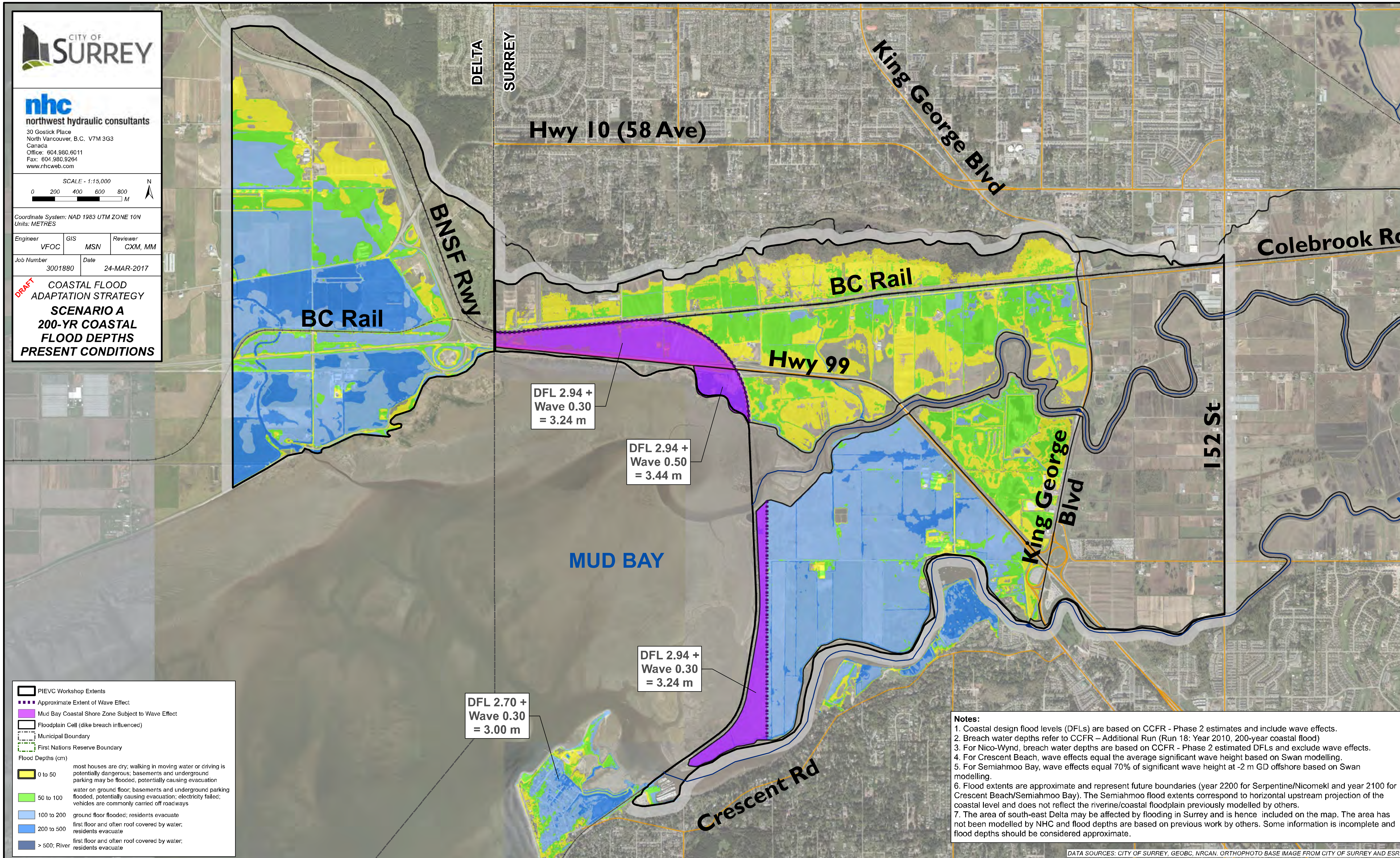

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Units: METRES
Engineer VFOC
GIS MSN
Reviewer CXM, MM
Job Number 3001880
Date 24-MAR-2017
DRAFT
COASTAL FLOOD ADAPTATION STRATEGY
SCENARIO A
200-YR COASTAL FLOOD DEPTHS
PRESENT CONDITIONS
DELTA
SURREY
Hwy 10 (58 Ave)
King George Blvd
BNSF Rwy
Colebrook Rd
BC Rail
BC Rail
Hwy 99
King George Blvd
152 St
MUD BAY
Crescent Rd
DFL 2.94 + Wave 0.30 = 3.24 m
DFL 2.94 + Wave 0.50 = 3.44 m
DFL 2.94 + Wave 0.30 = 3.24 m
DFL 2.70 + Wave 0.30 = 3.00 m
PIEVC Workshop Extents
Approximate Extent of Wave Effect
Mud Bay Coastal Shore Zone Subject to Wave Effect
Floodplain Cell (dike breach influenced)
Municipal Boundary
First Nations Reserve Boundary
Flood Depths (cm)
0 to 50 most houses are dry; walking in moving water or driving is potentially dangerous; basements and underground parking may be flooded, potentially causing evacuation
50 to 100 water on ground floor; basements and underground parking flooded, potentially causing evacuation; electricity failed; vehicles are commonly carried off roadways
100 to 200 ground floor flooded; residents evacuate
200 to 500 first floor and often roof covered by water; residents evacuate
> 500; River first floor and often roof covered by water; residents evacuate
Notes:
1. Coastal design flood levels (DFLs) are based on CCFR - Phase 2 estimates and include wave effects.
2. Breach water depths refer to CCFR – Additional Run (Run 18: Year 2010, 200-year coastal flood)
3. For Nico-Wynd, breach water depths are based on CCFR - Phase 2 estimated DFLs and exclude wave effects.
4. For Crescent Beach, wave effects equal the average significant wave height based on Swan modelling.
5. For Semiahmoo Bay, wave effects equal 70% of significant wave height at -2 m GD offshore based on Swan modelling.
6. Flood extents are approximate and represent future boundaries (year 2200 for Serpentine/Nicomekl and year 2100 for Crescent Beach/Semiahmoo Bay). The Semiahmoo flood extents correspond to horizontal upstream projection of the coastal level and does not reflect the riverine/coastal floodplain previously modelled by others.
7. The area of south-east Delta may be affected by flooding in Surrey and is hence included on the map. The area has not been modelled by NHC and flood depths are based on previous work by others. Some information is incomplete and flood depths should be considered approximate.
DATA SOURCES: CITY OF SURREY, GEOBC, NRCAN. ORTHOPHOTO BASE IMAGE FROM CITY OF SURREY AND ESRI.

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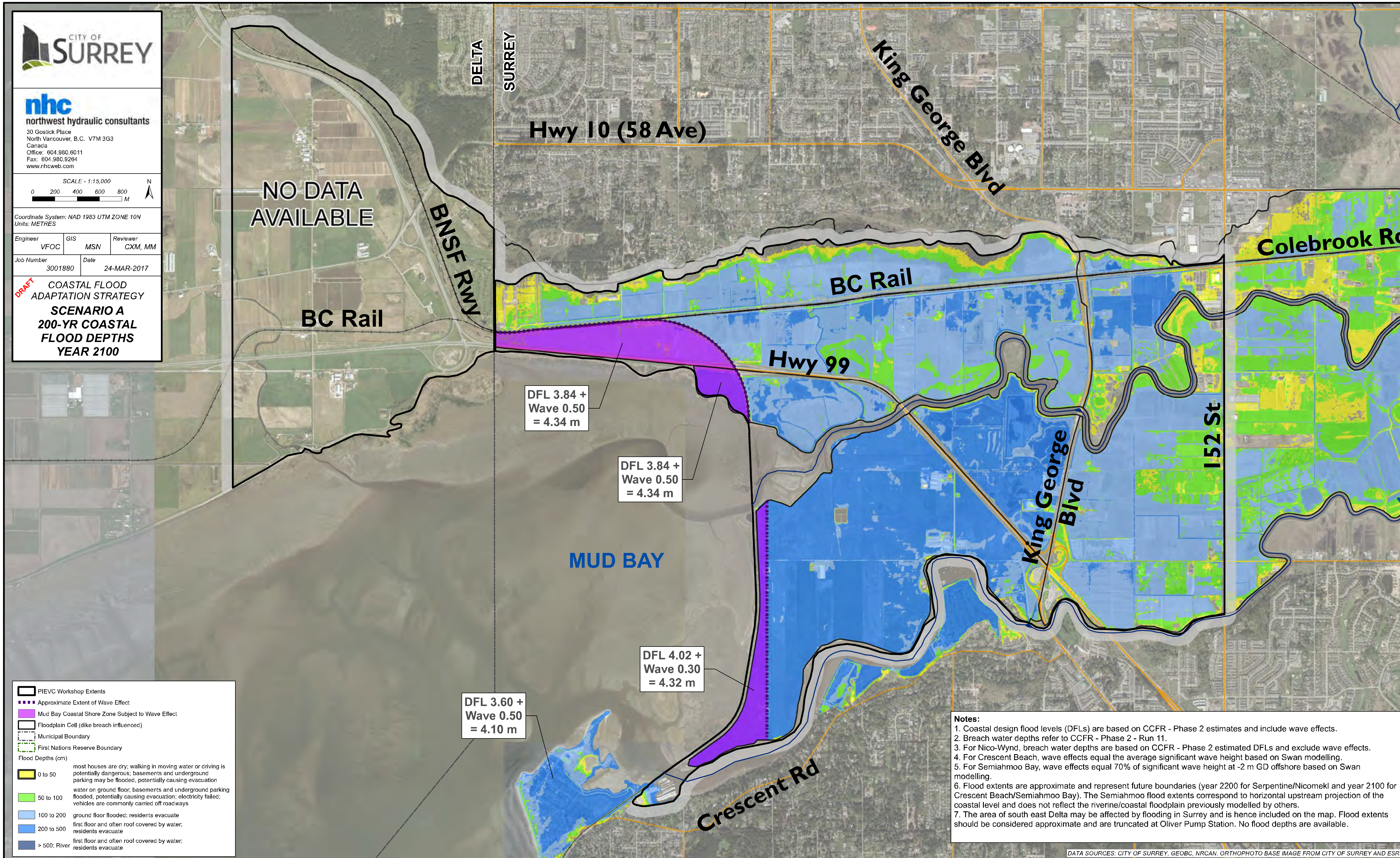
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Units: METRES
Engineer VFOC
GIS MSN
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Job Number 3001880
Date 24-MAR-2017
DRAFT
COASTAL FLOOD ADAPTATION STRATEGY
SCENARIO A
200-YR COASTAL FLOOD DEPTHS
YEAR 2100
DELTA
SURREY
NO DATA AVAILABLE
BNSF Rwy
Hwy 10 (58 Ave)
King George Blvd
Colebrook Rd
BC Rail
BC Rail
Hwy 99
152 St
King George Blvd
MUD BAY
Crescent Rd
DFL 3.84 + Wave 0.50 = 4.34 m
DFL 3.84 + Wave 0.50 = 4.34 m
DFL 4.02 + Wave 0.30 = 4.32 m
DFL 3.60 + Wave 0.50 = 4.10 m
PIEVC Workshop Extents
Approximate Extent of Wave Effect
Mud Bay Coastal Shore Zone Subject to Wave Effect
Floodplain Cell (dike breach influenced)
Municipal Boundary
First Nations Reserve Boundary
Flood Depths (cm)
0 to 50 most houses are dry; walking in moving water or driving is potentially dangerous; basements and underground parking may be flooded, potentially causing evacuation
50 to 100 water on ground floor; basements and underground parking flooded, potentially causing evacuation; electricity failed; vehicles are commonly carried off roadways
100 to 200 ground floor flooded; residents evacuate
200 to 500 first floor and often roof covered by water; residents evacuate
> 500; River first floor and often roof covered by water; residents evacuate
Notes:
1. Coastal design flood levels (DFLs) are based on CCFR - Phase 2 estimates and include wave effects.
2. Breach water depths refer to CCFR - Phase 2 - Run 11.
3. For Nico-Wynd, breach water depths are based on CCFR - Phase 2 estimated DFLs and exclude wave effects.
4. For Crescent Beach, wave effects equal the average significant wave height based on Swan modelling.
5. For Semiahmoo Bay, wave effects equal 70% of significant wave height at -2 m GD offshore based on Swan modelling.
6. Flood extents are approximate and represent future boundaries (year 2200 for Serpentine/Nicomekl and year 2100 for Crescent Beach/Semiahmoo Bay). The Semiahmoo flood extents correspond to horizontal upstream projection of the coastal level and does not reflect the riverine/coastal floodplain previously modelled by others.
7. The area of south east Delta may be affected by flooding in Surrey and is hence included on the map. Flood extents should be considered approximate and are truncated at Oliver Pump Station. No flood depths are available.
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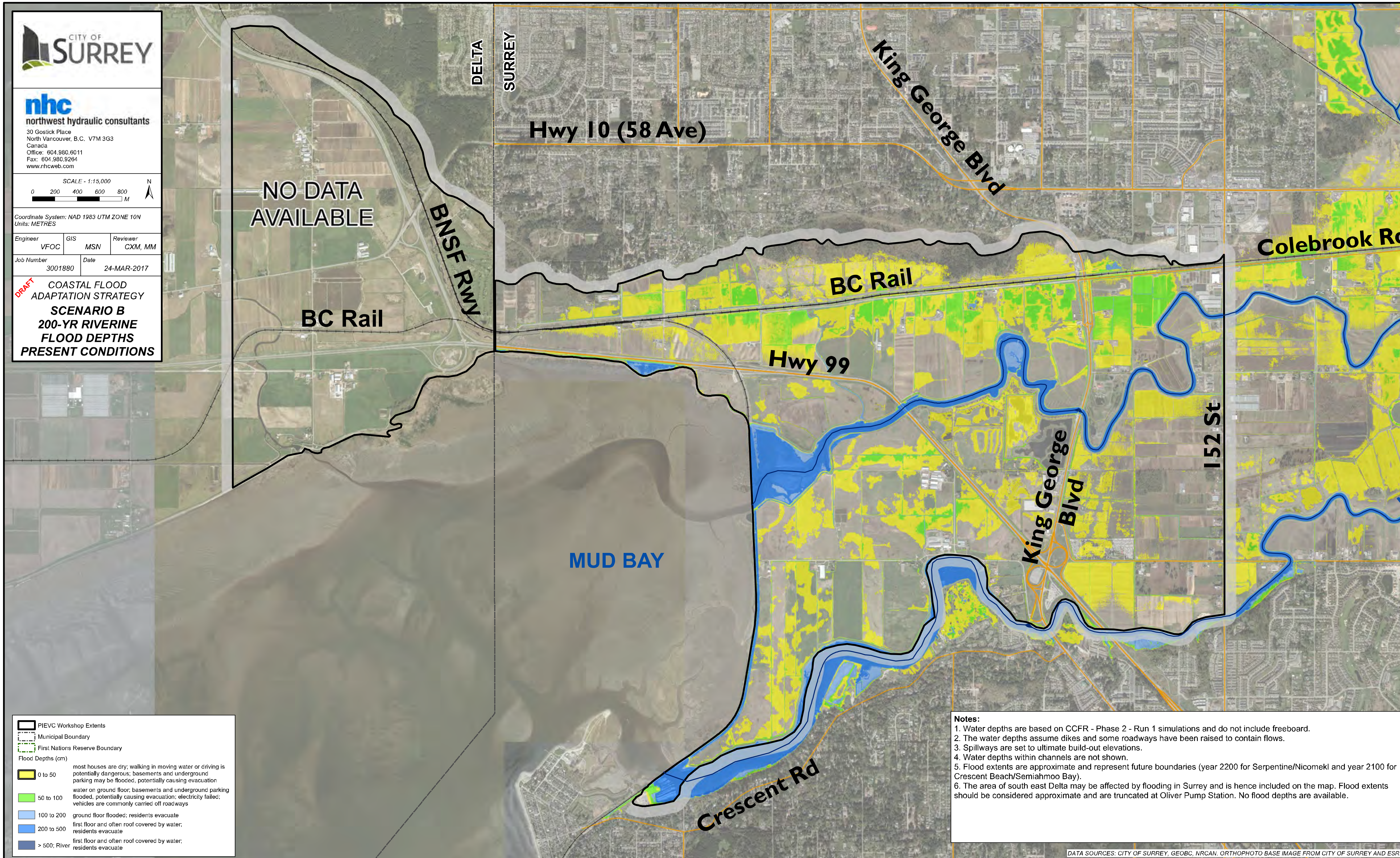

Notes:

1. Water depths are based on CCFR - Phase 2 - Run 1 simulations and do not include freeboard.
2. The water depths assume dikes and some roadways have been raised to contain flows.
3. Spillways are set to ultimate build-out elevations.
4. Water depths within channels are not shown.
5. Flood extents are approximate and represent future boundaries (year 2200 for Serpentine/Nicomekl and year 2100 for Crescent Beach/Semiahmoo Bay).
6. The area of south east Delta may be affected by flooding in Surrey and is hence included on the map. Flood extents should be considered approximate and are truncated at Oliver Pump Station. No flood depths are available.

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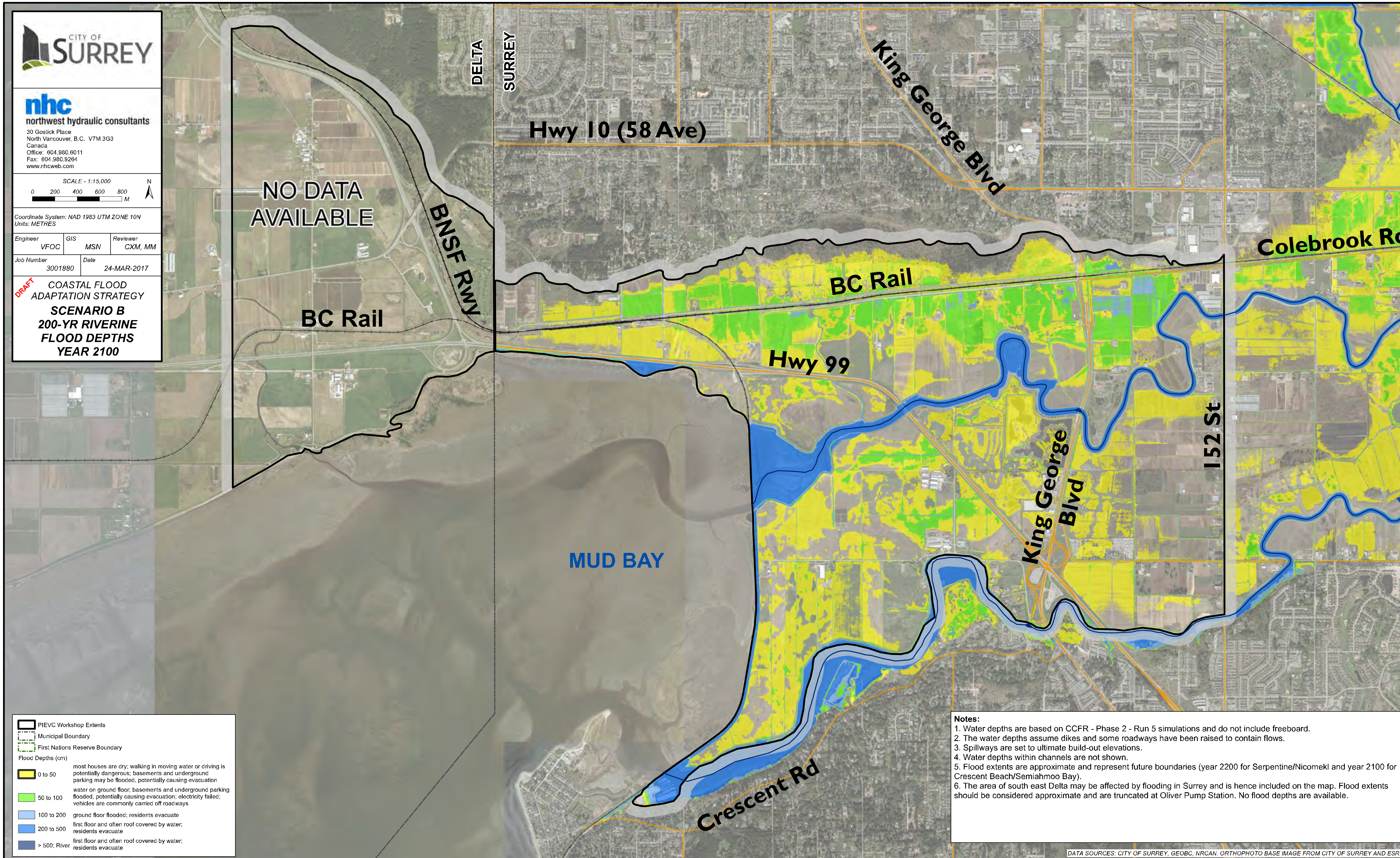

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COASTAL FLOOD ADAPTATION STRATEGY
SCENARIO B
200-YR RIVERINE FLOOD DEPTHS
YEAR 2100
DELTA
SURREY
Hwy 10 (58 Ave)
King George Blvd
NO DATA AVAILABLE
BNSF Rwy
BC Rail
BC Rail
Colebrook Rd
Hwy 99
152 St
King George Blvd
MUD BAY
Crescent Rd
PIEVC Workshop Extents
Municipal Boundary
First Nations Reserve Boundary
Flood Depths (cm)
0 to 50 — most houses are dry; walking in moving water or driving is potentially dangerous; basements and underground parking may be flooded, potentially causing evacuation
50 to 100 — water on ground floor; basements and underground parking flooded, potentially causing evacuation; electricity failed; vehicles are commonly carried off roadways
100 to 200 — ground floor flooded; residents evacuate
200 to 500 — first floor and often roof covered by water; residents evacuate
> 500; River — first floor and often roof covered by water; residents evacuate
Notes:
1. Water depths are based on CCFR - Phase 2 - Run 5 simulations and do not include freeboard.
2. The water depths assume dikes and some roadways have been raised to contain flows.
3. Spillways are set to ultimate build-out elevations.
4. Water depths within channels are not shown.
5. Flood extents are approximate and represent future boundaries (year 2200 for Serpentine/Nicomekl and year 2100 for Crescent Beach/Semiahmoo Bay).
6. The area of south east Delta may be affected by flooding in Surrey and is hence included on the map. Flood extents should be considered approximate and are truncated at Oliver Pump Station. No flood depths are available.
DATA SOURCES: CITY OF SURREY, GEOBC, NRCAN. ORTHOPHOTO BASE IMAGE FROM CITY OF SURREY AND ESRI.

