CFAS

SURREY COASTAL FLOOD ADAPTATION STRATEGY (CFAS)

Infrastructure Asset Managers, Operators and Emergency Services Stakeholders

PIEVC Workshop

nhc northwest hydraulic consultants

epi

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Agenda

- Registration
- Roundtable Introductions and Opening Remarks
- PIEVC and CFAS and Introduction
- History of Flooding
- Flood Scenario A - Coastal Flood with Dyke Breach - Current and Future
- Group Exercise 1 - Discuss Impacts from Flood Scenario A
- Group Discussion
- PIEVC Risk Assessment Orientation
- Group Exercise 2 - Risk Assessment for Scenario A
- Lunch

Agenda

- Group Discussion
- Flood Scenario B - Riverine Flood - Current and Future (NHC)
- Group Exercise 3 - Discuss Impacts from Flood Scenario B
- Group Discussion
- Group Exercise 4 - Risk Assessment for Scenario A
- Group Discussion
- Adaptation Background
- Group Exercise 5 - Adaptation Options
- Group Discussion
- Closing Remarks and Next Steps

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ROUNDTABLE INTRODUCTIONS AND OPENING REMARKS

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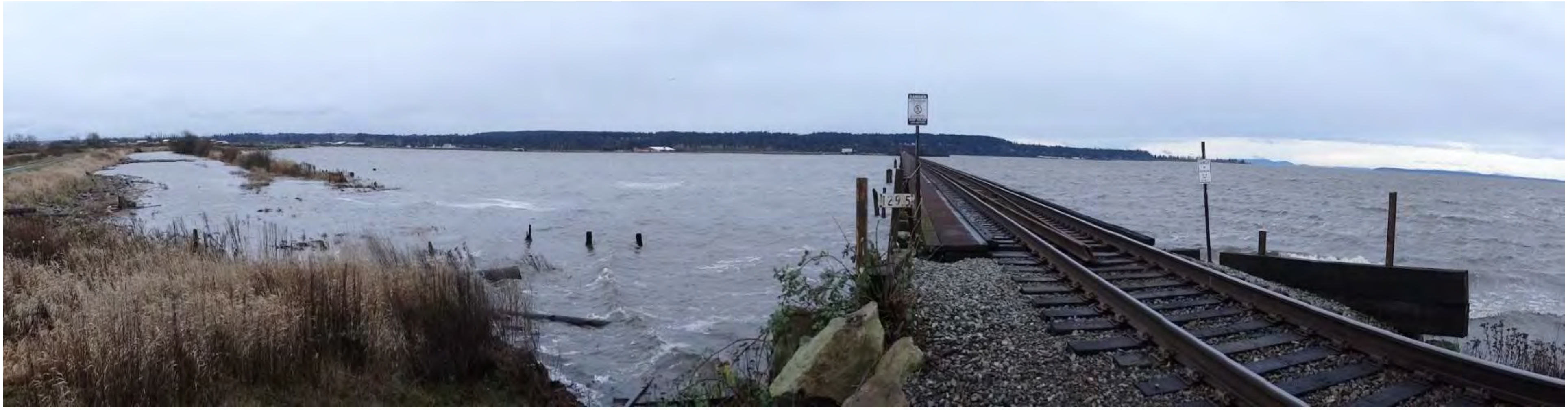

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Ministry of Transportation and Infrastructure