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4 Step 3 - Risk Assessment

Step 3
Conduct Risk Assessment

The workshop participants, working in table groups, completed a risk assessment of the Mud Bay infrastructure based on the two flood scenarios (A and B) using the PIEVC Screening Tool.

To determine the risk score (R) for each interaction, a probability score (P) was established for each flood scenario and the participants selected a consequences score (C) for each interaction between flood scenarios and infrastructure.

The resulting risk **R = P x C,** is product of the probability score (P) and the consequence score (C).

Flood mapping, and probability and consequence tables, and other resources were provided the participants to assist in the determination.

Score	Probability	Score	Consequence
	Method A		Method D
0	Negligible Not Applicable	0	No Effect
1	Highly Unlikely Improbable	1	Insignificant
2	Remotely Possible	2	Minor
3	Possible Occasional	3	Moderate
4	Somewhat Likely Normal	4	Major
5	Likely Frequent	5	Catstrophic

The probability (P) scores for each scenario and time horizon were assigned in advance of the workshop by AE in collaboration with NHC. The probability scores were 4 and 3 for Scenario A and B, respectively under existing conditions; and were 5 for both scenarios under future conditions.

A resulting risk score is established where:

- R = >10 — Low Risk — Risk requiring minimal action
- R = 10 – 19 — Medium Risk — Risks that may require future action
- R = 20 – 25 — High Risk — Risks that require action

5	CONSEQUENCE	Catastrophic	0	5	10	15	20	25
4		Major	0	4	8	12	16	20
3		Moderate	0	3	6	9	12	15
2		Minor	0	2	4	6	8	10
1		Insignificant	0	1	2	3	4	5
0		No Effect	0	0	0	0	0	0
			Negligible Not Applicable	Highly Unlikely Improbable	Remotely Possible	Possible Occasional	Somewhat Likely Normal	Likely Frequent
			PROBABILITY					
			0	1	2	3	4	5

4.1 RISK ASSESSMENT RESULTS

4.1.1 Group Results

The workshop participants risk assessment results are summarized in Tables 4-1, 4-2, and 4-3.

Table 4-1: Transportation Infrastructure Risk Assessment Results

	Infrastructure	Flood Scenario A Current	Flood Scenario A Future	Flood Scenario B Current	Flood Scenario B Future
Transportation	**Runway**				
	Surrey/King George Airpark Turn Runway	4	5	3	5
	Regional / International Transportation Infrastructure				
	4 km of four-lane arterial roadway	12	25	3	10
	7 km section of Highway 99 linking Peace Arch Border	16	25	3	10
	Highway 91 and 99 Interchange	12	20	3	10
	4 km section of Highway 91	8	20	3	10
	6 km dyke trail connecting to parks	4	5	3	10
	Delta-Surrey Greenway	4	5	3	10
	Local Government Arterial and Collector Roads				
	King George Boulevard (City of Surrey)	12	25	3	10
	152nd Street (City of Surrey)	4	20	3	5
	112 Street (City of Surrey)	8	15	6	15
	Colebrook Road (City of Surrey)	8	15	6	15
	Ladner Trunk Road (Corporation of Delta)	12	20	9	20
	Class 1 Railways Originating at Port Metro Vancouver				
	Burlington Northern Santa Fe (BNSF) Nicomekl Swing Bridge and Trestles	16	20		
	6 km of BNSF Railway (Freight frequencies ~ 20 trains daily and up to 4 daily Amtrak Cascades trains)	16	25		
	Roberts Bank Railway Corridor (BC Railway Co. ownership with usage by CN, CP and BNSF) ~ 18 trains daily	8	20		
	Connection to Southern Railway of British Columbia	4	20	9	20

Table 4-2: Utilities Infrastructure Risk Assessment Results

Infrastructure		Flood Scenario			
		A Current	A Future	B Current	B Future
Utilities	**Sanitary Lift Stations**				
	City of Surrey: Elgin	12	15		
	City of Surrey: South Port	16	20		
	City of Surrey: Winter Crescent	12	15		
	City of Surrey: Stewart Farm	16	20	6	20
	Metro Vancouver: Crescent Beach	16	20		
	Underground Infrastructure				
	5 km of Metro Vancouver 750 mm diameter Water Transmission Main	16	20	6	10
	10 km of Metro Vancouver Sanitary Sewer Forcemains (500 mm to 1050 mm diameter)	12	15	6	10
	>10 km of FortisBC Gas Mains	8	10	9	15
	Overhead Utility Infrastructure				
	BC Hydro Twin 500kV bulk transmission line providing Intertie between BC Hydro and Bonneville Power	12	15		20
	BC Hydro local overhead distribution lines	16	20		20
	Shaw and Telus telecom lines	8	10	6	10
	Green Infrastructure (Added)	8	15		15

Table 4-3: Flood Control / Marine Infrastructure Risk Assessment Results

	Infrastructure	Flood Scenario A Current	Flood Scenario A Future	Flood Scenario B Current	Flood Scenario B Future
Flood Control / Marine	City of Surrey Sea Dams (2)	20	20	6	25
	15 km of dyking, including ditches and floodboxes	20	25	9	20
	City of Surrey: Colebrook Pump Station	16	20	6	15
	City of Surrey: Maple Pump Station	16	20	3	15
	Corporation of Delta: Oliver Pump Station	16	25	6	15
	Ducks Unlimited Canada Serpentine Fen Nature Reserve	8	10	3	5
	Water control features to maintain environmentally sensitive area including freshwater irrigation system	12	15		
	Screw Pump Stations (Added)	4	10	3	10
	Marine Facilities				
	Crescent Beach Marina	8	15	6	10
	Wards Marina	8	15	6	10
	Private docks	8	15	9	10
	Farms				
	Private dairy facilities for over 1,000 head of Cattle	16	25	3	10

4.1.2 Risk Assessment Summary

- 40 assets assessed per scenario

- **Flood Scenario A – Coastal Flood with Dyke Breach**
  - Current risks are mostly low and medium
  - Future risks increase to medium and high

	Number of Assets in Each Category							
	Flood Scenario A Current				Flood Scenario A Future			
	Transportation	Utilities	Flood Control / Marine	Total: Scenario A Current	Transportation	Utilities	Flood Control / Marine	Total: Scenario A Future
Low Risk	9	3	5	**17**	3	0	0	**3**
Medium Risk	7	9	5	**21**	2	7	6	**15**
High Risk	0	0	2	**2**	11	5	6	**22**

- **Flood Scenario B – Riverine Flood**
  - All assets are currently at low risk
  - The number of assets subject to medium risk increases to 23 (>50% of the number of assets assessed), while 7 assets (~20%) are at high risk.

	Number of Assets in Each Category							
	Flood Scenario B Current				Flood Scenario B Future			
	Transportation	Utilities	Flood Control / Marine	Total: Scenario B Current	Transportation	Utilities	Flood Control / Marine	Total: Scenario B Future
Low Risk	16	12	12	**40**	5	3	2	**10**
Medium Risk	0	0	0	**0**	9	6	8	**23**
High Risk	0	0	0	**0**	2	3	2	**7**

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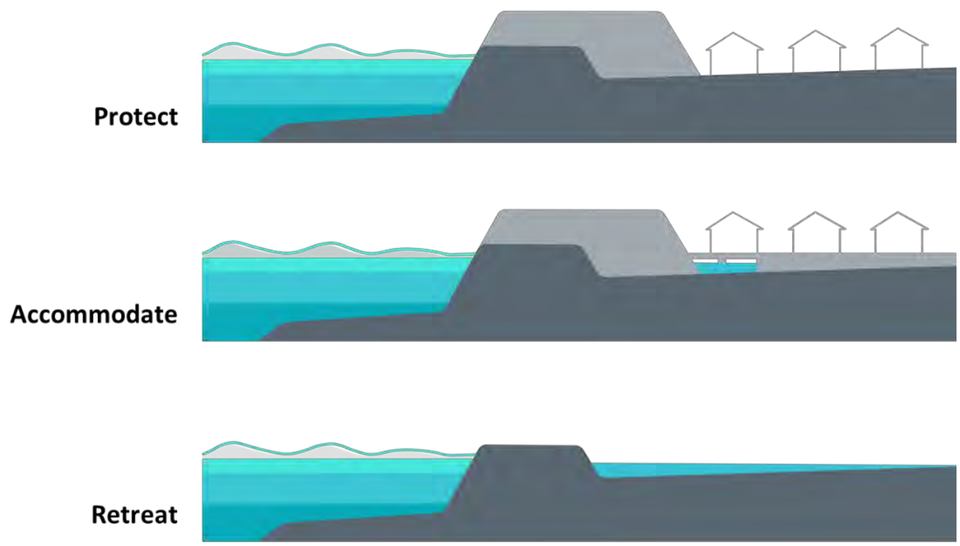
5 Step 5 - Outcomes and Integration

Step 5
Adaptation Comments and Strategies

Following the risk assessment, adaptation scenarios and strategies were discussed with an emphasis on high risk interactions on the Mud Bay infrastructure.

Prior to the discussion, the City of Surrey presented some background information on adaption options and some general ideas of strategies that could be considered in reducing risk to the Mud Bay and surrounding infrastructure.

In the context of the CFAS project, three adaptions approaches were presented: Protect, Accommodate, and Retreat.



5.1 ADAPTATION ASSESSMENT RESULTS

5.1.1 Group Results

The summary results of the workshop participants' adaptation options discussions are included in Appendix B. The tables in Appendix B summarize comments on the individual adaptation options that were considered, as well as broader general comments.

It is worth noting that the adaptation options discussion was influenced by the presentation of the adaptation options being considered for the area, and so alternate adaptation options beyond those presented were not brainstormed or explored. Additionally, because the workshop focus was on risk assessment, full exploration of the benefits and constraints associated with each adaptation option was not feasible, considering the breadth of the topic.

During the discussion, many participants found it challenging to commit to firm answers, and important points were raised, such as: '*at what time does ongoing protection and accommodation become too* *infeasible or costly, such that retreat becomes the only viable option? If retreat is the only applicable ultimate solution, then perhaps a stepped progression towards that end needs to be pursued'.*

Further exploration of adaptation options is recommended, but the comments received provide insight into the opinions of the participants on adaptation measures. A selection of representative adaptation comments is listed below. See Appendix B for the remainder of both option-specific and general adaptation comments.

- *Accommodate and do incremental upgrades.*
- *Rock groin / breakwater (offshore 7 km long extending from beyond Crescent Beach to Highway 91) complete with tide gate (Stage construction with barrier raised over time, add gate later, upgrade dyke and pump station as required). Create better habitat internally.*
- *Retreat was not looked upon favorably since it will significantly impact transportation corridors. However, partial retreat was not explored (and it should be).*
- *Without offshore improvements, dyke upgrades will be challenging and will take a long time.*
- *Retreat for highways not considered feasible.*
- *Incremental adaptations are needed to meet changing needs of climate change.*
- *If we retreat, how will be transportation corridors be maintained? Could a long bridge be an option spanning the retreated area? Would the public be okay with intermittent road closures during high tide?*
- *Build a sea wall across Mud Bay.*
- *Dyking is a good option. Offshore islands are a no-go for Crescent Beach.*
- *Benefits of offshore islands on reducing flood vulnerability to infrastructure in Mud Bay.*
- *Raise the dykes - build a barrier wall.*
- *BC Hydro may implement protect or accommodate adaptation features for its infrastructure.*
- *No single approach but rather a combination of different options will need to be employed with input and support of all stakeholders in the Lower Mainland.*
- *What would be a global approach to adopt options to develop strategies against coastal flood risks?*
- *Sea level rise and subsidence are long term processes that will continue indefinitely. Protect options buy time, rather than permanent protection. You might consider how long protect options would be effective for.*
- *Look at options and evaluate problems they solve instead of vice versa.*
- *Incremental adaptations.*
- *Engage the whole Lower Mainland area.*
- *Yes, engagement with neighbouring municipalities should be needed for this type of workshop.*
- *Focus on people, infrastructure, ALR lands over Mud Bay environmental impacts (i.e. if a sea wall was constructed).*

5.1.2 Post Workshop Survey Comments

The workshop participants post-workshop survey comments are summarized in Table 5-1. The comments are in response to the survey question: "Are there any adaptation options or strategies you would like to see explored further related to infrastructure in the area?".

Table 5-1: Infrastructure Adaptation Comments

Infrastructure	Adaptation Comments
Transportation / Utilities / Flood Control / Marine	• Foreshore dyke. • Off-shore dyke with multiple uses. • Feasibility of off-shore options. • Offshore barrier islands? Raise Highway 99 as a dyke? • Look at development strategies and policies to assure net-zero surface flow post/predevelopment. Low-impact development strategies. Buy / lease back land options. • The great Mud Bay dyke / wall to reclaim more land. • Benefits of offshore islands on reducing flood vulnerability to infrastructure in Mud Bay. • Raise the dykes - build a barrier wall. • BC Hydro may implement protect or accommodate adaptation for its infrastructure. • Green infrastructure. • No single approach but rather a combination of different options will need to be employed with input and support of all stakeholders in the Lower Mainland. • What would be a global approach to adopt options to develop strategies against coastal flood protections. • Sea level rise & subsidence are long term processes that will continue indefinitely. Protect options buy time, rather than permanent protection. You might consider how long protect options would be effective for. • Look at options and evaluate problems they solve instead of vice versa. • PIEVC has good risk ranking procedure to suit outstanding priorities • Options analysis for all 3 options. • Incremental adaptations. • Engage the whole Lower Mainland area. • Yes, engagement with neighboring municipalities should be needed for this type of workshop. • Focus on people, infrastructure, ALR lands over Mud Bay environmental impacts (i.e. if a sea wall was constructed). • All that we discussed. Very valuable!

Further information on the post-workshop survey responses are included in Appendix C.

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6 Next Steps

The findings based on the information obtained in the infrastructure flood vulnerability assessment will be used in the next steps of the CFAS study in conjunction with other feedback from stakeholders in other engagement sessions and workshops.

The information will also be shared with the workshop participants and the public to engage in further dialog on the CFAS project.

This project focused on the first three steps in the PIEVC process, namely the definition of infrastructure (Step 1), evaluation of climate changes (Step 2), and a risk / vulnerability assessment (Step 3). The overall CFAS project would benefit from further engineering analysis on each of the sectors defined here (transportation, utilities, flood control, marine), and follow-up risk assessments. This would follow Step 4 of the PIEVC protocol. The initial broader adaptation options developed as part of the CFAS project could then be refined to develop improved micro-scale adaptation options for high-risk infrastructure sectors. These options could be analyzed and discussed during a follow-up workshop with stakeholders to better define conclusions and recommendations (Step 5 of the protocol).

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Closure

This report was created by Associated Engineering to summarize the outcomes of the Mud Bay Infrastructure Flood Vulnerability Assessment PIEVC Workshop, held on March 28, 2017 at Surrey City Hall.

The services provided by Associated Engineering (B.C.) Ltd. in the preparation of this report were conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions. No other warranty expressed or implied is made.

Respectfully submitted,
Associated Engineering (B.C.) Ltd.

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June 15/2017

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Appendix A - Workshop Backgrounder, Primer, and Questionnaire

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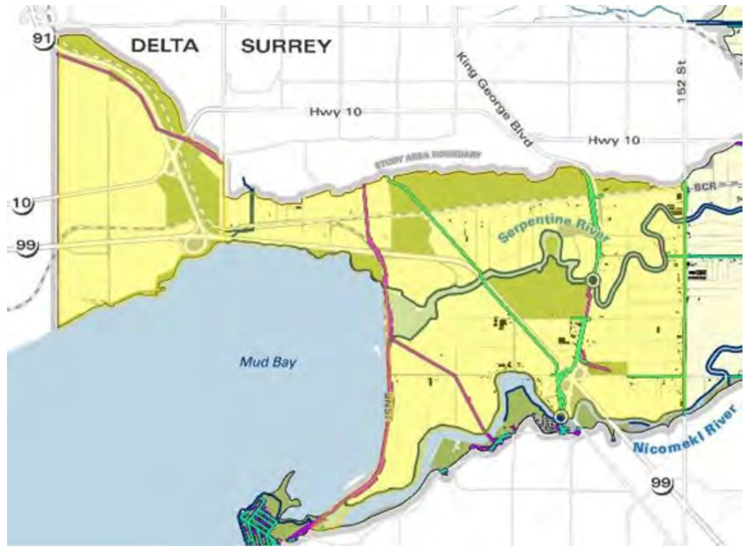
INFRASTRUCTURE WORKSHOP SAVE THE DATE

Join us on Tuesday, March 28, 2017 for an important stakeholder workshop to explore the impacts of sea level rise on public infrastructure in the Mud Bay area (see yellow area below).

Time & location

Date: Tuesday, March 28, 2017
Location: Surrey City Hall, 2nd Floor
13450 104 Ave, Surrey
Time: 8:30 – 4:30 (lunch provided)



Moving toward a Coastal Flood Adaptation Strategy (CFAS)

Surrey's coast is changing. Our coast can expect more frequent and severe flooding from sea level rise and storm surges. About 20% of Surrey's land base is in the coastal floodplain with a wide array of infrastructure assets, ranging from transportation corridors to power transmission infrastructure.

Surrey is developing a Coastal Flood Adaptation Strategy for our coastal floodplain area in order to prepare our communities and infrastructure for the future. The three-year project builds on recent and ongoing work Surrey has undertaken in the project area.

We need your infrastructure knowledge

As part of this process, Surrey is planning a workshop to explore infrastructure vulnerability to sea level rise in a portion of the project area (see map), to navigate a path towards adaptation. We are requesting your input as an infrastructure asset manager in the process, and will be holding this workshop to identify critical assets and identify resilient strategies for adaptation. The workshop will be structured around the Engineers Canada Public Infrastructure Vulnerability Committee (PIEVC) Engineering Protocol to assess vulnerability.

Who should attend and why?

Representative(s) in your organization that plan, manage and operate the infrastructure and who can speak to the level of service and engineering vulnerability of the systems related to flooding, current or future. Why? We need to collectively develop an adaption strategy for all affected in the Mud Bay area.

What can you do?

- Review the attached primer and project backgrounder.
- Identify personnel you would like to be involved in the workshop.
- Complete the attached questionnaire to identify your critical infrastructure, and any issues related to flooding.
- Join us for an interactive workshop on infrastructure vulnerability on March 28.

Please RSVP by March 17, 2017 to attend here, or at 604-591-4340.

For more information, please contact Matt Osler at 604-591-4657 or coastal@surrey.ca. If confidentiality is an issue in responding and participating, please call Matt to discuss. **We want you to be involved.**

CITY OF SURREY
the future lives here.

SURREY COASTAL FLOOD ADAPTATION STRATEGY (CFAS)

BACKGROUNDER

Infrastructure Asset Managers, Operators and Emergency Services

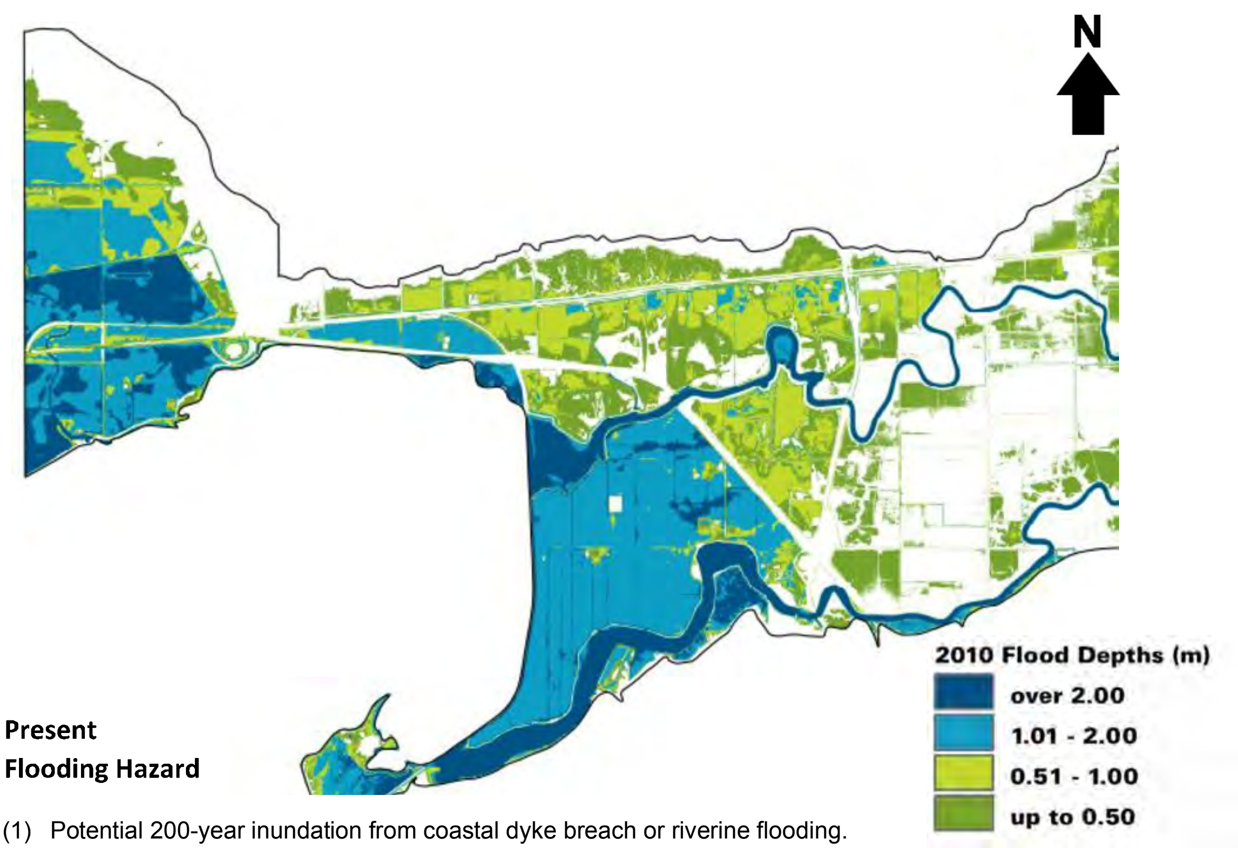
CFAS

What are the present flood hazards?