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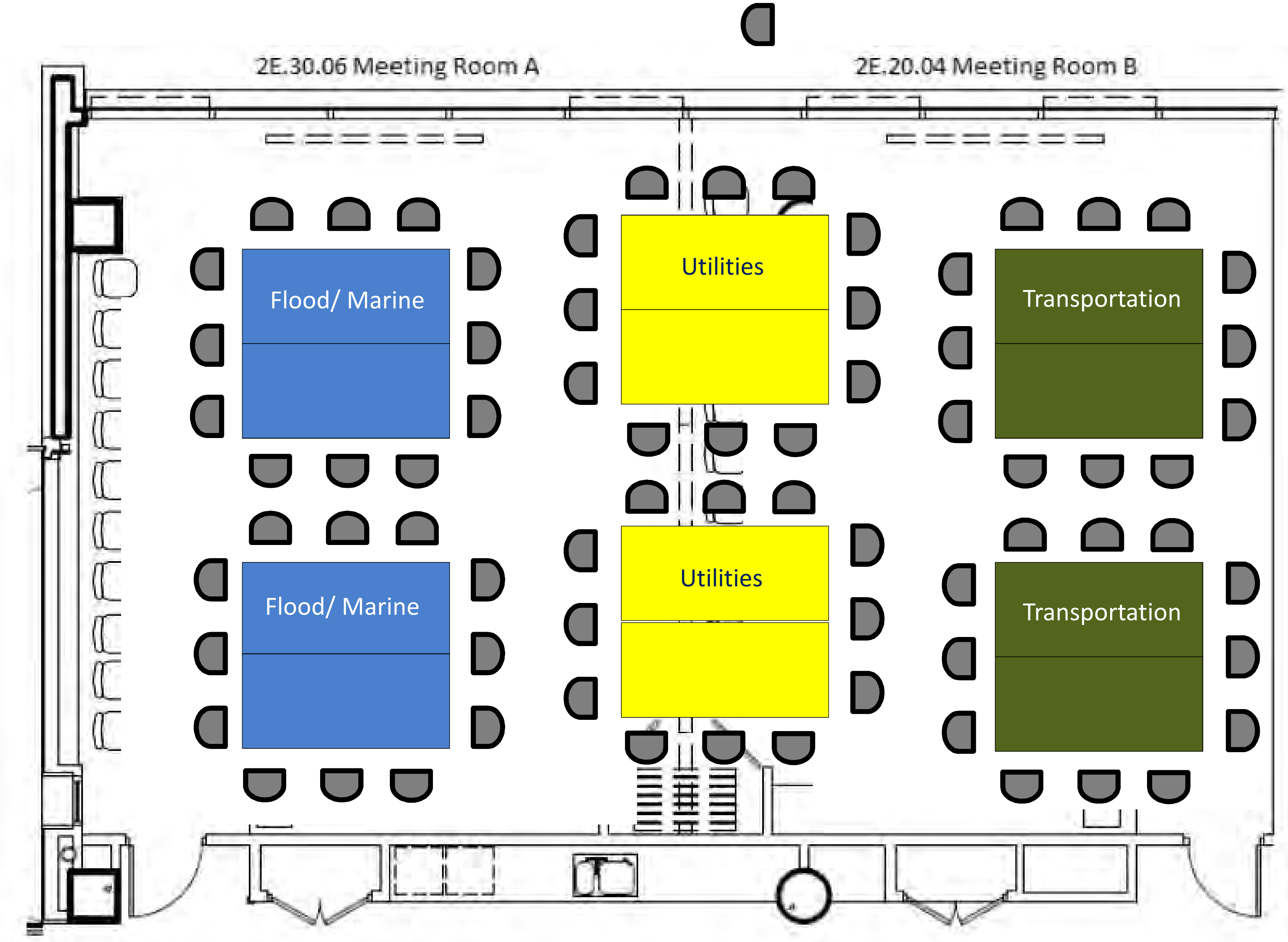

WASHROOM

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Our objectives for the day

- Get a better understanding of:
  - Sea level rise and its impacts on coastal flooding and riverine flooding in relation to infrastructure in Surrey,
  - The Coastal Flood Adaptation Strategy (CFAS) project
- Identify your issues and concerns and potential vulnerabilities
  - Risk assessment using the PIEVC framework
- Explore some preliminary options for addressing coastal flood hazards
- Discuss how best to keep you engaged in the CFAS project

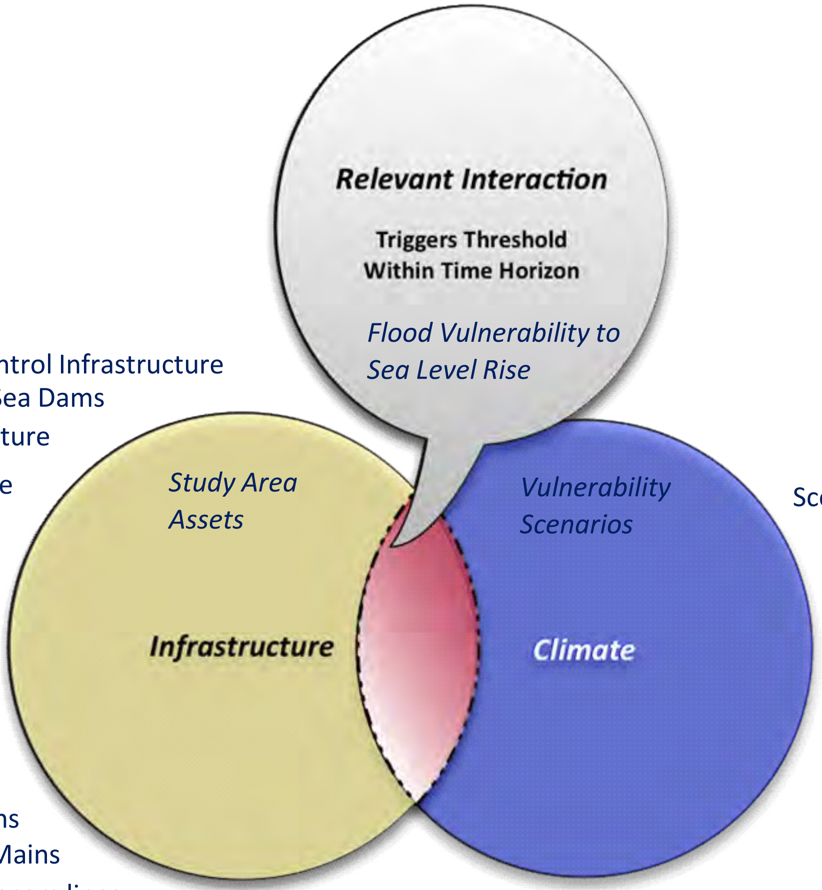
Our objectives for the day

- Today
  - Large cross section of stakeholders with interests, experiences and goals
  - Respectful all discussion (no right or wrong comments)
  - Focus on today's process
  - Don’t get lost in the detail
  - Make this a ‘safe’ discussion
    - Without prejudice
    - No ‘got you’ comments
  - Be mindful of your technology - breaks will be provided
  - Serious topic but we will try to enjoy the process and our day
  - Video and interviews
  - Thank everyone for their time and commitment

Disclaimer

Please note that this workshop shall not be construed as an acceptance or assumption of risk, responsibility, or liability by or on behalf of the City for the 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.

Our objectives for the day



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PIEVC INTRODUCTION

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Climatic Risk Assessment and Adaptation Strategies