The City of Surrey lowlands are prone to flooding from high ocean levels, peak flows on the Serpentine/ Nicomekl Rivers, or a combination of the two. The area was settled in the 1800's and in the early 1900's sea dams were built near the mouth of each river to prevent salt water from inundating fertile farmland. Over time, coastal and riverine dykes were built and upgraded to improve the degree of flood protection. The riverine dykes upstream of the sea dams are unique in the sense that they include spillways, intended to overflow and equitably distribute flood waters at medium flood flows, with return periods in the order of 10-15 years. At extreme flows, such as the 200-year flood, the system would be overwhelmed, resulting in extensive flooding. The side slopes of the river dykes are too steep, making them vulnerable to failure even before they overtop. Similarly, the coastal dykes do not meet 200-year flood protection standards and locations exposed to wave action are at risk of failing during relatively frequent events. The seismically-unstable sea dams are aging structures, requiring extensive upgrading or replacement in the near term.

Severe floods usually occur in the winter months. High coastal water levels are a result of high tides, so called King Tides, in combination with storm surge events caused by low atmospheric pressures, and severe wind storms generating high waves and wind set-up. River flows are also highest in the winter, and are typically the result of long duration rainfall or rain-on-snow events. River flows can drain through the sea dams only while ocean levels are below river levels. Consequently, the lowlands upstream of the sea dams experience the worst flooding when high ocean levels and river flows coincide.

There is an extensive history of past floods and associated dyke failures in the area. In December of 1982, a storm surge coincided with high tides resulting in water levels overtopping a dyke in Mud Bay Dyking District, inundating agricultural fields. Large waves during that same event caused overtopping of the boulevard at Crescent Beach and logs washing up inland. In January of 2009, a rain-on-snow event caused extensive flooding of the lowlands upstream of the sea dams, while an October 2003 rain storm flooded the upper river basins.



Present Flooding Hazard

(1) Potential 200-year inundation from coastal dyke breach or riverine flooding.

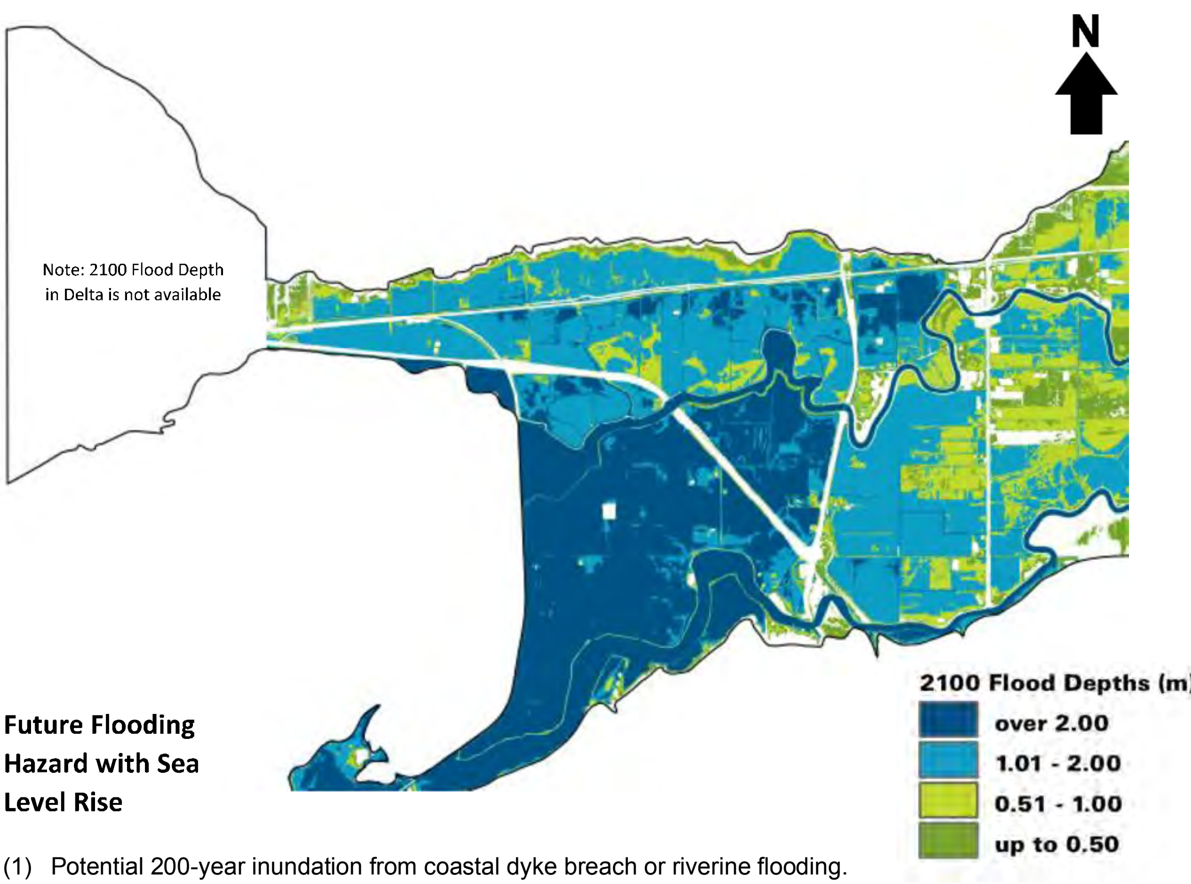
(2) Coastal flooding assumes coastal dyke breaching, riverine flooding assumes riverine dykes remain intact.

What will the future hold?

Climate change will exacerbate flood hazards, primarily through sea level rise, increased storminess and increased precipitation during the winter months. Sea level rise estimates vary, with present Provincial Guidelines recommending that an increase of 1.0 m from year 2000 to 2100 be considered for coastal design projects. Past research suggests increases in storminess and also variations in wind patterns; however, specific design values have not been proposed. Provincial legislated flood assessment guidelines recommend increasing design flood flows by 10% unless more detailed analysis is performed. Estimates of future precipitation intensities imply more significant peak flow increases for the Serpentine/Nicomekl Rivers.

The Surrey lowlands are gradually subsiding. Subsidence rates vary with location but will average about 1 mm/year within the floodplain, resulting in a predicted relative sea level rise over this century of 1.1 m.

Due to the flat topography of the floodplain and relatively steep valley walls, the areal extent of flooding will increase only marginally by the end of the century. Instead, the depth of flooding and, more importantly, the frequency of flooding is expected to increase dramatically. The present 200-year flood level will have a return period of less than two years in the area just upstream of the sea dams in year 2100.



Future Flooding Hazard with Sea Level Rise

(1) Potential 200-year inundation from coastal dyke breach or riverine flooding.

(2) Coastal flooding assumes coastal dyke breaching, riverine flooding assumes riverine dykes remain intact.

What will be the impacts on infrastructure?

A previous vulnerability assessment of the sea dams, dykes, bridges, roads and railroads indicated that at the **present 200-year flood condition**:

- Freeboard would be compromised at the Serpentine Sea Dam;
- The Serpentine left bank dyke downstream of the sea dam would be inundated and freeboard would be compromised at all of the lowland dykes;
- Bridge decks would be inundated at three of the bridges and the low chords submerged at nine other bridges;
- A portion of Highway 99 would be inundated and freeboard compromised at Colebrook Road, with a few sections of railroad having compromised freeboard as well.

In other words, extensive infrastructure upgrades are required for current conditions.

In **2100 at the 200-year flood condition**, ignoring potential precipitation increases:

- Both the Serpentine and Nicomekl Sea Dams would be inundated;
- The lowland dykes upstream and downstream of the sea dams would also be inundated and nearly all other dykes would have compromised freeboard;
- The bridge decks would be inundated at seven bridges and the low chords submerged at 10 other bridges;
- Major roads and railroads would have either compromised freeboard or some inundation. Even during moderate present floods, some damage to infrastructure can be expected. Consequences of inundation may include widespread power outages, damage to transportation routes, challenges for emergency services and loss of critical assets such as water and sewage transmission. These primary impacts are likely to lead to cascading impacts outside the floodplain and in neighbouring municipalities.

What is the Infrastructure?

Flood Control Infrastructure

- 2 City of Surrey Sea Dams
- 15 km of dyking including ditches and floodboxes
- City of Surrey: Colebrook and Maple Pump Stations
- Corporation of Delta: Oliver Pump Station

Ducks Unlimited Canada Serpentine Fen

- Water Control Features to maintain environmentally sensitive area including freshwater irrigation system.

Sanitary Lift Stations

- City of Surrey: Elgin; South Port; Winter Crescent; Stewart Farm
- Metro Vancouver: Crescent Beach

Underground infrastructure

- 5 km of Metro Vancouver 750 mm diameter Water Transmission Main
- 10 km of Metro Vancouver Sanitary Sewer Forcemains (500 mm to 1050 mm diameter)
- >10 km of FortisBC Gas Mains

Overhead Utility Infrastructure

- BC Hydro Twin 500kV bulk transmission line providing Intertie between BCH & Bonneville Power
- BC Hydro local overhead distribution lines
- Shaw and Telus Telecom lines

Marine Facilities

- Crescent Beach Marina
- Wards Marina
- Private docks

Regional / International Transportation Infrastructure

- 4 km of four-lane arterial roadway
- 7 km section of Highway 99 linking Peace Arch Border
- Hwy 91 and 99 Interchange
- 4 km section of Highway 91
- 6 km dyke trail connecting to parks
- Delta-Surrey Greenway

Local Government Arterial and Collector Roads

- King George Boulevard (City of Surrey)
- 152^{nd} Street (City of Surrey)
- Colebrook Road (City of Surrey)
- Ladner Trunk Road (Corporation of Delta)

Class 1 Railways Originating at Port Metro Vancouver

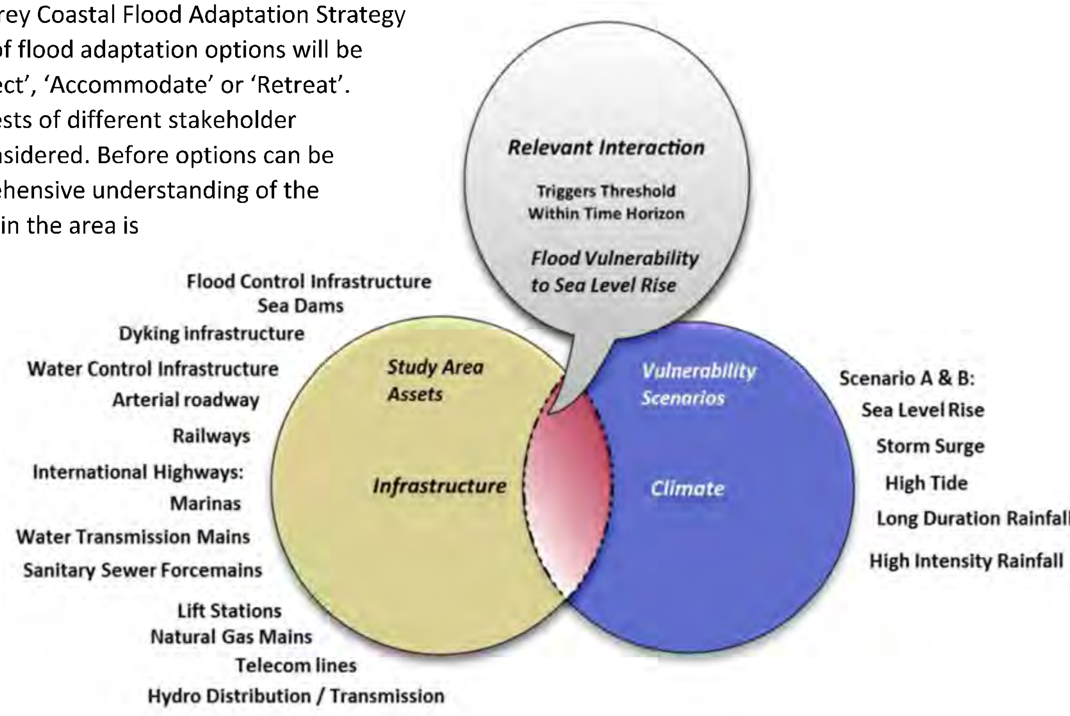
- Burlington Northern Santa Fe (BNSF) Nicomekl Swing Bridge and Trestles
- 6 km of BNSF Railway with freight frequencies between 16 and 20 trains daily and up to 4 daily Amtrak Cascades trains
- Roberts Bank Railway Corridor (BC Railway Company ownership with usage by CN, CP and BNSF) with up to 18 trains daily.
- Connection to Southern Railway of British Columbia.

Surrey/King George Airpark Turf Runway

Private Dairy Facilities for over 1,000 head of Cattle

How can we participate?

As part of the Surrey Coastal Flood Adaptation Strategy (CFAS), a variety of flood adaptation options will be explored to 'Protect', 'Accommodate' or 'Retreat'. The diverse interests of different stakeholder groups will be considered. Before options can be studied, a comprehensive understanding of the vulnerable assets in the area is needed.



A **PIEVC workshop** occurring **March 28, 2017** will involve infrastructure managers early on and solicit input to the project. Infrastructure vulnerability from two potential coastal flooding scenarios will be explored.

The scenarios include:

A) a 200-year riverine flood scenario with the water level at the ocean boundary reflecting sea level rise, and

B) a 200-yr coastal flood scenario that accounts for dyke breach and wave effects.

Both scenarios will be considered at multiple time scales from the present year to 2100. The anticipated outcomes of this workshop will be a relative risk rating of the infrastructure components and recommendations of remedial or management actions for medium- to high-risk infrastructure, which will feed into the development of the adaptation strategy.

Want more information?

For more information, please visit www.surrey.ca/coastal or email coastal@surrey.ca.

SURREY COASTAL FLOOD ADAPTATION STRATEGY (CFAS)

PRIMER

PROJECT OVERVIEW

SURREY IS PREPARING FOR CLIMATE CHANGE AND SEA LEVEL RISE WITH THE DEVELOPMENT OF A COASTAL FLOOD ADAPTATION STRATEGY (CFAS). TO BE DEVELOPED OVER THREE YEARS, THE FINAL STRATEGY WILL IDENTIFY THE CURRENT AND POTENTIAL IMPACTS OF CLIMATE CHANGE-DRIVEN SEA LEVEL RISE ON SURREY'S COASTLINE, AND THE LONG-TERM ADAPTATION OPTIONS AVAILABLE TO ADDRESS THE IMPACTS AND ADAPT TO THE CHANGES CLIMATE CHANGE WILL BRING IN THE FUTURE.

Making up about 20% of Surrey's entire land area, the coastal floodplain is a large low-lying area that stretches from Boundary Bay and Mud Bay along the Nicomekl and Serpentine Rivers towards Cloverdale and Newton. The area also includes the Campbell River/Semiahmoo Bay area near White Rock and Semiahmoo First Nation. It is home to historic and important neighbourhoods, farms and businesses, critical infrastructure and transportation corridors, and internationally recognized bird and wildlife habitat.

CFAS TIMELINE

The CFAS project is broken into five general phases that will be completed over the next three years. This Primer is part of Phase 1, but will be used in future phases. It is intended to help build awareness of sea level rise and Surrey's coastal flooding challenge, and to help residents and others stakeholders actively engage in the CFAS project.

▲ Coastal floodplain and study area

Communities and People

- Many residential areas and neighbourhoods, including Crescent Beach, Panorama/Gray Creek, Cloverdale, Inter-River Area, Colebrook, Mud Bay, Nico-Wynd/Crescent Road
- Semiahmoo First Nation
- 1,500+ residents
- Approximately 20% of Surrey's land area

Local and Regional Economy

- Over 30km^2 of agricultural land in production
- 700+ jobs
- Over $100 million in annual farm gate revenue
- Over $1 billion in assessed property value
- Almost $25 billion annual truck and rail freight traffic

Parks and Environment

- Regional and City parks, beaches and recreation areas, including Surrey's only public ocean beach
- Significant natural areas with very high biodiversity values, including foreshore, riparian and coastal areas
- Internationally important migratory bird habitat

Infrastructure

- Over 10km of Provincial Highways
- Over 200,000 vehicle trips a day
- Over 30km of railway (freight and passenger)
- Regional sewer and water lines
- Major power transmission lines
- Natural gas pipelines

PHASE 1: summer 2016 - spring 2017
WHAT MATTERS MOST AND WHO IS AFFECTED?
Education, awareness building, and community values

PHASE 2: spring 2017 - summer 2017
WHAT CAN WE DO?
Exploring adaptation options

PHASE 3: summer 2017 - fall 2017
WHAT IS ACCEPTABLE?
Developing adaptation strategies

PHASE 4: fall 2017 - spring 2018
HOW WILL WE DO IT?
Detailing preferred strategies

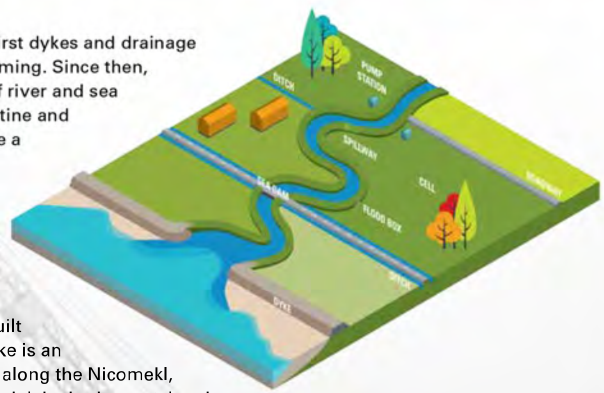
PHASE 5: spring 2018
REPORTING BACK
Final reporting

SURREY'S COASTAL FLOODPLAIN

AS A NATURAL FLOODPLAIN, THE AREA HAS REGULARLY EXPERIENCED SOME COASTAL FLOODING OVER THE YEARS FROM HIGH TIDES AND STORM SURGES, AND RIVER FLOODS WHICH ARE TYPICALLY CAUSED BY RAIN STORMS AND RAPID SNOW MELT. RIVER FLOODING CAN ALSO BE INFLUENCED BY HIGH TIDES AND STORM SURGES.

WHAT'S KEEPING US DRY TODAY?

European settlement in the 1890's saw the first dykes and drainage ditches being created to reclaim land for farming. Since then, Surrey has developed a complex network of river and sea dykes along the coast and along the Serpentine and Nicomekl Rivers. Working with the dykes are a system of drainage ditches, spillways and pumps that help move water from behind dykes.



DYKES

A sea dyke is a long wall or embankment built to prevent flooding from the sea. A river dyke is an embankment built to prevent river flooding along the Nicomekl, and Serpentine Rivers. Most of Surrey's floodplain, both coastal and inland sections, are protected by dykes. Many dykes in Surrey are also popular walking trails and bicycle routes.

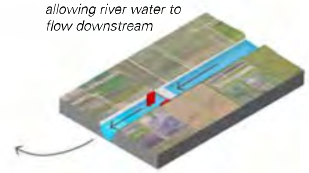
- *Background image: Construction of dyke at Mud Bay, c.1890. Photo courtesy Surrey Archives and Museum.*
- *Below: Dyke and recreation path at Mud Bay Park today.*

Wondering why we spell dyke with a 'y'?
In 1912, early settlers to the Municipality of Surrey formed the Surrey Dyking District, using the preferred spelling at that time. While dike is now the preferred spelling, in recognition of the extensive work done to improve drainage by the all the dyking districts over the past 100-years, Surrey continues to spell dyke in Old English, when referring to flood control works. In the USA, the term levee is generally used as an alternative to dyke.

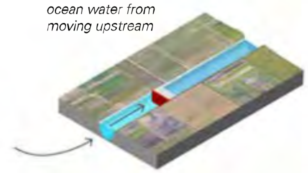
SEA DAMS

Sea dams are constructed along tidal rivers, like the Nicomekl and Serpentine Rivers, to keep salty ocean water from moving upstream where it could have detrimental effects on agricultural irrigation. Sea dams are tidally influenced and gravity-fed, with the incoming tide pushing their gates closed (B) and the river pushing them open once the tide moves out (A). The Nicomekl and Serpentine sea dams were first built in 1912 and 1913.