David Lapp, FEC, P.Eng.
Practice Lead, Globalization and Sustainable Development

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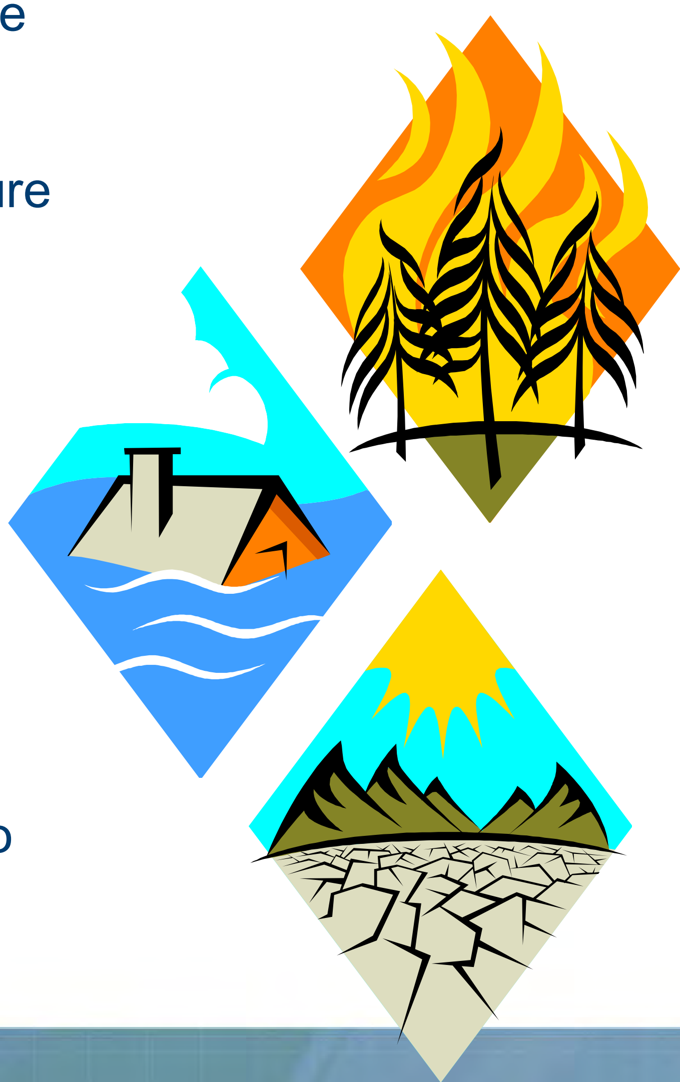
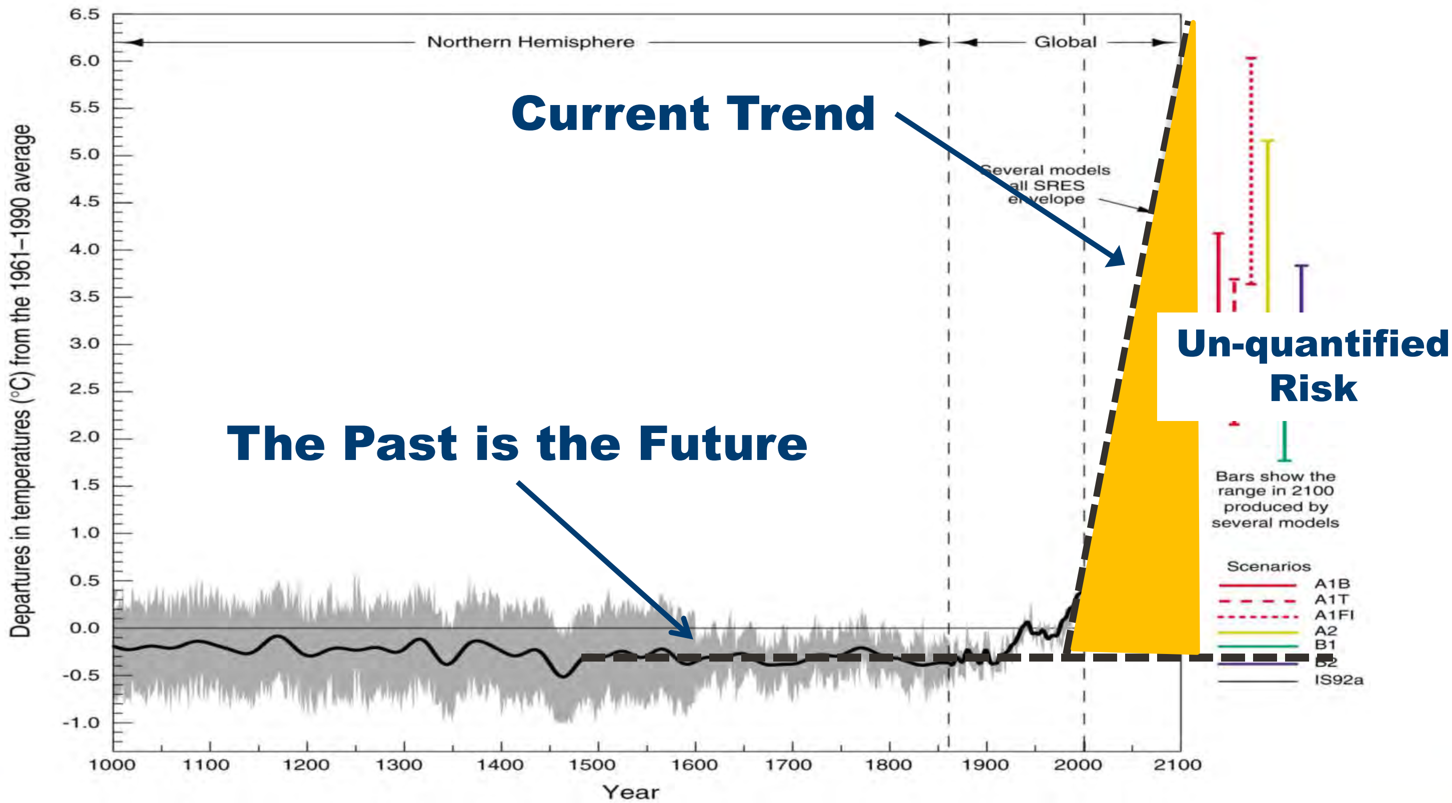
Why Define Infrastructure Risks?

- To deal with the uncertainties of future climate
- To deal with risks to the physical infrastructure and risks to infrastructure service
- Minimize service disruptions
- Protect people, property and the environment
- Optimize service
  - Manage lifecycle
  - Manage operations
  - Avoid surprises
  - Reduce/avoid costs
- First step in risk reduction planning to improve (climate) resilience

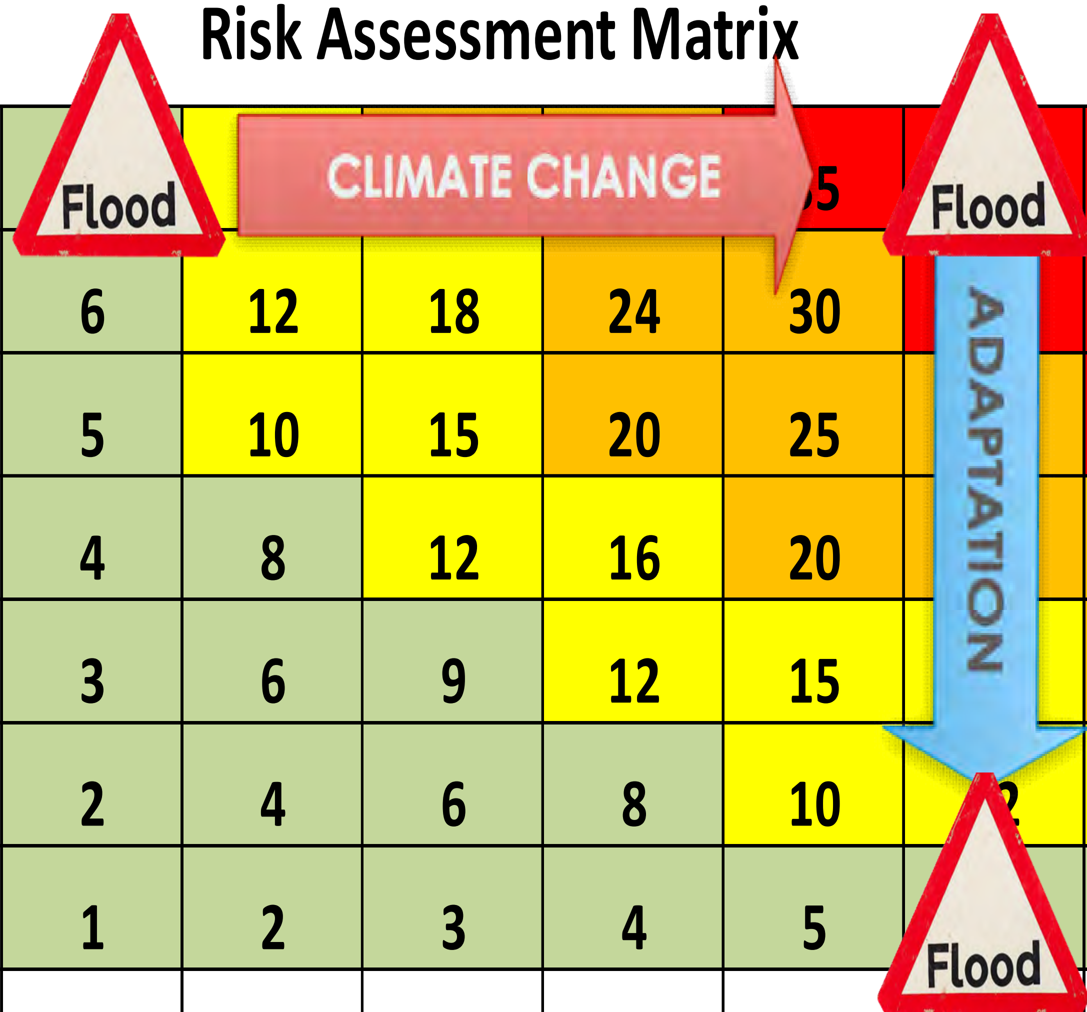


From an Infrastructure Planning, Design and Operations Perspective

- Past climate is not a good predictor of the future

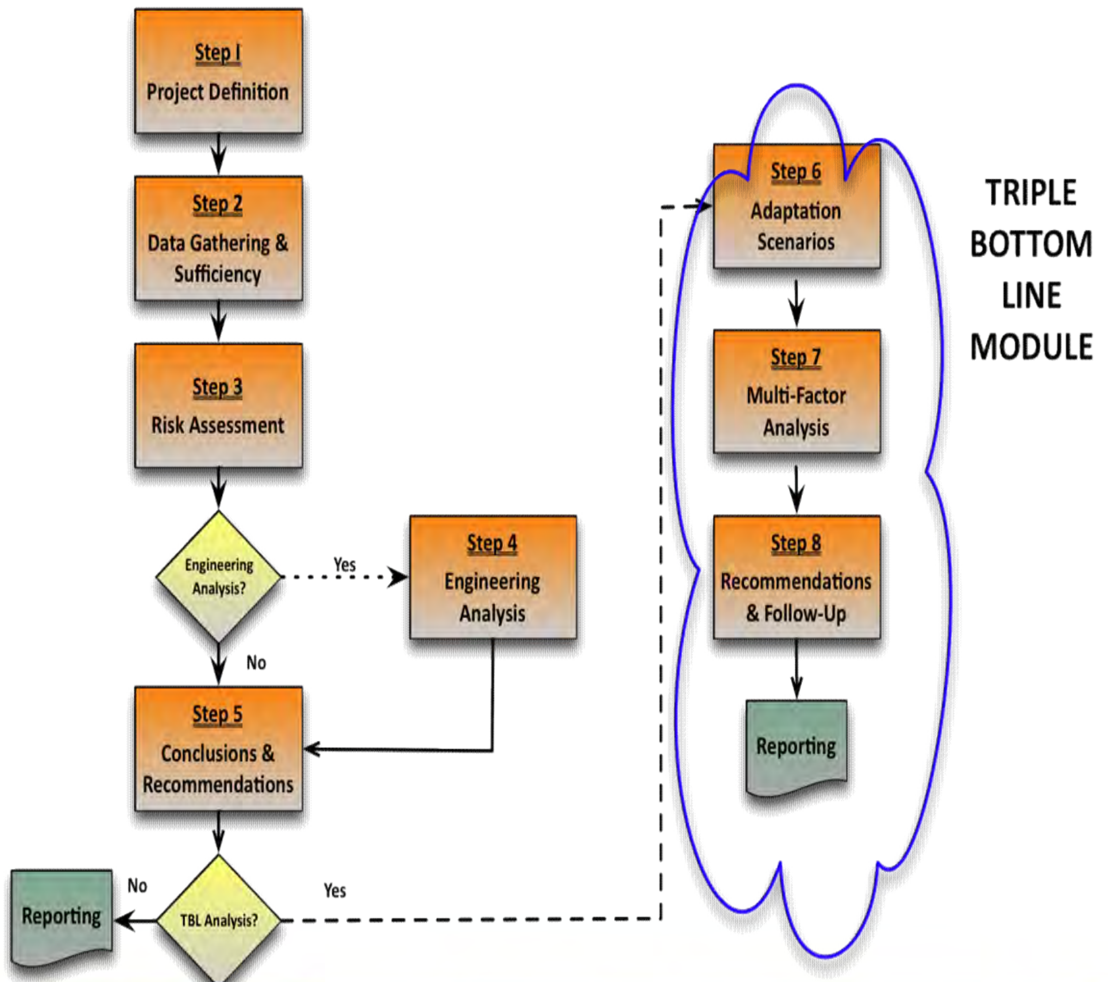


Risk Assessment Matrix