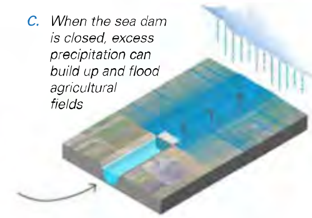
A. The gravity-fed sea dam opens as tides recede, allowing river water to flow downstream



B. The sea dam closes as tides rise, preventing ocean water from moving upstream



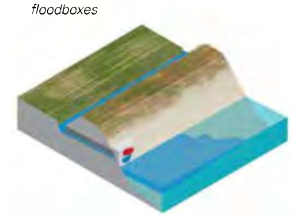
C. When the sea dam is closed, excess precipitation can build up and flood agricultural fields



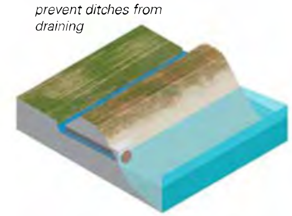
DITCHES, FLOODBOXES AND PUMPS

Surface water flows into drainage ditches which then direct water through floodboxes located along the river. During low tides and when the river water is low enough, the water drains into the river by gravity-fed flap gates (A). When river levels are higher the flood boxes are submerged and their gates are closed (B). During high tides or when sea dams are closed, electrically powered pumps, like the Maple Pump Station in Crescent Beach, are used to help push the water into the rivers.

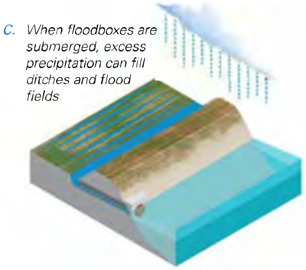
A. When river levels are low, ditches drain through floodboxes



B. When river levels are high, submerged floodboxes prevent ditches from draining



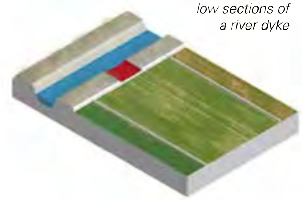
C. When floodboxes are submerged, excess precipitation can fill ditches and flood fields



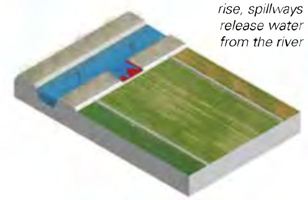
SPILLWAYS

A spillway is a low section of a river dyke (A) where, during floods, water can spill over into a holding area called a cell (B&C). These cells are located on agricultural fields and typically only used in winter months when the fields are fallow. Once the flood event has ended and river level returns to normal, water stored in the cells will drain back into the river through floodboxes or with the assistance of pumps.

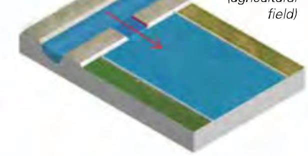
A. Spillways are low sections of a river dyke



B. As water levels rise, spillways release water from the river



C. The water spills over into a temporary holding area (agricultural field)



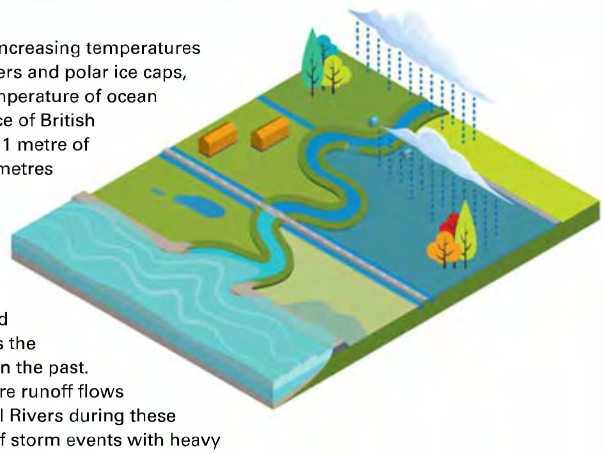
THE CHANGING CLIMATE MEANS THAT THE HISTORIC CONTROLS THAT HAVE BEEN PUT IN PLACE WILL LIKELY NOT PERFORM WELL IN THE FUTURE WITH RISING SEA LEVELS, MORE FREQUENT STORM SURGES, AND INCREASED PRECIPITATION. WITH SEA LEVEL RISE, THE DURATION THAT RIVERS CAN FREELY DRAIN WILL BE SHORTER.

CLIMATE CHANGE, CLIMATE HAZARDS, AND COASTAL FLOODING

AS WITH MANY COASTAL FLOODPLAINS AROUND THE WORLD, THE TWO PRINCIPAL CAUSES OF INCREASED FLOODING IN SURREY'S COASTAL FLOODPLAIN ARE SEA LEVEL RISE AND INCREASED MAGNITUDE AND INTENSITY OF RAIN. THE EFFECTS OF SEA LEVEL RISE ARE GREATER THAN THOSE OF RAINFALL IN SURREY'S COASTAL FLOODPLAIN.

SEA LEVEL RISE

Global sea level is rising. This is a result of increasing temperatures throughout the world that are melting glaciers and polar ice caps, and that are also increasing the average temperature of ocean waters causing them to expand. The Province of British Columbia advises municipalities to plan for 1 metre of sea level rise over the next 80 years, and 2 metres by 2200.



INCREASED RAINFALL

With the changing climate, we can expect more extreme weather conditions. For example, in Surrey, winters are expected to have fewer wet days, but on the wet days the rainfall amounts will be much greater than in the past. This will result in increased flooding, as more runoff flows into the Nicomekl, Serpentine and Campbell Rivers during these storm events. The frequency and intensity of storm events with heavy precipitation are also expected to increase.

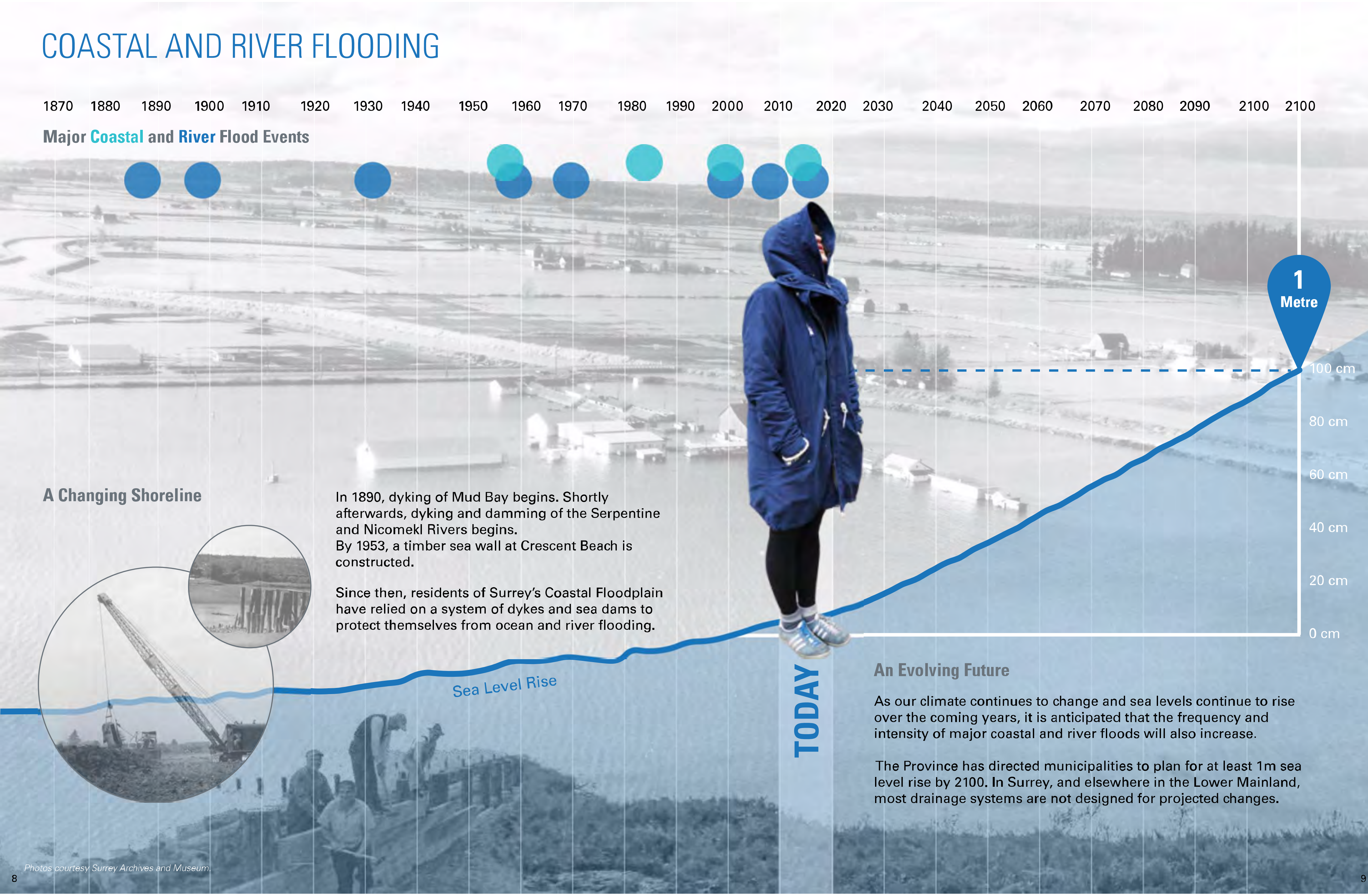
Projected impacts for Surrey's coastal area include higher sea levels, increased frequency and intensity of storms and storm surges (when water is pushed ashore by wind and waves), more erosion of the coastline, impacts on infrastructure, loss of beaches and coastal ecosystems, soil salinization, and groundwater pooling.

FLOOD HAZARD IMPACTS

	TODAY	FUTURE
OCEAN FLOOD HAZARDS	· *High tides* · *Storm surges*	· *High tides* · *Storm surges* · *Sea level rise*
IMPACTS	· *Breach or overtopping of dykes* · *Temporary inundation* · *Coastal erosion* · *Potential injuries or loss of life* · *Damage to residential, commercial & other development* · *Infrastructure & transportation damage & disruption* · *Business disruptions* · *Agricultural losses (livestock, crops)* · *Habitat loss & impacts (with associated impacts to species)* · *Cultural & social losses* · *Longer duration of sea dam closures, which creates more water backing river, reduced fish passage, and water quality problems*	· *Long-term inundation* · *Salination* · *Coastal squeeze* · *Same as TODAY but more frequent and more severe consequences*

	TODAY	FUTURE
RIVER FLOOD HAZARDS	· *Long duration and intense rainfall or rain-on-snow event*	· *Increased and more intense rainfall and runoff* · *Reduced sea dam capacity due to sea level rise*
IMPACTS	· *Activation of spillways and inundation of floodplain* · *Sea dams inadequate for drainage* · *Potential injuries* · *Damage to residential and commercial development* · *Business/transportation disruptions* · *Some agricultural losses* · *Some cultural and social losses*	· *Frequent activation of spillways and longer-term inundation of fields* · *Floodboxes closed for longer periods (combined with higher runoff and longer dam closures)* · *Limited land-use potential* · *Frequent or permanent transportation disruptions* · *Same as TODAY but more frequent and more severe consequences*

COASTAL AND RIVER FLOODING



A Changing Shoreline

In 1890, dyking of Mud Bay begins. Shortly afterwards, dyking and damming of the Serpentine and Nicomekl Rivers begins.
By 1953, a timber sea wall at Crescent Beach is constructed.

Since then, residents of Surrey's Coastal Floodplain have relied on a system of dykes and sea dams to protect themselves from ocean and river flooding.

An Evolving Future

As our climate continues to change and sea levels continue to rise over the coming years, it is anticipated that the frequency and intensity of major coastal and river floods will also increase.

The Province has directed municipalities to plan for at least 1m sea level rise by 2100. In Surrey, and elsewhere in the Lower Mainland, most drainage systems are not designed for projected changes.

Photos courtesy Surrey Archives and Museum.

AGRICULTURE AND FARMING

AGRICULTURE AND FARMING SECTOR PLAYS A SIGNIFICANT ROLE IN SURREY'S ECONOMY. WITH OVER 1/3 OF SURREY'S LAND BASE IN THE PROVINCIAL AGRICULTURAL LAND RESERVE (A PROVINCIAL ZONE IN WHICH AGRICULTURE IS RECOGNIZED AS THE PRIORITY USE), THE SECTOR GENERATES ABOUT A QUARTER OF TOTAL GROSS ANNUAL FARM RECEIPTS IN METRO VANCOUVER, OR ABOUT $170 MILLION IN 2010. THE SECTOR ALSO EMPLOYS HUNDREDS, INCLUDING FARM FAMILIES AND SEASONAL WORKERS. THE PROJECT STUDY AREA IS A LARGE AND IMPORTANT PART OF SURREY'S AGRICULTURAL SECTOR.

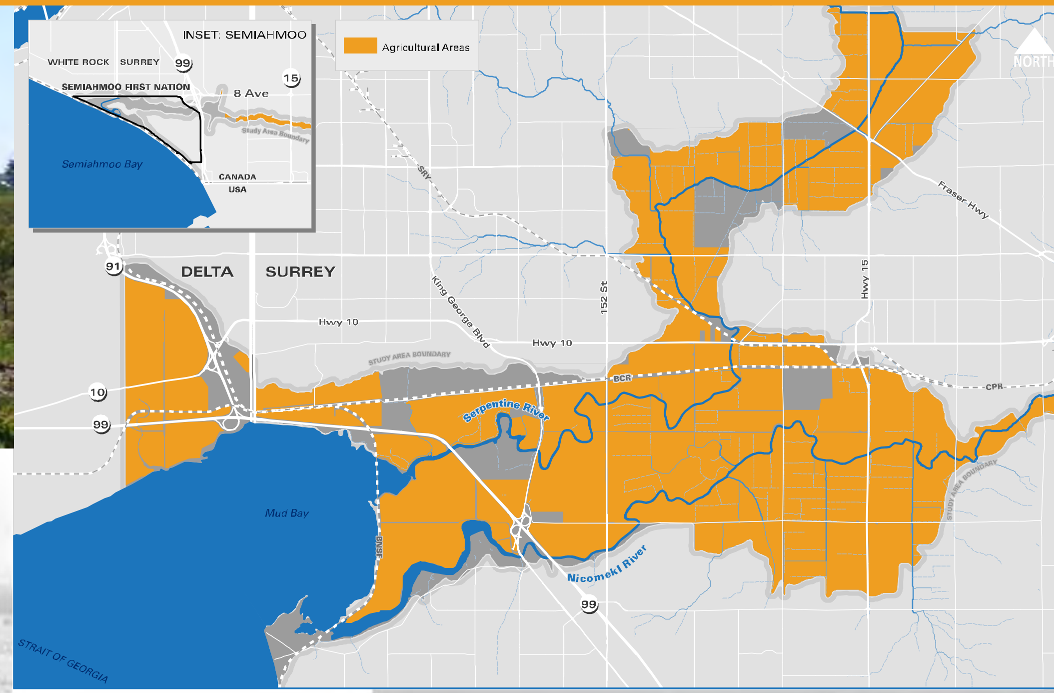
FACTS

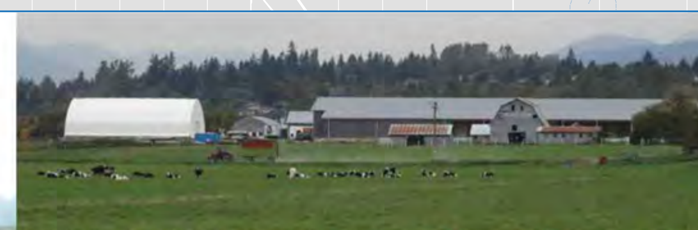
- *Over 30km² of Agriculture Land in production*
- *Over $100 million in annual farm gate revenue (or about 60% of Surrey's total farm gate revenue)*
- *Diversified crops and production – dairy, berries, field crops, mushrooms*

Background image: Farmer rescuing pumpkins floating in a flooded field, c.1955. Photo courtesy Surrey Archives and Museum.

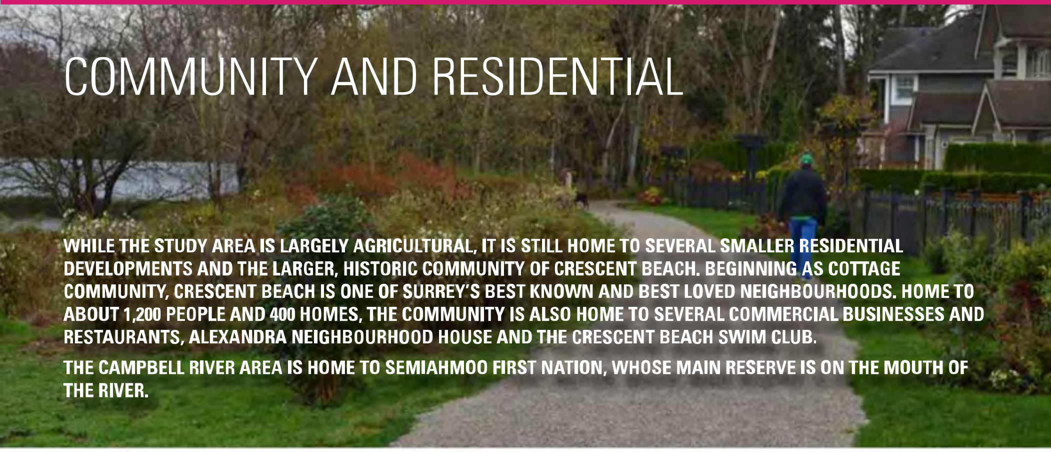
CLIMATE CHANGE IMPACTS

- *Increased flooding (from higher, climate change-driven precipitation and river levels)*
- *Poor and reduced field drainage (pumps and drainage system impeded by increased flooding)*
- *Increased risk to coastal areas from coastal flooding (seawater inundation leaves residues of salts, such as sodium, on the soil – high concentrations of which can damage soil structure for years)*
- *Increased precipitation, storm frequency and intensity can delay or impact field crop planting, growing season, and harvesting*





COMMUNITY AND RESIDENTIAL



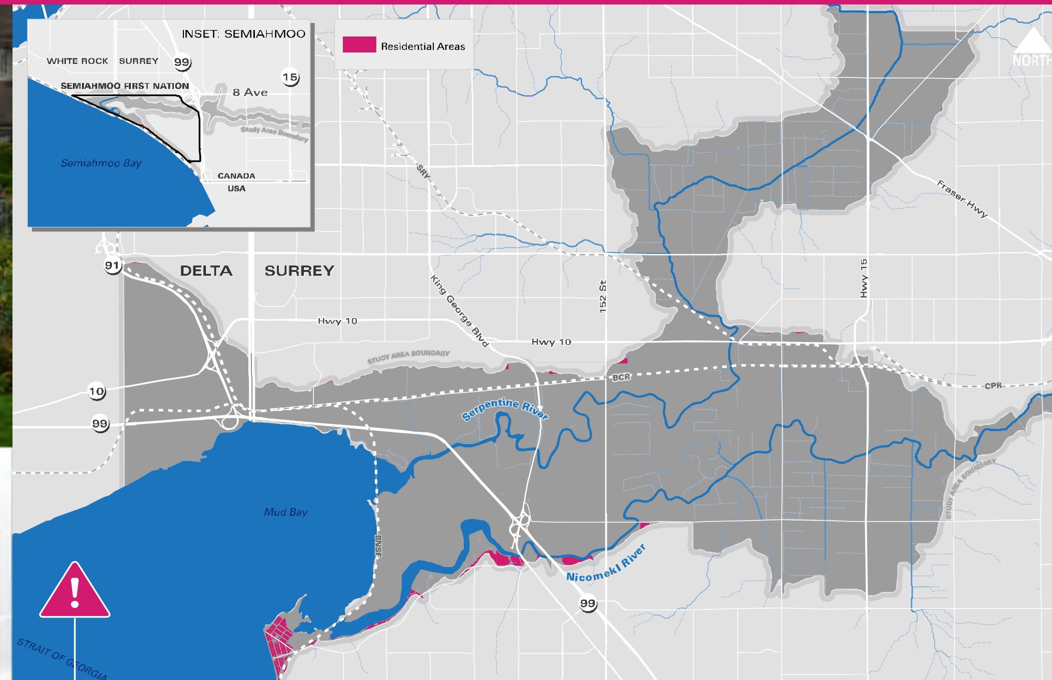
WHILE THE STUDY AREA IS LARGELY AGRICULTURAL, IT IS STILL HOME TO SEVERAL SMALLER RESIDENTIAL DEVELOPMENTS AND THE LARGER, HISTORIC COMMUNITY OF CRESCENT BEACH. BEGINNING AS COTTAGE COMMUNITY, CRESCENT BEACH IS ONE OF SURREY'S BEST KNOWN AND BEST LOVED NEIGHBOURHOODS. HOME TO ABOUT 1,200 PEOPLE AND 400 HOMES, THE COMMUNITY IS ALSO HOME TO SEVERAL COMMERCIAL BUSINESSES AND RESTAURANTS, ALEXANDRA NEIGHBOURHOOD HOUSE AND THE CRESCENT BEACH SWIM CLUB.

THE CAMPBELL RIVER AREA IS HOME TO SEMIAHMOO FIRST NATION, WHOSE MAIN RESERVE IS ON THE MOUTH OF THE RIVER.

FACTS

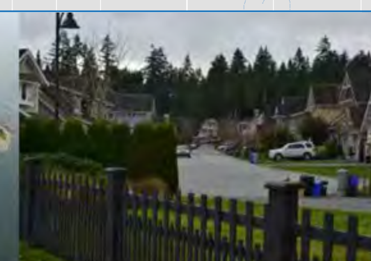
- *About 1,500 residents in total in study area.*
- *Semiahmoo First Nation is home to about 50 members*
- *Alexandra Neighbourhood House started out as a camp for orphaned children from Vancouver in 1916 and has since grown into a diversified community service agency.*
- *There are three strata developments in the study area - Nico Wynd, SouthPort, and Anderson Walk – which together include about 250 residences*
- *Surrey developed a comprehensive stormwater management strategy for Crescent Beach to help prepare the community for increased flooding behind its protective dykes*

Background image: Alexandra Orphanage Camp, c.1926. Photo courtesy Surrey Archives and Museum.



CLIMATE CHANGE IMPACTS

- *Catastrophic flooding will become frequent (without future improvements)*
- *Surface ponding and so-called nuisance flooding may become near permanent over time in Crescent Beach*
- *Increased chance of road closures and lengthy detours from flooding and overtopping during storm surges*
- *Property damage – residential and commercial*
- *Business interruptions*



ENVIRONMENTAL AND RECREATION

THE CFAS PROJECT AREA IS HOME TO SEVERAL POPULAR SURREY AND METRO VANCOUVER PARKS THAT INCLUDE SEVERAL KILOMETRES OF SHORELINE TRAILS WITH INCREDIBLE VIEWS OF BOUNDARY BAY. DIVERSE WILDLIFE HABITATS, INCLUDING EELGRASS MEADOWS, MUD FLATS, SALT MARSH AND OLD FIELDS, MAKE IT ONE OF THE BEST WILDLIFE VIEWING AREAS IN SURREY. IT IS ALSO HOME TO PROVINCIALLY AND FEDERALLY PROTECTED WILDLIFE AREAS AND THE SPECIES AT RISK THAT LIVE THERE (SEE BELOW). THOUSANDS OF MIGRATORY BIRDS USE MUD BAY AND THE LARGER AREA AS A REST STOP AS THEY TRAVEL ALONG THE PACIFIC FLYWAY, WHICH IS A 'HIGHWAY IN THE SKY' STRETCHING FROM ALASKA AND THE CANADIAN ARCTIC TO CENTRAL AND SOUTH AMERICA.

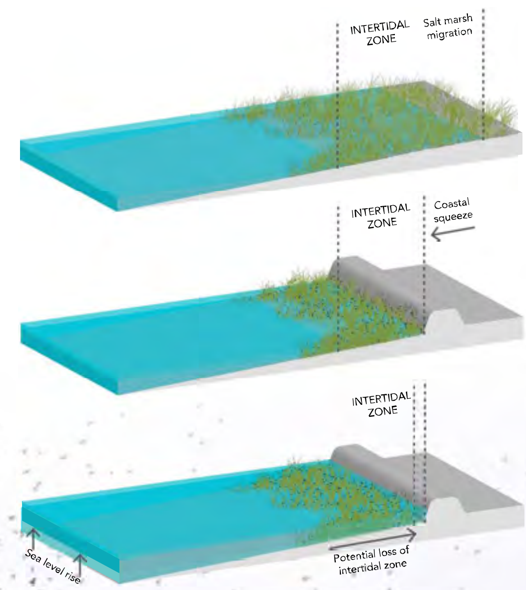
FACTS

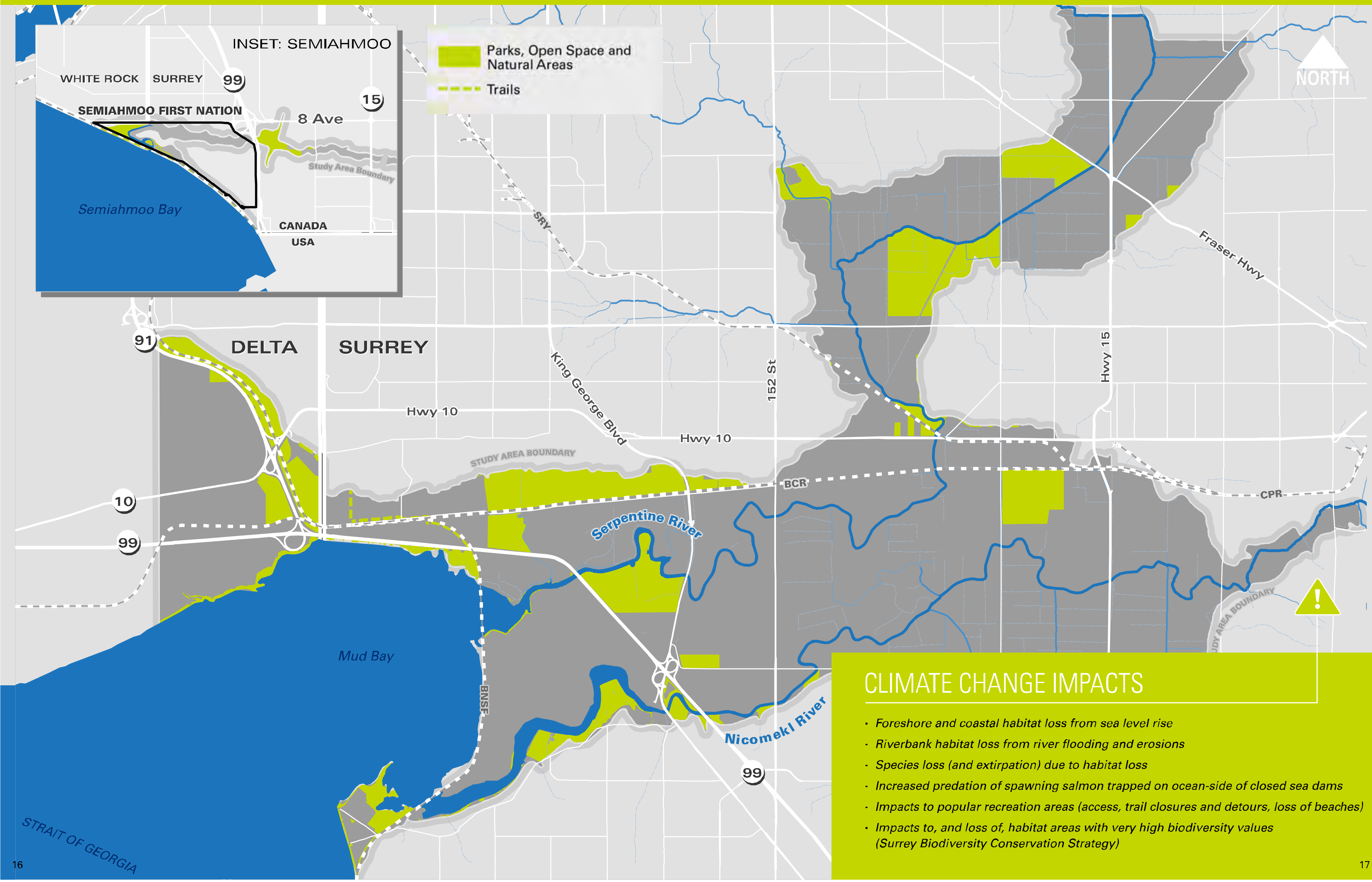
- *Almost 100,000 visitors a year walk, jog, wheel and bike the trails at Mud Bay Park and along Colebrook Dyke trail*
- *Internationally recognized wildlife area - Migratory Bird Sanctuary (federal), National Wildlife Area (federal), Provincial Wildlife Management Area, Ramsar Site (Wetland of International Significance), Western Hemisphere Shorebird Reserve Network*
- *Several Red Listed and Blue Listed species at risk, including birds, animals, fish and plants*

COASTAL SQUEEZE

Coastal habitats are being trapped and "squeezed" between dykes and rising sea levels, reducing the amount of the important foreshore and coastal habitat over time.

- *Thousands of migratory birds use Mud Bay as a rest stop as they travel along the Pacific Flyway, which is a 'highway in the sky' stretching from Alaska and the Canadian Arctic to Central and South America*





CLIMATE CHANGE IMPACTS

- Foreshore and coastal habitat loss from sea level rise
- Riverbank habitat loss from river flooding and erosions
- Species loss (and extirpation) due to habitat loss
- Increased predation of spawning salmon trapped on ocean-side of closed sea dams
- Impacts to popular recreation areas (access, trail closures and detours, loss of beaches)
- Impacts to, and loss of, habitat areas with very high biodiversity values (Surrey Biodiversity Conservation Strategy)

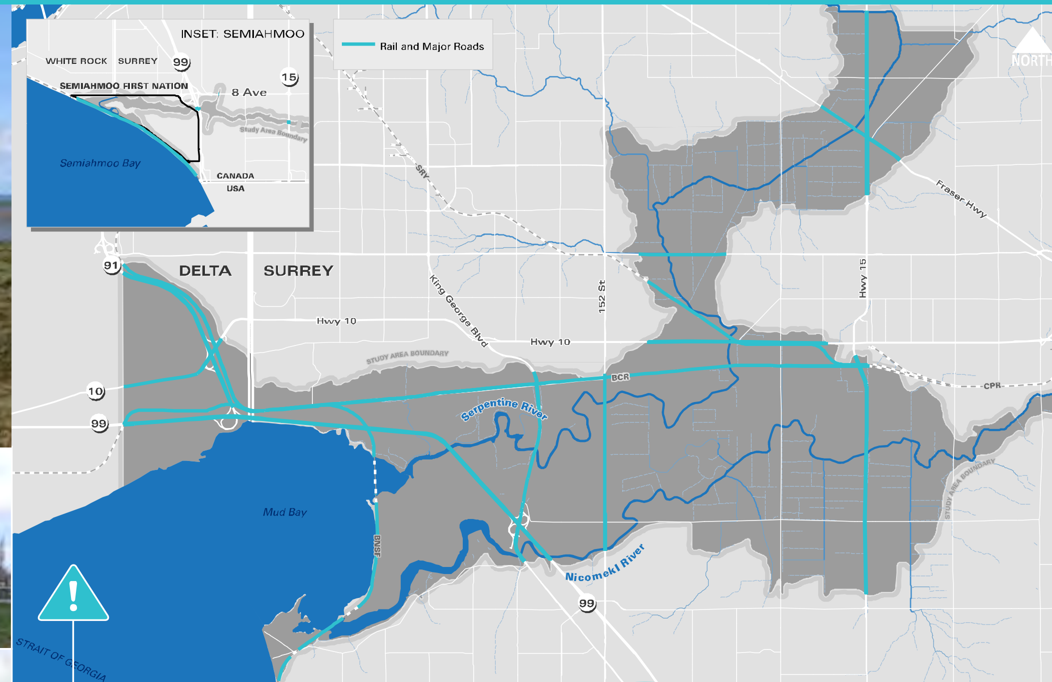
TRANSPORTATION AND INFRASTRUCTURE

MAJOR INFRASTRUCTURE, INCLUDING RAIL LINES, HIGHWAYS AND UTILITY CORRIDORS, ALL PASS THROUGH THE CFAS PROJECT AREA. IN ADDITION TO EXISTING INFRASTRUCTURE, THE CITY OF SURREY IS CURRENTLY IN THE MIDDLE OF A $25 MILLION COMPREHENSIVE STORMWATER MANAGEMENT STRATEGY FOR CRESCENT BEACH TO HELP PROTECT AND PREPARE THE COMMUNITY FOR INCREASED COASTAL FLOODING AND CLIMATE CHANGE WHICH INCLUDES A NEW PUMP STATION (MAPLE PUMP STATION), NEW STORM SEWERS, AND A PLAN TO RAISE KEY ROADS ~0.3M METRES AS A FIRST STEP IN A LONG-TERM ROAD RAISING STRATEGY.

Surrey has also embarked upon a $15 million project with support from the Province to upgrade and raise about 8 kilometres of dyke along Colebrook Road from King George Boulevard to Delta and along Mud Bay. The area is considered one of the Surrey's most vulnerable areas for flooding because of its sinking soils, low-level dykes, wind and wave exposure and king tides.

FACTS

- *Major international utility corridors – BC Hydro and Fortis*
- *Major regional utilities – Metro Vancouver water supply and sewage lines*
- *Over 10 km of Provincial Highways*
- *Over 200,000 vehicle trips a day*
- *Over 30 km of railway (BNSF freight and Amtrak passenger)*
- *Almost $25 billion annual truck and rail freight traffic*

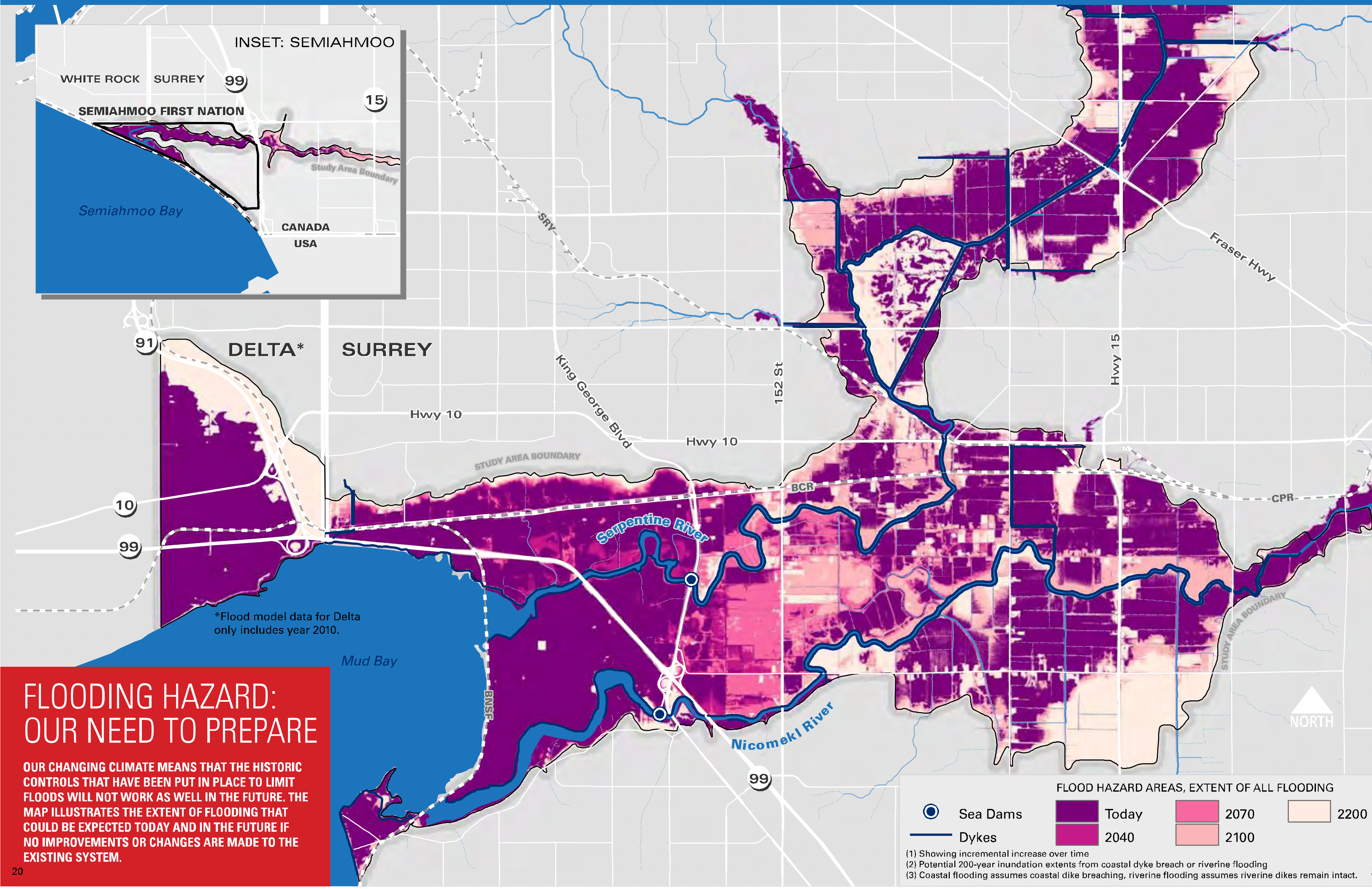


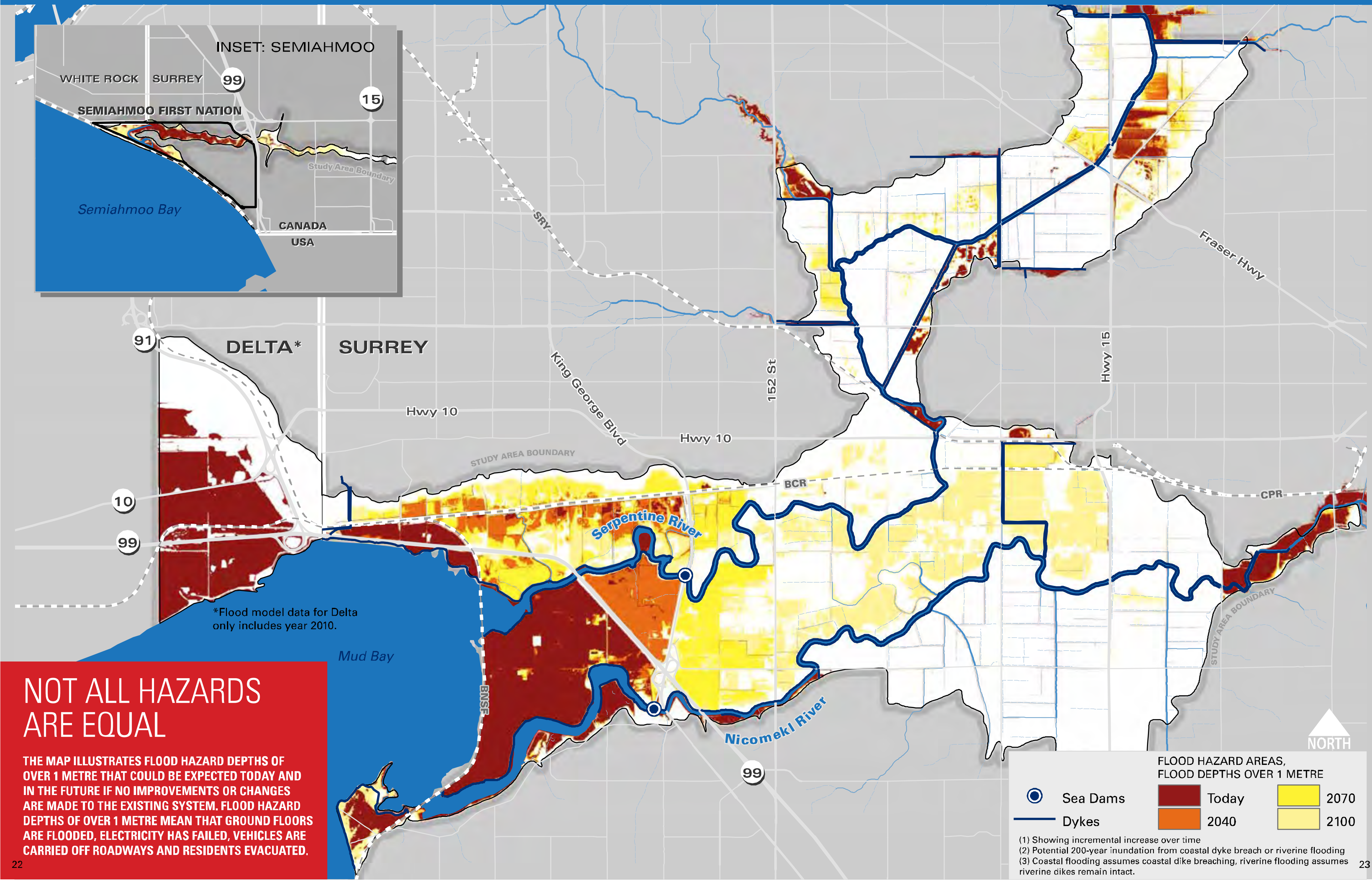
CLIMATE CHANGE IMPACTS

- *Serpentine and Nicomekl dykes are not high enough to protect against anticipated 2100 flood levels*
- *Serpentine sea dam is not seismically sound*
- *Few of the Serpentine and Nicomekl River dykes will meet the Provincial 200-year standard by 2020.*
- *By 2070, it is expected that all dykes will be overtopped multiple times per year, with overtopping likely resulting in dyke failure.*
- *At present, under the 200-year flood condition, a portion of Highway 99 would be inundated, including bridge decks at three locations*
- *Erosion, interruption of railway operations and goods movement*

FLOODING HAZARD: OUR NEED TO PREPARE

OUR CHANGING CLIMATE MEANS THAT THE HISTORIC CONTROLS THAT HAVE BEEN PUT IN PLACE TO LIMIT FLOODS WILL NOT WORK AS WELL IN THE FUTURE. THE MAP ILLUSTRATES THE EXTENT OF FLOODING THAT COULD BE EXPECTED TODAY AND IN THE FUTURE IF NO IMPROVEMENTS OR CHANGES ARE MADE TO THE EXISTING SYSTEM.