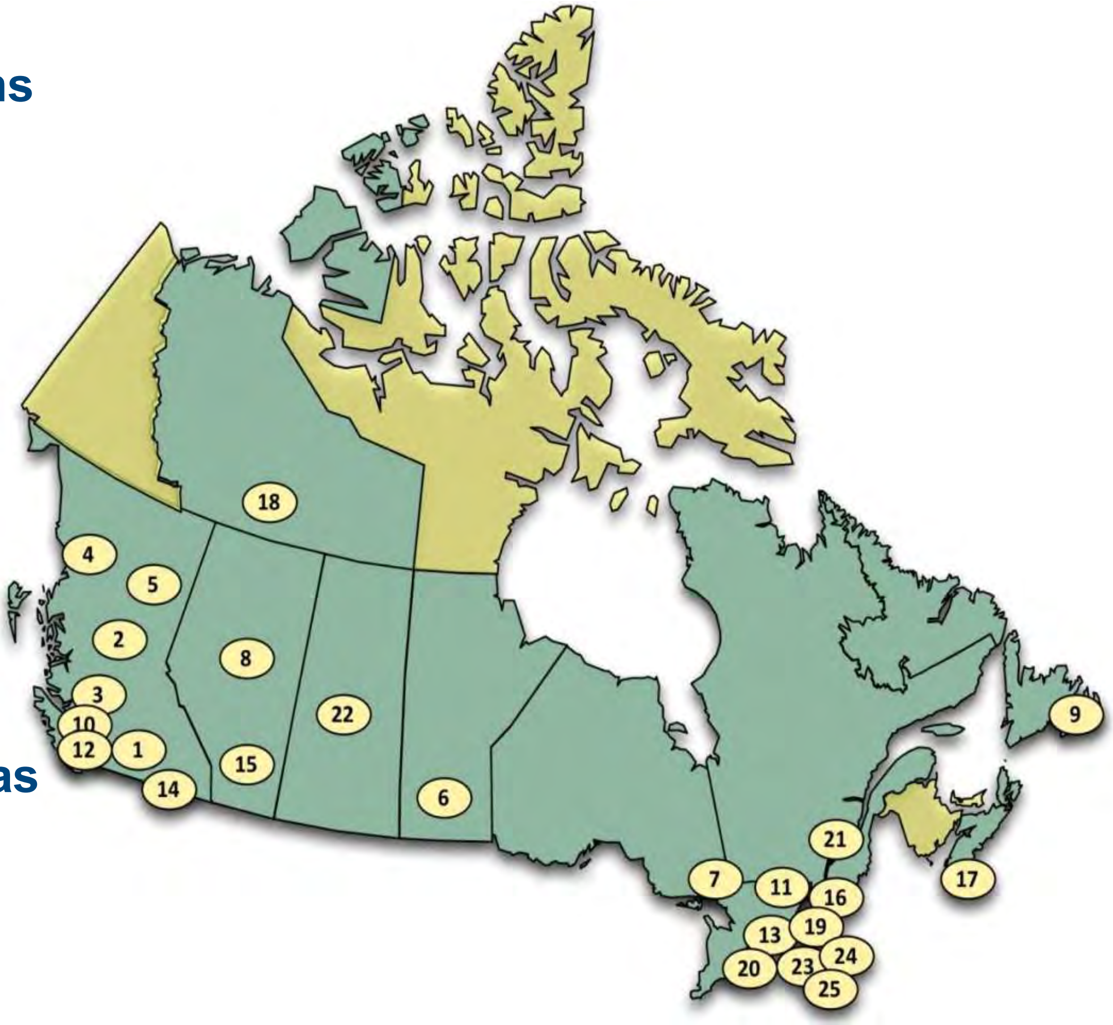
Consequence							
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	49
6	6	12	18	24	30	[illegible]	42
5	5	10	15	20	25	[illegible]	35
4	4	8	12	16	20	[illegible]	28
3	3	6	9	12	15	[illegible]	21
2	2	4	6	8	10	[illegible]	14
1	1	2	3	4	5	[illegible]	7
	1	2	3	4	5	6	7
	Probability of Occurrence						