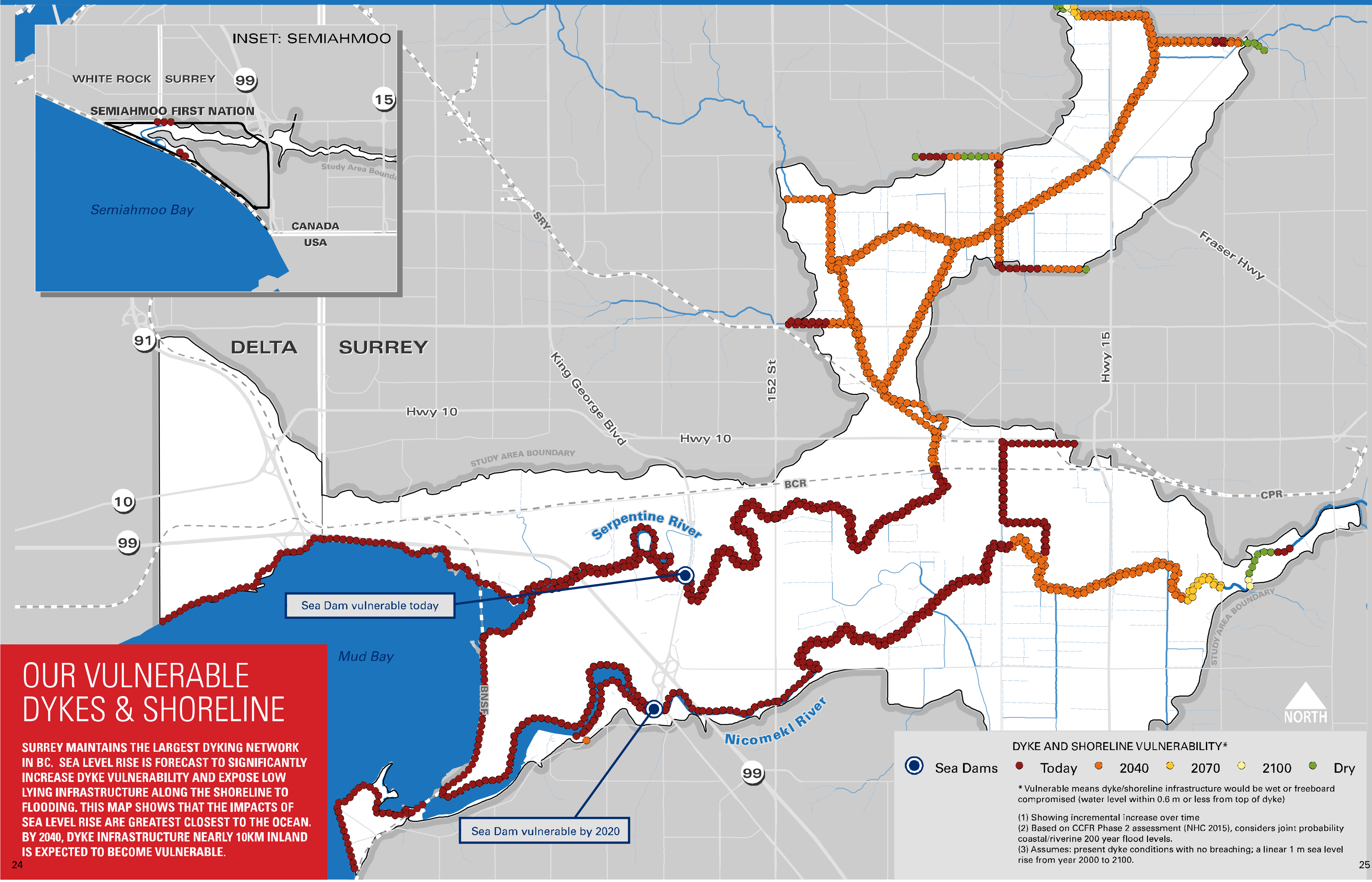


NOT ALL HAZARDS ARE EQUAL

THE MAP ILLUSTRATES FLOOD HAZARD DEPTHS OF OVER 1 METRE THAT COULD BE EXPECTED TODAY AND IN THE FUTURE IF NO IMPROVEMENTS OR CHANGES ARE MADE TO THE EXISTING SYSTEM. FLOOD HAZARD DEPTHS OF OVER 1 METRE MEAN THAT GROUND FLOORS ARE FLOODED, ELECTRICITY HAS FAILED, VEHICLES ARE CARRIED OFF ROADWAYS AND RESIDENTS EVACUATED.

OUR VULNERABLE DYKES & SHORELINE

SURREY MAINTAINS THE LARGEST DYKING NETWORK IN BC. SEA LEVEL RISE IS FORECAST TO SIGNIFICANTLY INCREASE DYKE VULNERABILITY AND EXPOSE LOW LYING INFRASTRUCTURE ALONG THE SHORELINE TO FLOODING. THIS MAP SHOWS THAT THE IMPACTS OF SEA LEVEL RISE ARE GREATEST CLOSEST TO THE OCEAN. BY 2040, DYKE INFRASTRUCTURE NEARLY 10KM INLAND IS EXPECTED TO BECOME VULNERABLE.



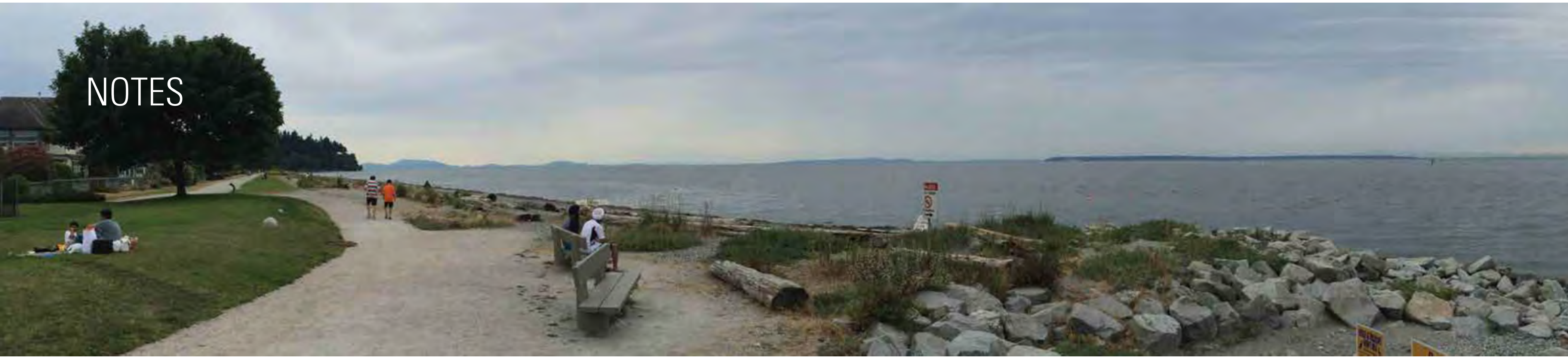
DYKE AND SHORELINE VULNERABILITY*

Sea Dams · Today · 2040 · 2070 · 2100 · Dry

* Vulnerable means dyke/shoreline infrastructure would be wet or freeboard compromised (water level within 0.6 m or less from top of dyke)

(1) Showing incremental increase over time
(2) Based on CCFR Phase 2 assessment (NHC 2015), considers joint probability coastal/riverine 200 year flood levels.
(3) Assumes: present dyke conditions with no breaching; a linear 1 m sea level rise from year 2000 to 2100.

NOTES



WHAT'S NEXT?

Engagement with residents, stakeholders, and other project partners is paramount to the success of the CFAS project. A range of stakeholder engagement activities and opportunities for feedback and participation will be provided throughout the multi-year process. If you or your organization are interested in learning more about the project, or are interested in a presentation, let us know (see contact information).

All project information, including dates for upcoming presentations and events, and all CFAS project materials (videos, information materials, reports) will be posted on the project website. This Primer is also available on the website.

www.surrey.ca/coastal

There will be a second round of feedback sessions later this spring to present back what was heard at the kick-off Focus Groups.

CONTACT US

For more information, please contact:

Matt Osler
Project Engineer
City of Surrey
coastal@surrey.ca
604.591.4657

CFAS

CITY OF SURREY
the future lives here.

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Surrey Coastal Flood Adaptation Strategy (CFAS) Infrastructure Asset Managers, Operators and Emergency Services Questionnaire

We invite you to fill out the following questionnaire to identify the critical infrastructure in the study area that you manage or rely on to delivering services in the Mud Bay area. This information will assist us in the preparation of the stakeholder workshop.

Who are you?

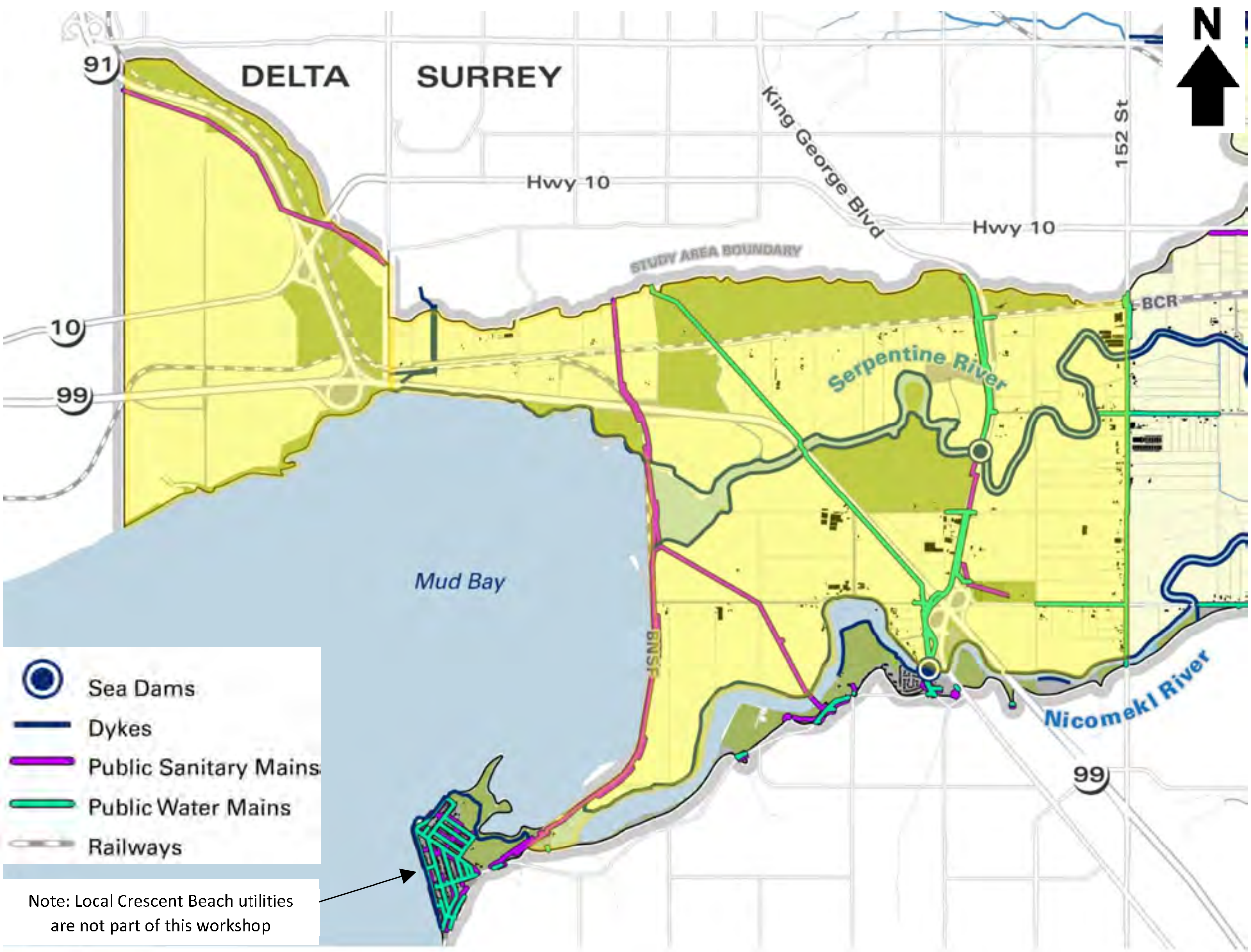
Organization:

Position:

Tell us about the infrastructure?

What infrastructure/ assets do you manage or rely on, in the Mud Bay area?

(To assist in this, please reference the infrastructure listing in the backgrounder and the area map below. Is the information complete? If not please provide additional details or corrections.)



PLEASE TURN OVER

Surrey Coastal Flood Adaption Strategy (CFAS)
Infrastructure Asset Managers, Operators and Emergency Services Questionnaire

What is your experience with flooding?

How has flooding affected your organization's infrastructure or delivery of services in the Mud Bay area?

What is your knowledge of current and future flood risk?

What are you doing about it?

What steps are you taking to adapt to increased flood risk?

Other issues?

Are there other areas of concerns or issues in the area that may be of interest in the workshop?

Thank you for your input. If you have any questions, please contact Matt Osler at 604-591-4657.

Please return this survey to MFOsler@surrey.ca by March 17, 2017.

Appendix B - Participant Risk Score and Adaptation Comments

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PIEVC Assessment Worksheet - Participant Risk Scores and Comments

Flood Scenario

Associated Engineering

Table Group A

Infrastructure Components	Flood Scenario A - Current				Flood Scenario A - Future				Rational For Consequence
TRANSPORTATION	Y/N	P	C	R	Y/N	P	C	R	
Runway									
Surrey/King George Airpark Turf Runway	Y	4	1,1,1,1,1,2,1	4	Y	5	1,1,1,1,1,1,1,4,1	5	Fuel on-site: environmental issue. Mostly private impacts. Low due to it being a recreational facility. Fuel on site - private site. Fuel stored on site. Oil / gas stored at site. Fuel stored on site. Grass runway is fairly resilient. Most aircraft can be flown out with advance notice.
Regional / International Transportation Infrastructure									
4 km of four-lane arterial roadway	Y	4	3,3,3,3,3,4,3	12	Y	5	4,5,5,5,5,5,5	25	Lower impact in today's conditions. Infrastructure damages. Commuter traffic.
7 km section of Highway 99 linking Peace Arch Border	Y	4	3,4,4,4,4,4,3,4,4	16	Y	5	4,5,5,5,5,5,4,5,5	25	Today infrastructure would be intact if damaged. At higher flood levels, impact on Hwy 99 is elevated. Major consequence of highway closure due to flooding. Major corridor; structural damage; main commerce thruway. Major corridor. Major damages to infrastructure / commerce. Bridges. Major corridor & source of commerce. International customs alternate crossings at Hwy 15. Connection to US border tourism, local emergency response, truck trade, scouring at bridges (typical for Hwy 99 and 91)
Highway 91 and 99 Interchange	Y	4	4,3,3,3,3,4,3,3	12	Y	5	4,4,4,4,5,4,4,4,4	20	Interchange is elevated and higher than dyke, but impact is mostly on Hwy 99. Interchange at higher elevation - depends on connections. Assumptions: no data for future; dependent on connections. Major corridor / commerce. No data - connectivity issue. Structural. Assumption no data; dependent network connectivity. Wave impacts damage / erosion / drawdown. Spread footing damage, EPS flotation at approaches.
4 km section of Highway 91	Y	4	2,1,1,1,1,5,1	8	Y	5	3,1,1,1,4,1,5,5,1	20	No data for future. Traffic impacts. Can be used for serviceability / access. Highway likely closed, maybe used to direct traffic to ? No data for future. Traffic congestion. Limited data. No data. No way around.
6 km dyke trail connecting to parks	Y	4	1,1,1,1,1,1,1	4	Y	5	1,1,1,1,1,1,2,1	5	Loss of trail itself is inconvenience, dyke is another issue as far as impact. If trail isn't replaced, loss of public asset and quality of life impacted. Trail loss / recreational loss. Rated as a trail, not as a dyke - 1 million visitors / year. Dyke 'significant' - trail perspective ' insignificant' Rated as trail. Rated as trail - could effect community quality of life. Some environmental damage. loss of trail use an inconvenience only - cost to rebuild, quality of life (typical for Delta Surrey Greenway)
Delta-Surrey Greenway	Y	4	1,1,1,1,1,1,1	4	Y	5	2,1,1,1,1,1,2,1	5	Loss of trail itself is inconvenience, dyke is another issue as far as impact. If trail isn't replaced, loss of public asset and quality of life impacted. Loss of connectivity . Rated as a trail, not a dyke - 1 million visitors / year. Consideration of quality of life - 1M visitors / year. Local.
Crescent Road									
Local Government Arterial and Collector Roads									
King George Boulevard (City of Surrey)	Y	4	4,3,3	12	Y	5	4,5,5	25	Considered duplicate of #6 for many responses. Lower impact in today's conditions. Bridges.
152nd Street (City of Surrey)	Y	4	1,1,1,1,1,1	4	Y	5	4,4,4,4,3,4,3,4	20	Important network connection. Divide line - emergency services; network reliability. Network reliability. Community divide line - access to South Surrey / White Rock. Volume of services; network reliability. No current risk but yes in future.
Colebrook Road (City of Surrey)	Y	4	2,1,1,1,1,3,1,2,1	8	Y	5	3,3,3,3,2,3,3,3	15	Not a critical link, few people and bus. Access to properties.

Table Group B

Infrastructure Components	Flood Scenario A - Current				Flood Scenario A - Future				Rational For Consequence
TRANSPORTATION	Y/N	P	C	R	Y/N	P	C	R	
Runway									
Surrey/King George Airpark Turf Runway	Y	4	1,1,1,1,1,1,1,1	4	Y	5	1,1,1,1,1,1,1	5	Impacts very little for very few. Costs / risks borne privately. Private. Not for the overall communities - private, few people. Not catastrophic for anyone other than those effected (few people). Not regionally significant. Private, few people.
Regional / International Transportation Infrastructure									
4 km of four-lane arterial roadway	N	4				5			Interpreted as King George below.
7 km section of Highway 99 linking Peace Arch Border	Y	4	4,4,4,4,4,3,4	16	Y	5	5,5,5,5,5,5,5	25	International border - N/S link. If we lose the bridge, takes longer to recover. 2 bridges + 2 culverts, approaches. Wave impacts, approaches, structural loss, scour. 2 (older) bridges, 2 culverts. Many months if lost a bridge. Corrosion (culverts etc) - wave impacts. 2 major bridges / wave impacts existing / major routes. Waves impacts during existing. Bridges and culverts.
Highway 91 and 99 Interchange	N	4			Y	5	5,5,5,5,5,5,5	25	Erosion from wave impact - possible structural issue. Major. Structural. Approaches are gone. Both highway - high foundation. Rotational failure. Structural. Major route / may impact approaches. Wave impacts / approaches / structural loss (scour).
4 km section of Highway 91	N	4			Y	5	4,4,4,4,4,4,4	20	Time to recover. Major. No way around. Ways around it - less time to recover. Alternate routes. Major route, can bypass. Ways around easier / time to recover.
6 km dyke trail connecting to parks	Y	4	1,1,1,1,1,1,1	4	Y	5	1,1,1,1,1,1,1	5	Local. Local impact. Local impact. Local impacts. Not significant to region for short term. Local impact not high.
Delta-Surrey Greenway	N	4			Y	5	1,1,1,1,1,1,1	5	Local. Local. Local impacts. Not significant to region for short term. Local impact not high.
Crescent Road									
Local Government Arterial and Collector Roads									
King George Boulevard (City of Surrey)	N	4			Y	5	5,5,5,5,5,5,5	25	N/S link. 2 bridges. Major ? For King George Boulevard, Bridges (1 old 1 new). Access / egress for emergency vehicles. 1 new bridge / 1 old - major road. 2 bridges - time to recover.
152nd Street (City of Surrey)	N	4			Y	5	3,4,3.5,3.5,3,3.5	20	Time to recover is less. Less time to recover. Congestion? Major impact to traffic - slower velocity, less water. Less waves / depth easier to recover.
Colebrook Road (City of Surrey)	Y	4	2,2,2,2,2,2,2	8	Y	5	2,2,2,2,2,2,2	10	Local - limited area and use. Minor - affects local people only. Local. Local road - affect limited area. Local farm road - affects limited area. Other ways around - not as critical. Local affects limited area.

PIEVC Assessment Worksheet - Participant Risk Scores and Comments	Flood Scenario																	
Infrastructure Components	**Flood Scenario A - Current**				**Flood Scenario A - Future**				**Rational For Consequence**	**Flood Scenario A - Current**				**Flood Scenario A - Future**				**Rational For Consequence**
Ladner Trunk Road (Corporation of Delta)	Y	4	3,3,3,3,1,3,3,3	12	Y	5	4,4,4,1,5,4,4,4	20	Large - significant for Delta - airport / hospital.	Y	4	3,3,3,3,3,3	12	Y	5	5,5,5,5,5,5,5	25	Access to -- very limited access out. Major for Delta (hospital, airport). Might use for airport access / hospital. Significant - access airport & hospital. Major route to Delta, may not be reinstated. Significant for Delta / access to airport and hospital.
112 Street (added)	Y	4	2,2,2,2,2	8	Y	5	3,3,3,3,3	15	Access to properties; hard to tell level to which road itself is affected. Rated with respect to access to properties. Only west end at crescent beach.		4				5			
Class 1 Railways Originating at Port Metro Vancouver																		
Burlington Northern Santa Fe (BNSF) Nicomekl Swing Bridge and Trestles	Y	4	2,2,2,2,2,2,2,2	8	Y	5	4,4,4,4,5,4,4,4	20	Not the limiting piece of infrastructure here. Future will have more shutdown. Inundation - time to repair (typical for all rail crossings). Effects not captured accurately on maps.	Y	4	4,4,4,4,4,4,4	16	Y	5	4,5,5,5,5,5,5	25	Swing bridge, how to sustain trade in your area. Wave effects. Months to recover. Unintentional dike - wave effects. Wave effects / critical route for trade to USA. Wave effects existing / catastrophic bigger.
6 km of BNSF Railway (Freight frequencies ~ 20 trains daily and up to 4 daily Amtrak Cascades trains)	Y	4	4,4,4,4,4,4,4,4	16	Y	5	5,5,5,5,5,5,5,5	25	Impact to highway if you have to raise railroad at underpass. Potential Hwy 99: raise if railway raise. Wave action vs saturation. Potential impact to the highway.	Y	4	4,4,4,4,4,4	16	Y	5	4,5,5,5,5,5,4	25	Lost all USA connections. Wave effect / critical route for trade to USA / acts as dyke. Wave effects existing / catastrophic bigger.
Roberts Bank Railway Corridor (BC Railway Co. ownership with usage by CN, CP and BNSF) ~18 trains daily.	Y	4	2,2,2,2,2,2,2,2	8	Y	5	4,4,4,4,5,4,4,4	20	Weakest link is western portion. Damage to infrastructure, but would likely stay intact. Impact operations for storing trains at BNSF. Economic and structural impacts. Constrained by BNSF at Hwy 91 / 99 - I/C east, low water both sides. Constrain operation of Mud Bay siding and Oliver siding. No high waves hitting the tracks. Constraints of section and water on both sides - compromises to siding. Weakest link NR Colebrook	Y	4	2,2,2,2,2,2,2	8	Y	5	4,5,5,5,5,5,4	20	Train more likely to be in the area. Minor for Scenario A - consequence is high. Train more likely present, minor. Lost all USA connections. Wave effects / one of major exits to Canada. Train more likely present (minor in existing).
Connection to Southern Railway of British Columbia	Y	4	1,1,1,1,1,1,1,1	4	Y	5	1,1,1,1,4,1,1,1	5	Impacts on rail network. Low consequence. Outside study area, minimal impact. Outside study area. Outside study area.	N	4			Y	5	4,4,4,4,4,4,4	20	Future. Loss all USA connections. Not affected by sea event currently. Will be affected in future, will get back in service quicker. Actual connection at 192

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PIEVC Assessment Worksheet - Participant Risk Scores and Comments	Flood Scenario																	
Infrastructure Components	**Flood Scenario A - Current**				**Flood Scenario A - Future**				**Rational For Consequence**	**Flood Scenario A - Current**				**Flood Scenario A - Future**				**Rational For Consequence**
UTILITIES	Y/N	P	C	R	Y/N	P	C	R		Y/N	P	C	R	Y/N	P	C	R	
	Table Group A									Table Group B								
Sanitary Lift Stations																		
City of Surrey: Elgin	N	4			Y	5	3,3	15	Sewer backup. N = behind dykes, at higher elevation.	Y	4	3,3,3,3,3,2	12	Y	5	3,3,3,3	15	Affected by flooding at Stewart.
City of Surrey: South Port	N	4			Y	5	3,3	15	Sewer backup. N = behind dykes, at higher elevation.	Y	4	4,4,4,4,4,2	16	Y	5	4,4,4,3	20	Affected by flooding at Stewart
City of Surrey: Winter Crescent	N	4			Y	5	3,3	15	Sewer backup. N = behind dykes, at higher elevation.	Y	4	3,3,3,3,3,3	12	Y	5	3,3,3,3	15	Affected by flooding at Stewart
City of Surrey: Stewart Farm	Y	4	2,2,2	8	Y	5	3,4,4	20	Sewer backup. In floodzone, services ~200 properties.	Y	4	4,4,4,4,4,4	16	Y	5	4,4,4,4	20	Affected directly by flooding. Chain effect of failures. Interconnected - all stations would fail. Highest consequence because it is on the series - starts chain reaction upstream. Possible cascade of failing of the pump stations.
Metro Vancouver: Crescent Beach	Y	4	2,2,2,2	8	Y	5	4,4	20	Sewage overflows. If PS completely flooded and genset fails, sanitary sewer overflows.	Y	4	3,4,4,3,3,3	16	Y	5	3,4,4,3,2	20	Inflow through flooding of sewers. L/S itself wouldn't flood. Indirectly impacted in existing conditions. Inflow from Crescent Beach. Impact partly dependent on response of public (not flushing toilets)
Underground infrastructure																		
5 km of Metro Vancouver 750 mm diameter Water Transmission Main	Y	4	2	8	Y	5	3	15	Low probability of failure - welded steel; flooded valve chambers.	Y	4	4,4,4,4,4,4	16	Y	5	4,4,4,4	20	Local PRVs vulnerable to flooding / MV reroute supply. Erosion concern = potential break. Water more important than sanitary (fire). Chlorinated water released if break. Impact would be on the local system. Some routing around could be done, but would be limited supply. Nicomekl sea dam has w/m through it. Questionable supply. Water is the most important can reroute through south Surrey. Farm lands can be flushed (chlorine)
10 km of Metro Vancouver Sanitary Sewer Forcemains (500 mm to 1050 mm diameter)	Y	4	2,2	8	Y	5	3,3	15	If valve chambers flood, reduced O&M access and corrosion of valves and equipment. If dike abandoned, then pipe at risk of erosion and flotation, so may need relocation.	Y	4	3,3,4,3,3	12	Y	5	3,3,4,3	15	As long as PS can release to ocean. Environmental impacts mitigated by tide in and out. Impacts to residents from backup.
>10 km of FortisBC Gas Mains	Y	4	2,2,2,2	8	Y	5	3,3,3,3,3	15	Minimal infrastructure loss and min. customers affected (higher consequence in the winter). Number of customers lost - insignificant. Damage to infrastructure is minimal. Number of customers lost (2 more such comments)	Y	4	2,2,2,2,2	8	Y	5	2,2,2,2	10	Limited impact because not much infrastructure is affected, and usually has several shutoff locations.
Overhead Utility Infrastructure																		
BC Hydro Twin 500kV bulk transmission line providing Intertie between BC Hydro and Bonneville Power	Y	4	2	8	Y	5	4	20	Extended power outage over large area.	Y	4	3,1	12	Y	5	3,4,3,3,1	15	Ground clearance can be an issue. Issue with tower at Serpentine river. Transmission lines may need to be refurbished, raised, armored. Present consequence insignificant - if lost, lost revenue. Rerouting not possible in real time. Could be scour / erosion around pedestals. Possible flow past footings
BC Hydro local overhead distribution lines	Y	4	2,4	12	Y	5	4,4	20	Extended power outage. Long restoration time (for the ranking of 4)	Y	4	4,4,4,4,3	16	Y	5	4,4,4,3	20	Pump station affected and cannot pump. If poles are flooded, difficult to inspect. Could fail, loss of power to pump stations. Issue for sanitary pump station. Power loss to streetlights would contribute to traffic congestion - affect emergency response and evacuation.
Shaw and Telus telecom lines	Y	4	2,2,2	8	Y	5	2,5,2,2	10 (25)	Essential for communication. Communication infrastructure affect many different interested parties - loss of communication can cause a number of different problems (for the ranking of 5). O&M: need access to site to operate and maintain. ER: cannot call for help if loss of service.	Y	4	2,2,2,2	8	Y	5	2,2,2,2	10	Affect communications in operations. From operating and monitoring perspective. Communications for SCADA infrastructure.
Green Infrastructure (Added)	Y	4	2	8	Y	5	3	15	Erosion / deposition of soil leads to increased need to dredge / maintain other infrastructure to remove buildup; reduced oxygen production in region; reduced carbon sequestration; urban heat island effect increased.									

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PIEVC Assessment Worksheet - Participant Risk Scores and Comments

Flood Scenario

Infrastructure Components	Flood Scenario A - Current				Flood Scenario A - Future				Rational For Consequence	Flood Scenario A - Current				Flood Scenario A - Future				Rational For Consequence
Flood / Marine	Y/N	P	C	R	Y/N	P	C	R		Y/N	P	C	R	Y/N	P	C	R	
	Table Group A									Table Group B								
Flood Control Infrastructure																		
City of Surrey Sea Dams (2)	Y	4	4,4,4,4,4	16	Y	5	5,5,5,5,5,5	25	Velocities high with dam breaches Debris potential, salt intrusion, loss of life in 2100	Y	4	5,2,2,2,5,2,5,2	20		5	2,1,3,4,4,5,4	20	Sea dam will continue to operate but will be less effective. Sea dam will return to function post-event. Can't function as efficiently as when there is no flood. Future, loss of functionality - harder to repair. Not really affected (current ranking of 2). Future major damage possible as water recedes (erosion). Wide effect & consequence to City / region. Road access for emergency services, water resources for fish, agricultural impacts. Future: sea dam will need major repair, access road over seadam will be affected.
15 km of dyking, including ditches and floodboxes	Y	4	4,4,4,4,4	16	Y	5	5,5,5,5,5	25		Y	4	5,4,4,4,4,5,5,4	20		5	5,4,5,5,5,5	25	Dyking is allowing water over, ditches / floodboxes not effective. Failure to protect Crescent Beach / farmland. Crescent Beach - loss of homes, damage, debris, cannot temporary repair, higher economic impact in future. Major flooding, economic loss, evacuation, major dikes damage (current). Widespread flooding, larger economic loss (future). Wide effect & consequence to City / region. Compromised integrity and function to protect - $up
City of Surrey: Colebrook Pump Station	Y	4	2,2,2,2,2	8	Y	5	2,2,2,2,2	10	Power loss, longer salt water, blueberries	Y	4	5,3,1,3,4,3,3,4	16		5	4,3,5,4,4,5	20	Pumps should continue operating provided power / backup power is not affected. Potential damage to housing structure. Should survive / function in current scenario, doubtful in future. Elevation of backup generator, maintenance an issue. Extra time (24/7) to pump out water. Still generally functioning
City of Surrey: Maple Pump Station	Y	4	2,2,4,2,2,2	8	Y	5	3,2,2,2,2,4,2	15	Pump station services primarily people and property Breach and break slows recovery Pump station is ineffective during breach	Y	4	5,3,1,3,4,3,3,4	16		5	4,2,5,4,4,5	20	Rebuilt and updated Damage to building holding the pumps. Damage to power / backup power, ability to repair. Major repairs probably required. Still generally functioning.
Corporation of Delta: Oliver Pump Station	Y	4	2,2,2,2,2	8	Y	5	2,2,2,2,2	10	Pump station services primarily agricultural land Pump station is ineffective during breach	Y	4	5,3,1,3,4,3,3,4	16		5	4,3,5,5,4,5	25	No immediate effect - post flood requirement. Difficult access, not function as intended. Needed to be serviceable for recovery. Lengthy post-flood recovery, potential irreparable damage. Major PS in Delta. Will not keep up with flooding (current). Genset may be flooded (future) . Still generally functioning.
Ducks Unlimited Canada Serpentine Fen Nature Reserve	Y	4	1,1,1,1,2	4	Y	5	1,1,2,2,2	10	Birds will relocate during event. Rodents will also relocate. Pump station is ineffective during breach	Y	4	2,1,2,1,4,1,2	8		5	2,1,2,2,2,4	10	Large / significant waterfowl refuge area. Saltwater will affect vegetation. Environmental impact minor - somewhat designed to handle flooding. Flooding is a natural process for a fen but salt water intrusion may be harmful. Environmental damage - difficult to reverse. Critical habitat for pacific flyway, Canada's largest wintering waterfowl populations.
Water control features to maintain environmentally sensitive area including freshwater irrigation system	Y	4	1,1,1,2,2	4	Y	5	1,1,2,2	10	Salt intrusion	Y	4	3,4,2,2,4,1,2	16		5	3,4,3,2,4,3	15	More effective area as fresh water marsh. Difficult to reverse salt water in short / medium term - potential fisheries impacts. Intrusion into freshwater habitat, complete loss of functionality. Difficult to reverse damage. More study of impacts required, fisheries impact, increased pollution, lower biological productivity, highly social impact. Distribution system is not essential. Environmental damage - difficult to reverse. Contaminated water for long time.
Marine Facilities																		
Crescent Beach Marina	Y	4	2,2,2,2,2,2	8	Y	5	2,2,2,3,2,2	10	Possible use by CCG as landing spot / patient transfer Boats might seek refuge here - not large marinas	Y	4	1,1,1,2,2,1,1	4		5	3,4,3,3	15	Marinas are not protected by the dyke system Difficult access / debris damage (current) - flood damage to marina / docks (future) Damage to buildings, wharfs - higher in future scenario. Boats & docks floating unfettered may cause damage to other infrastructure or cause oil spills. Private property - limited effect on others. Building damage.
Wards Marina	Y	4	2,2,2,2,2	8	Y	5	2,2,2,3,2,2	10	Boats might seek refuge here - not large marinas	Y	4	1,1,1,2,2,1,1	4		5	3,4,3,3	15	Most of infrastructure can accommodate the water. Difficult access / debris damage (current) - flood damage to marina / docks (future). Private property - limited effect on others. Building damage.
Private docks	Y	4	2,2,2,1,2	8	Y	5	2,2,2,3,2	10	Boats might seek refuge here	Y	4	1,1,1,1,3,1,1	4		5	4,3,2,3	15	Difficult access / debris damage (current) - flood damage to marina / docks (future) Longer time to get back access, perhaps higher damage and cost to repair - future scenarios. Private property - limited effect on others.
Farms																		
Private dairy facilities for over 1,000 head of Cattle	Y	4	4,4,4,4,4	16	Y	5	5,5,5,5,5	25	Cattle will be relocated to Cloverdale Race Track. During future scenario, people's lives likely lost. Food insecurity, lives at risk. Current condition, cattle should survive. Not in 2100.	Y	4	4,3,5,4	16		5	5,5,5	25	Entire farm area and livestock would be affected. Potential to evacuate the animals, high risk of harm - cattle evacuation route (current). Less potential to save animals - high mortality expected (future). Evacuation necessary, cannot drink water. High value economic impact of interrupted production, cow health & safety, sustainability very questionable in long run. Destruction of animal life & generations old, large regional / national / international dairy business (unless there is some higher ground.

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PIEVC Assessment Worksheet - Participant Risk Scores and Comments	Flood Scenario																	
Infrastructure Components	Flood Scenario B - Current				Flood Scenario B - Future				Rational For Consequence	Flood Scenario B - Current				Flood Scenario B - Future				Rational For Consequence
TRANSPORTATION	Y/N	P	C	R	Y/N	P	C	R		Y/N	P	C	R	Y/N	P	C	R	
	Table Group A									Table Group B								
Runway																		
Surrey/King George Airpark Turf Runway	Y	3	1,1,1,1	3	Y	5	1,1,1,1,1	5		Y	3	1,1,1,1,1,1	3	Y	5	1,1,1,1,1	5	Local airport impacted but not significant to regional issues.
Regional / International Transportation Infrastructure																		
4 km of four-lane arterial roadway	Y	3	1,1,1,1	3	Y	5	2,2,2,2,2	10			3				5			
7 km section of Highway 99 linking Peace Arch Border	Y	3	1,1,1,1	3	Y	5	2,2,2,2	10		Y	3	1,1,1,1,2,1,1	3	Y	5	1,2,2,3,2,2	10	But minor. Highways are not greatly impacted by standing water in farm fields.
Highway 91 and 99 Interchange	Y	3	1,1,1,1	3	Y	5	2,2,2,2	10		N	3			N	5			
4 km section of Highway 91	Y	3	1,1,1,1	3	Y	5	2,2,2,2	10		N	3			N	5			
6 km dyke trail connecting to parks	Y	3	1,1,1	3	Y	5	2,2,2	10		N	3			N	5			Dyke is not overtopped. Trails not affected.
Delta-Surrey Greenway	Y	3	1,1,1	3	Y	5	2,2,2	10		Y	3	1,1,1	3	Y	5	1,1,1,1,1	5	Trails not affected.
Crescent Road																		
Local Government Arterial and Collector Roads																		
King George Boulevard (City of Surrey)		3	1,1	3		5	2,2	10	Often interpreted as duplicate of #6	N	3			N	5			Major city roads not affected, similar to highway.
152nd Street (City of Surrey)	Y	3	1,1,1,1,1	3	Y	5	1,1,1,2,1	5	Congestion impacts	N	3			N	5			
Colebrook Road (City of Surrey)	Y	3	2,2,2,2,2	6	Y	5	3,3,3,3,3	15	Access issues, contaminants from cars.	Y	3	2,2,2,2,1,2,2		Y	5	2,3,3,3,2,3,3		Minor inconvenience - affects local roads. More often future & longer to clean.
Ladner Trunk Road (Corporation of Delta)	N	3			N	5				Y	3	2,3,3,3,3,2		Y	5	2,5,4,5,3		Minor inconvenience - affects local roads.
112 Street (added)	Y	3	2,3,2,2	6	Y	5	3,3,3,3	15	Access issues, contaminants from cars.		3				5			
Class 1 Railways Originating at Port Metro Vancouver																		
Burlington Northern Santa Fe (BNSF) Nicomekl Swing Bridge and Trestles	N	3			N	5			Minimal impacts. Railways likely continue operating.	N	3			N	5			

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PIEVC Assessment Worksheet - Participant Risk Scores and Comments	Flood Scenario																		
Infrastructure Components	**Flood Scenario B - Current**				**Flood Scenario B - Future**				**Rational For Consequence**	**Flood Scenario B - Current**				**Flood Scenario B - Future**				**Rational For Consequence**
6 km of BNSF Railway (Freight frequencies ~ 20 trains daily and up to 4 daily Amtrak Cascades trains)	N	3			N	5			Minimal impacts. Railways likely continue operating.	N	3			N	5			Not affected by rainfall (typical of other rail crossings except Southern Railway)
Roberts Bank Railway Corridor (BC Railway Co. ownership with usage by CN, CP and BNSF) ~18 trains daily.	N	3			N	5			Minimal impacts. Railways likely continue operating.	N	3			N	5			
Connection to Southern Railway of British Columbia	Y	3	3,3,3	9	Y	5	4,4	20	Vulnerable connection.	Y	3	3,3,3,3,3,3	9	Y	5	4,4,4,4,4,4	20	Railway is impacted by seawater and rainfall events.

PIEVC Assessment Worksheet - Participant Risk Scores and Comments

Flood Scenario

Infrastructure Components	Flood Scenario B - Current				Flood Scenario B - Future				Rational For Consequence
UTILITIES	Y/N	P	C	R	Y/N	P	C	R	
	Table Group A								
Sanitary Lift Stations									
City of Surrey: Elgin	N	3			N	5			
City of Surrey: South Port	N	3			N	5			
City of Surrey: Winter Crescent	N	3			N	5			
City of Surrey: Stewart Farm	Y	3	2,2,2	6	Y	5	4,4,4	20	Not protected by a dyke.
Metro Vancouver: Crescent Beach	N	3			N	5			
Underground infrastructure									
5 km of Metro Vancouver 750 mm diameter Water Transmission Main	Y	3	2		Y	5	2		Valve chamber flooding. Fresh water okay.
10 km of Metro Vancouver Sanitary Sewer Forcemains (500 mm to 1050 mm diameter)	Y	3	2,2,2,2	6	Y	5	3,2,2,2	10	Erosion over creek crossings. May have tougher time accessing pipe & valve chamber but any flooding would be fresh water so no corrosion.
>10 km of FortisBC Gas Mains	Y/N	3	1	3	Y	5	4,4,4	20	One response identified Y for current - remainder N.
Overhead Utility Infrastructure									
BC Hydro Twin 500kV bulk transmission line providing Intertie between BC Hydro and Bonneville Power		3				5	4	20	Extended power outage over a large area.
BC Hydro local overhead distribution lines		3				5	4,4	20	Extended power outage. Long restoration time.
Shaw and Telus telecom lines		3				5	1	5	If any customers are out of service due to flood it may impede maintenance / repair vehicles.
Green Infrastructure (Added)							3,3		Larger / frequent events detrimental to plant / tree growth. Erosion / deposition of soil leads to increased need to dredge / maintain other infrastructure to remove buildup; reduced oxygen production in region; reduced carbon sequestration; urban heat island effect increased.

Infrastructure Components	Flood Scenario B - Current				Flood Scenario B - Future				Rational For Consequence
UTILITIES	Y/N	P	C	R	Y/N	P	C	R	
	Table Group B								
Sanitary Lift Stations									
City of Surrey: Elgin	N	3				5			Pumps directly to the MV main - not affected by Stewart Farm. Based on Stewart not being an online pump station.
City of Surrey: South Port	N	3				5			Pumps directly to the MV main - not affected by Stewart Farm.
City of Surrey: Winter Crescent	N	3				5			Pumps directly to the MV main - not affected by Stewart Farm.
City of Surrey: Stewart Farm	Y	3	3,3,3,1	9	Y	5	3,3,3,1	15	May or may not be affected by flooding at all. If the pump station is within the flood area - location was not exact. Possible water impact of overtopping of the 2100 flood event.
Metro Vancouver: Crescent Beach	N	3				5			
Underground infrastructure									
5 km of Metro Vancouver 750 mm diameter Water Transmission Main	Y	3	2,2,2,2	6		5	2,2,2	10	Likely the only impact is on CoS local connections. Lower risk of scour versus sea flooding. Not significant risks (slow moving water).
10 km of Metro Vancouver Sanitary Sewer Forcemains (500 mm to 1050 mm diameter)	Y	3	2,2,2,2,1	6		5	2,2,2,1	10	Loss of line is not a doomsday scenario. Localized flood areas could effect.
>10 km of FortisBC Gas Mains	Y	3	3,2,3,3	9		5	3,2,3,3	15	Number of Fortis Stations affected. Modest consequence. Based on Fortis comments. Possible break in lines.
Overhead Utility Infrastructure									
BC Hydro Twin 500kV bulk transmission line providing Intertie between BC Hydro and Bonneville Power	Y	3	2,3,2,2	6		5	2,3,3,2	15	Towers are close to the river and may be affected. Erosion of tower near Serpentine River. Towers are 70 m or less from bank. If the river's water velocity is significant, it could erode foundations. Could be erosion risks, destabilization.
BC Hydro local overhead distribution lines	Y	3	3,3,3,3,2	9		5	3,3,3,3	15	Affected in local areas only. Saturated soil and high winds.
Shaw and Telus telecom lines	Y	3	3,1,2,2	6		5	3,1,2	10	Share poles with Hydro distribution. Impact is the same. Similar impact as distribution lines, because they usually follow beneath.
Green Infrastructure (Added)									

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PIEVC Assessment Worksheet - Participant Risk Scores and Comments	Flood Scenario																	
Infrastructure Components	Flood Scenario B - Current				Flood Scenario B - Future				Rational For Consequence	Flood Scenario B - Current				Flood Scenario B - Future				Rational For Consequence
Flood / Marine	Y/N	P	C	R	Y/N	P	C	R		Y/N	P	C	R	Y/N	P	C	R	
	Table Group A									Table Group B								
Flood Control Infrastructure																		
City of Surrey Sea Dams (2)	Y	3	2,2,2,2,2,2	6	Y	5	3.5,3,3.5,3.5	25	Extended duration may require larger floodboxes or pumping at sea dam. Increased pressure on sea dams. Scour hole on Serpentine sea dam.	Y	3	1,1,2	3	Y	5	3,1,1	15	Should not be greatly affected - operation will be reduced as sea levels rise. One responded not affected - passive structures, but SLR occurrence decreases their window of opening. Reduced functionality - take longer to drain the area. Reliant on pumping for internal drainage. May be affected by increased water pressure.
15 km of dyking, including ditches and floodboxes	Y	3	3,3,3,3,3	9	Y	5	4,4,4,4	20	The dykes need to be raised. Larger footprint. Stability. Assuming dykes are raised, much less impact. Velocity increases therefore erosion becomes more of a problem. Geotech, seepage issues.	Y	3	1,1,5,5	15	Y	5	3,1,2,1	10	Raised - improved capacity. Shorter low tide interval in future. Shorter time to gravity flow out of FB. Stress on dykes could lead to breach. Flooding may be from a breach, higher risk of breach.
City of Surrey: Colebrook Pump Station	Y	3	2,2,2,1,1,1	6	Y	5	3,3,3,3,3,3	15	Consequences based on not upgrading pump station. Impact on agricultural. Pump duration will be increased due to sea level rise.	Y	3	2,1,2,2,3,5	9	Y	5	3,2,1,2,2	10	Increased maintenance due to increased use (all pump stations). Need to replace & upgrade capacity per lifecycle requirements (low cons) Longer service cycle - operate for longer periods. Working full time (if at all).
City of Surrey: Maple Pump Station	Y	3	1,1,1,1,1,1	3	Y	5	3,3,3,2,2	15	Consequences based on not upgrading pump station. Pump duration will be increased due to sea level rise. Discharge gates submerged more.	Y	3	2,2,2	6	Y	5	3,2,1,2,2	10	
Corporation of Delta: Oliver Pump Station	Y	3	2,1,2,1,1,1	6	Y	5	3,3,3,2,3	15	Consequences based on not upgrading pump station. Pump duration will be increased due to sea level rise.	Y	3	2,2,2	6	Y	5	3,2,1,2,2	10	
Ducks Unlimited Canada Serpentine Fen Nature Reserve	Y	3	1,1	3	Y	5	1,1	5		Y	3	2,1,1,2,2,2	6	Y	5	2,1,1,1	5	Water flow change affect wildlife. Minor biologic impacts, debris, garbage. Limited impact. Reduced ability to manage water levels, different depths for dabbling vs diving ducks. Increased overland garbage floating in and pollutants.
Water control features to maintain environmentally sensitive area including freshwater irrigation system	N	3			N	5				Y	3	2,1,2,2,2		Y	5	2,1,1,2	10	Potential garbage / debris impacting system. Minor impacts, debris, garbage. Limited impact.
Screw pump stations (added)	Y	3	1,1,1,1	3	Y	5	2,2,3	10	Pumping stations improved to same standard as dykes. Assume upgrades at same standard as dykes. Limited by height ability / chosen for environmental status.									
Marine Facilities																		
Crescent Beach Marina	N	3			N	5				Y	3	2	6	Y	5	1,2	10	Will require adaptation for water levels / flows (all marine facilities)
Wards Marina	N	3			N	5				Y	3	2,2	6	Y	5	1,2	10	Some damage but limited.
Private docks	N	3			N	5				Y	3	2,3	9	Y	5	1,2	10	
Farms																		
Private dairy facilities for over 1,000 head of Cattle	Y	3	1,1,1	3	Y	5	2,2,1,2	10		Y	3	1,2	6	Y	5	1,2	10	Moderate floodin+Y98:AQ114g to grazing land. Reduced grazing areas. Limited damage.

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Infrastructure		Adaptation Option			
		A Current	A Future	B Current	B Future
Transportation	**Runway**				
	Surrey/King George Airpark Turf Runway	Retreat	Retreat	Retreat	Retreat
	Regional / International Transportation Infrastructure				
	4 km of four-lane arterial roadway	Full wall / sea barrier - Crescent Beach to Delta Border alignment		Accommodate: education and effective response systems	
	7 km section of Highway 99 linking Peace Arch Border	Enhance existing dyke system with new sea dams at mouth of river. Build up as dyke.			
	Highway 91 and 99 Interchange	Highway 99 new dyke alignment and retreat; move sea dam to Highway 99			
	4 km section of Highway 91	Combination of options			
	6 km dyke trail connecting to parks				
	Delta-Surrey Greenway				
	Crescent Road				
	Local Government Arterial and Collector Roads				
	Local Government Arterial and Collector Roads (general)				
	King George Boulevard (City of Surrey)				
	152nd Street (City of Surrey)				
	112 Street (City of Surrey)				
	Colebrook Road (City of Surrey)				
	Ladner Trunk Road (Corporation of Delta)				
	Class 1 Railways Originating at Port Metro Vancouver				
	Burlington Northern Santa Fe (BNSF) Nicomekl Swing Bridge and Trestles.				
	6 km of BNSF Railway (Freight frequencies ~ 20 trains daily and up to 4 daily Amtrak Cascades trains).				
	Roberts Bank Railway Corridor (BC Railway Co. ownership with usage by CN, CP and BNSF) ~18 trains daily.				
	Connection to Southern Railway of British Columbia				

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Infrastructure		Adaptation Option			
		A Current	A Future	B Current	B Future
Utilities	**Sanitary Lift Stations**				
	City of Surrey: Elgin	Add gen-sets where necessary. Add off-line emergency storage (Surrey only). Raise buildings and electrical (typical comment for all Sanitary Lift Stations and Scenarios). Not affected. None required. (Consensus).	Not affected. None required. (Consensus).	Not affected. None required. (Consensus).	Not affected. None required. (Consensus).
	City of Surrey: South Port	Not affected. None required. (Consensus).	Not affected. None required. (Consensus).	Not affected. None required. (Consensus).	Not affected. None required. (Consensus).
	City of Surrey: Winter Crescent	Not affected. None required. (Consensus).	Not affected. None required. (Consensus).	Not affected. None required. (Consensus).	Not affected. None required. (Consensus).
	City of Surrey: Stewart Farm	Coffer dam - floodproof. Flood protect. Flood proof - dam?	Dyke unprotected pump station. Raise elevation of pump station. May need to be raised. Raise station.	Coffer dam - floodproof. Flood Protect. Floodproof - dam?	Dyke unprotected pump station. Coffer dam - floodproof. May need to be raised. Raise station.
	Metro Vancouver: Crescent Beach	Use stainless steel at chambers. If needed, raise existing electrics and controls higher in building. Dykes around community. Offshore islands. Floodproof.	When it is time to replace the PS, design and construct to take into account the flood and sea level rise scenario. Dykes around community. Offshore islands. Raise as capital replacement.	OK as is, but adaptation for Scenario 'A' will also further reduce risk for Scenario B. Not affected. None required. (Consensus).	OK as is, but adaptation for Scenario 'A' will also further reduce risk for Scenario B.
	Underground Infrastructure				
	5 km of Metro Vancouver 750 mm diameter Water Transmission Main	Modify valve chambers as required. Upgrade already planned. Address scour in design criteria.	Upgrade already planned. Address scour in design criteria. Address during replacement by MV.	Upgrade already planned. Address scour in design criteria.	Upgrade already planned. Address scour in design criteria. Address during replacement by MV.
	10 km of Metro Vancouver Sanitary Sewer Forcemains (500 mm to 1050 mm dia.)	Upgrade as required. Use stainless steel at valve chambers. Address scour in next design criteria.	When it is time to upgrade pipes, design and construct to account for flood & sea level rise scenario. Also design and construct valve chambers that are not susceptible to salt water ingress. Armour river crossings if not already done. If the sea dyke is removed, then moving the sewer line to safety would be considered, but very $$. Address scour in next design criteria.	OK as is, but adaptation for Scenario 'A' will also further reduce risk for Scenario B. Address scour in next design criteria.	OK as is, but adaptation for Scenario 'A' will also further reduce risk for Scenario B. Address scour in next design criteria.
	>10 km of FortisBC Gas Mains	Install more isolation valves. Install deeper crossings at rivers. Raise stations. Common comment: add valves as isolation strategy, evaluate the crossings, stations elevated. Not affected	Install more isolation valves. Install deeper crossings at rivers. Raise stations. Raise stations. Add more valves to isolate shorter reaches Not affected	Install more isolation valves. Install deeper crossings at rivers. Raise stations. Not affected	Install more isolation valves. Install deeper crossings at rivers. Raise stations. Raise stations. Add more valves to isolate shorter reaches Not affected
	Overhead Utility Infrastructure				
	BC Hydro Twin 500kV bulk transmission line providing Intertie between BC Hydro and Bonneville Power	Not affected. Protect. Divert current at base to protect towers.	Reinforce foundation. Raise the towers. Protect towers near rivers. Accommodate (Raise).	Not affected.	Raise the towers. Accommodate (raise).
	BC Hydro local overhead distribution lines	Change to fibreglass poles in wet areas. Do nothing (listed for all scenarios) No action.	Change to fibreglass poles in wet areas. Replace poles with fibreglass (rot). Program to replace poles - poly/fibre? Accommodate (raise).	Change to fibreglass poles in wet areas. No action.	Change to fibreglass poles in wet areas. Replace poles with fibreglass (rot). Replace poles - poly / fibre? Accommodate (raise, FRP poles)
	Shaw and Telus telecom lines	Change to above ground in flood areas. Accommodate (listed for all scenarios): most of TELUS infrastructure is aerial any future design in accordance to the City can be designed above ground as well to minimize damage. Can't do much about existing infrastructure. Will replace as necessary. Not affected.	Change to above ground in flood areas. Keep services aerial. Some existing underground cables - would replace with aerial if / when there is an issue. Keep all plant aerial; all new developments should be serviced aerially. Not affected. Work in conjunction with BCH	Change to above ground in flood areas. Can't do much about existing infrastructure. Will replace as necessary. Not affected.	Change to above ground in flood areas. Keep all plant aerial; all new developments should be serviced aerially. Not affected. Work / replace in conjunction with BCH.
	Green Infrastructure (Added)	Adapt: plant salt tolerant / flood tolerant species. Protect: encourage tree / shrub growth. Retreat: let nature take its course (for all scenarios)			

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Infrastructure		Adaptation Option			
		A Current	A Future	B Current	B Future
Flood Control / Marine	City of Surrey Sea Dams (2)	Series of sea dams. What areas do we want to protect Replace & upgrade. Seismic upgrade - bigger gates, add pumps (Protect). Replace & upgrade (Protect). Protection strategy (sea dams and dyking infra). Replace sea dams. Replace for seismic reasons if nothing else (protect).	Augment with pumps.	Don't increase development Pumps (listed for Current & Future) Include pumping capacity. Protect.	Add pumping capacity at sea wall to increase drainage rate. Protect.
	15 km of dyking, including ditches and floodboxes	Upgrade (also listed for Colebrook, Maple (Scenario A Current; Crescent Beach Marina, Wards Marina, Private Dock all scenarios) Upgrade / better floodboxes / deeper ditch (Protect). Increase capacity. Offshore islands.	Consider retreat or accommodation (listed for Colebrook, Maple for both Scenario A and Scenario B Future scenarios). Accommodate? Protect? Offshore islands, raise dykes, other. Add more pumping stations. Offshore islands to reduce heights required. Offshore islands	Pumps (listed for Colebrook, Maple Current). Increase pumping capacity.	Accommodation and upgrades Add more pumping stations.
	City of Surrey: Colebrook Pump Station	Upgrade as required - rebuild with increased capacity.	Increase capacity, raise. Build higher & increase capacity. Upgrade. Accommodate (listed for all PS).		Accommodation and upgrades Accommodate. (listed for all PS)
	City of Surrey: Maple Pump Station		Build higher & increase capacity Abandon		Accommodation and upgrades
	Corporation of Delta: Oliver Pump Station		Upgrade.	Maintain	Accommodation and upgrades Raise water control structures.
	Ducks Unlimited Canada Serpentine Fen Nature Reserve	Accommodate - increase discharge capacity of saltwater.	Relocate west of Highway 99. Expand - transition upland to wetland long-term leases with phases for evaluation for retreat / accommodate.	Maintain	Raise water control structure levels.
	Water control features to maintain environmentally sensitive area including freshwater irrigation system				
	Screw pump stations				
	Marine Facilities				
	Crescent Beach Marina	Accommodate - as infrastructure is replaced / upgrades. Protect / accommodate (listed for all marine facilities current Scenario A and B)	Retreat? Or accommodate. Accommodate. Accommodate (listed for all future condition Scenario A and B)		Accommodate.
	Wards Marina				
	Private docks	Accommodate.			
	Farms				
	Private dairy facilities for over 1,000 head of Cattle	Accommodate (raise buildings, roads, build 'mounds' for cattle retreats). Protect / accommodate (listed for Current Scenario A and B)	Retreat / abandon. Accommodate (listed for Future Scenario A and B)		

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General Adaptation Comments

Transportation Tables

- Retreat for highways not considered feasible – unless sacrificing land.
- Consider co-benefits of approaches such as: retention / detention ponds – could be irrigation in summer.
- Offshore solution, rock groins, trestles, relocate BNSF
- Onshore: pumps capacity, higher elevations.
- Retreat common option for airpark.
- Accommodate: education and effective response systems.
- Elevate some local roads to prioritize movement.
- Combination of options likely required.
- If BNSF decides to remove their dyke crossing of Mud Bay, this could initiate a retreat, accommodate, or replace the dyke with another superstructure.
- Incremental adaptations are needed to meet changing needs of climate change.
- If the sea dams are upgraded or an offshore dyke barrier is constructed, how will this accommodate future climate changes?
- If we retreat, how will be transportation corridors be maintained? Could a long bridge be an option spanning the retreated area? Would the public be okay with intermittent road closures during high tide?
- There are too many unknowns. For example, if temperature rises due to climate change, blueberries might not be able to grow. Might not need to prevent the agriculture land. Should continue to monitor the changes over years.
- Do not think it is practical to raise the river dyke.
- Build dyke on the land side, and use Hwy 99 as buffer.
- 152 St will be widened in the future. There is an opportunity to raise 152 St to act as barrier as a secondary flood barrier.
- Retreat for highways not considered feasible – unless sacrificing land.
- Consider co-benefits of approaches such as: retention / detention ponds – could be irrigation in summer.
- Offshore solution, rock groins, trestles, relocate BNSF.
- Onshore: pumps capacity, higher elevations.
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- If BNSF decides to remove their dyke crossing of Mud Bay, this could initiate a retreat, accommodate, or replace the dyke with another super structure.
- Incremental adaptations are needed to meet changing needs of climate change.
- If the sea dams are upgraded or an offshore dyke barrier is constructed, how will this accommodate future climate changes?
- If we retreat, how will be transportation corridors be maintained? Could a long bridge be an option spanning the retreated area? Would the public be ok with intermittent road closures during high tide?
- There are too many unknowns. For example, if temperature rises due to climate change, blueberries might not be able to grow. Might not need to prevent the agriculture land. Should continue to monitor the changes over years.
- Do not think it is practical to raise the river dyke.
- Build dyke on the land side, and use Highway 99 as buffer.
- 152 St will be widened in the future. There is an opportunity to raise 152 St to act as barrier as a secondary flood barrier.

Utilities Tables

- Upgrade to Metro Vancouver watermain is planned. Address flood issues (especially scour / erosion) in design.
- Build a sea wall across Mud Bay.
- Relocate BNSF (helps White Rock) use new structure of BNSF piles as foundation for a new wall on that same alignment.
- BCH and Shaw/Telus share poles – distribution network prone to rot / destabilization. Can be accommodated by replacing with fibre-reinforced poly poles.
- Dyking good option. Offshore islands are no-go for Crescent Beach
- Need better understanding of sediment transport and flushing and how offshore options would affect this.
- Sewage transmission line to Annacis is needed for now – needs to go through the floodplain. Potential for utility through sea wall rather than through floodplain (risky).
- BCH does resiliency assessments on their transmission lines – approximately 45-year replacement cycle.
- Mainly accommodate.
- Retreating is NOT an option.
- No access to infrastructure.
- Infrastructure permanently submerged.
- Can't maintain infrastructure.
- If retreat from ocean – MV forcemain would be on ocean side of dyke and would be vulnerable. Replacement of forcemain further east. Valve chambers – could use stainless steel.
- Hydro check integrity of wood poles every 10 years, dig 2 feet down and check pole integrity.

Flood Control / Marine Tables

- Focus on off-shore options.
- Accommodate and do incremental upgrades.
- Options are largely driven by rail line management beyond jurisdiction of City.
- Protect seems to be leading contender (with little consideration of $)
- Assumption that dykes are raised in Scenario B – implies protect / accommodate – at what point is retreat considered – eventually will have to. Dyking affects everything else.
- Severity of Scenario B can be partly attenuated through upstream watershed management – decrease peak flow from new developments, or magnified by increases in precipitation
- Offshore solutions:
    - Rock groin\breakwater (offshore 7 km long extending from beyond Crescent Beach to Highway 91) complete with tide gate. (Stage construction with barrier raised over time, add gate later, upgrade dyke and pump station as required). Create better habitat internally.
    - Offshore Segmental wall – Geotechnical concerns.
    - Trestle (could extend beyond White Rock, BNSF could sell property and build raised trestle) – this would knock down wave height, but not surge and rising sea levels and provide many decades of protection.
    - Retreat was not looked upon favorably since it will significantly impact transportation corridors. However, partial retreat was not explored (and it should be).
    - Without offshore improvements dyke upgrades will be challenging and will take a long time.

Appendix C - Workshop Exit Survey Responses

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Exit Survey Responses

Compiled by City of Surrey

You understood the information that was presented	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
	12	21	0	0	0
	36%	64%	0%	0%	0%
	Agree		Undecided	Disagree	
	100%		0%	0%	

The logistics (location, time) of the Workshop were suitable:	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
	13	18	1	1	0
	39%	55%	3%	3%	0%
	Agree		Undecided	Disagree	
	94%		3%	3%	

You felt your opinion was heard?	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
	11	21	0	1	0
	33%	64%	0%	3%	0%
	Agree		Undecided	Disagree	
	97%		0%	3%	

You will like to continue to be involved in the CFAS planning process:	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
	7	13	12	0	0
	22%	41%	38%	0%	0%
	Agree		Undecided	Disagree	
	63%		38%	0%	

The length of the workshop was:	Much too short	Too short	Just right	Too long	Much too long
	0	0	27	6	0
	0%	0%	82%	18%	0%
	Short		Just Right	Long	
	0%		82%	18%	

To what extent is coastal flooding a concern for you and your family?	Low	Medium	High
	4	15	20
	10%	38%	51%

Do you feel that your top concerns about coastal flooding were captured today?	Yes	No
	37	4
	90%	10%

Do you have a greater awareness of the impacts of flooding on infrastructure in Mud Bay?	Yes	No
	37	1
	97%	3%

Response Statistics	
Participant Attendance	59
Submitted Exit Survey	38
Exit Survey Response Rate	64%
Submitted Workbooks	42
Workbook Response Rate	71%

Question 3	Question 5	Question 11
If your main concerns were not addressed, could you please tell us what are your top concerns?	Are there any adaptation options or strategies you would like to see explored further related to infrastructure in the area	Please provide any further comments on today's meeting (Feb 3, 2017)
Foreshore Dyke	Foreshore Dyke	
Yes & no.		
		As a federal response agency, I did not have much input other than to make aware the Coast Guard as a response option. Thank you for including us in the discussion
	Look at development strategies and policies to assure net zero surface flow post/pre development. Low impact development strategies. Buy/lease back land options	
Green infrastructure & its potential to provide solutions	Green infrastructure	Too slow developing and running through scenarios
	Feasibility of the offshore option	
		Great presentations - very informative
	Offshore barrier islands. Raise highway 99 as a dyke	
	No single approach but rather a combination of different options will need to be employed with input and support of all stakeholders in the lower mainland	Good cross section of stakeholder representations for awareness and future engagement on this subject matter...thank you
	What would be a global approach to adopt options to develop	
	Sea level rise & subsidence are long term processes that will continue indefinately. Protect options buy time, rather than provide permanent protection. You must consider how long protection options will be effective for	
		Well put together
Growing population in south surrey, impact on the network. Traffic congestion on alternate route not able/delay to get to work		
	PIEVC has good risk rank procedure to sort outstanding priorities	Very practical workshop but few more presentations would have been more helpful
	Options analysis for all 3 options	Job well done
	1. Incremental adaptions 2. Engage the whole lower mainland area	
Serpentine river basin rainfall outcomes on the upper basin; river basin dyke assumptions on "Part B" directed the conversation too quickly away from river issues.	The great mud bay dyke/wall to reclaim more land	Great facilitation by associated engineering
Emergency Services & impact on residents	All that we discussed	
	Look at options and evaluate problems they solve instead of vice versa	
	Yes, engagement with neighbouring municipalities should be needed for this type of workshop	
	Raise the dyke - build the a barrier wall	
	BC Hydro may implement protect or accommodate adaptation for its infrastructure	Environmental impacts: I didn't see much info on this in the workshop
	Benefits of offshore islands on reducing flood vulnerability to infrastructure in Mud Bay	Could have been accomplished in 3/4 of a day
Focus on people, infrastructure, ACR lands over Mud Bay environmental impacts	As per #3	Very good timely discussion, need Langely to come to the table. Delta should have remained after lunch