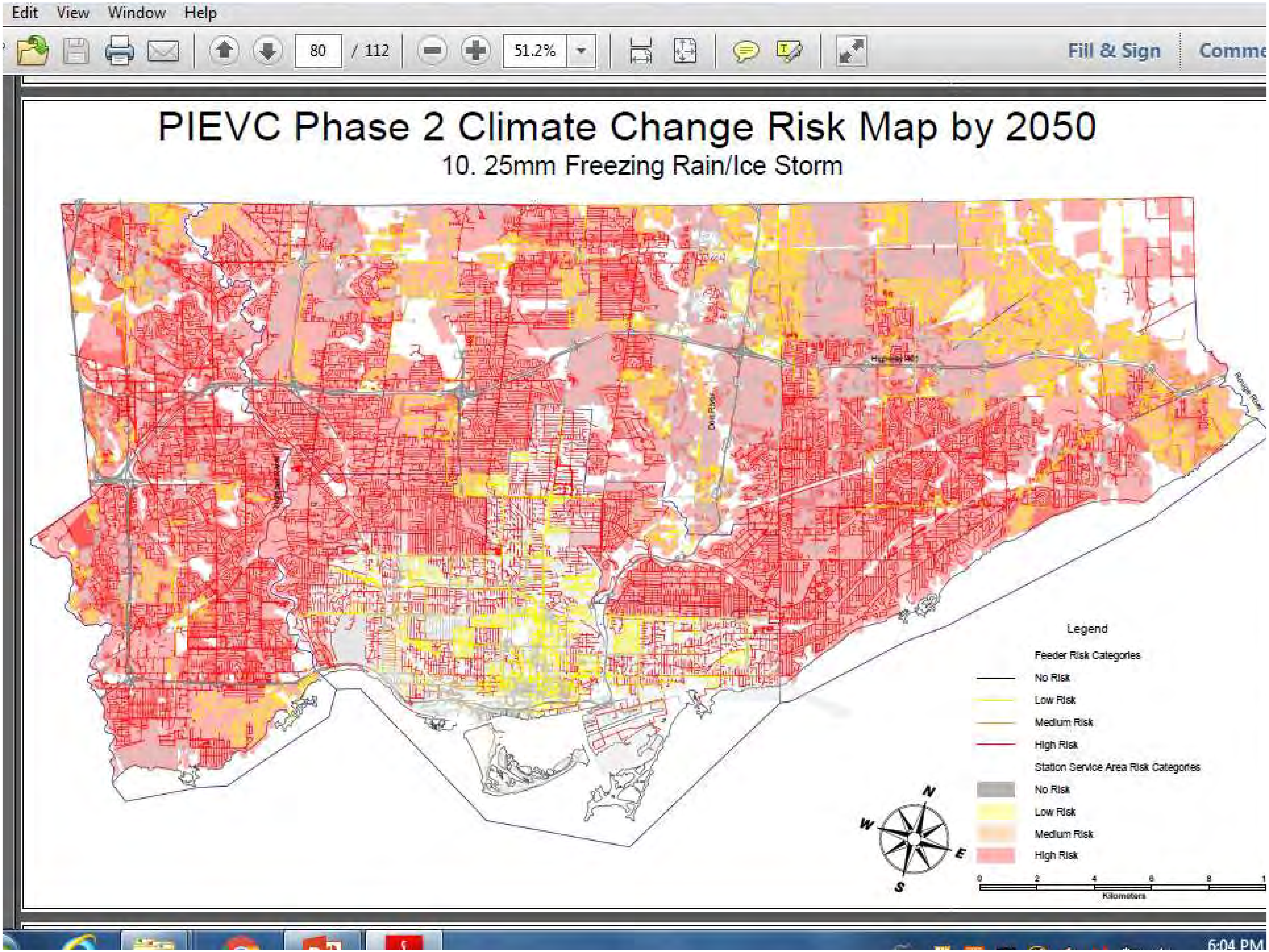
PIEVC Protocol
5 Steps plus an Optional TBL Module



Applied to 45+ Projects and Counting …

- Water resources systems
- Storm & waste water systems
- Roads & bridges
- Buildings
- Transportation infrastructure
- Energy Infrastructure
- International projects in Costa Rica and Honduras

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Fill & Sign
PIEVC Phase 2 Climate Change Risk Map by 2050
10. 25mm Freezing Rain/Ice Storm
Legend
Feeder Risk Categories
No Risk
Low Risk
Medium Risk
High Risk
Station Service Area Risk Categories
No Risk
Low Risk
Medium Risk
High Risk
N
W
E
S
0
2
4
6
8
Kilometers
6:04 PM

Infrastructure Assessment - Benefits

- PIEVC findings applicable to new designs, retrofitting, rehabilitation and operations and maintenance
- Links to emergency response to mitigate community risks
- Identify third-party risks and interdependencies
- Integrate CC risks into asset management and decision-making process
- Beyond engineering and "Need bigger and stronger" → adaptive measures

For more information:

www.pievc.ca

david.lapp@engineerscanada.ca |
613.232.2474 ext 240
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CFAS INTRODUCTION

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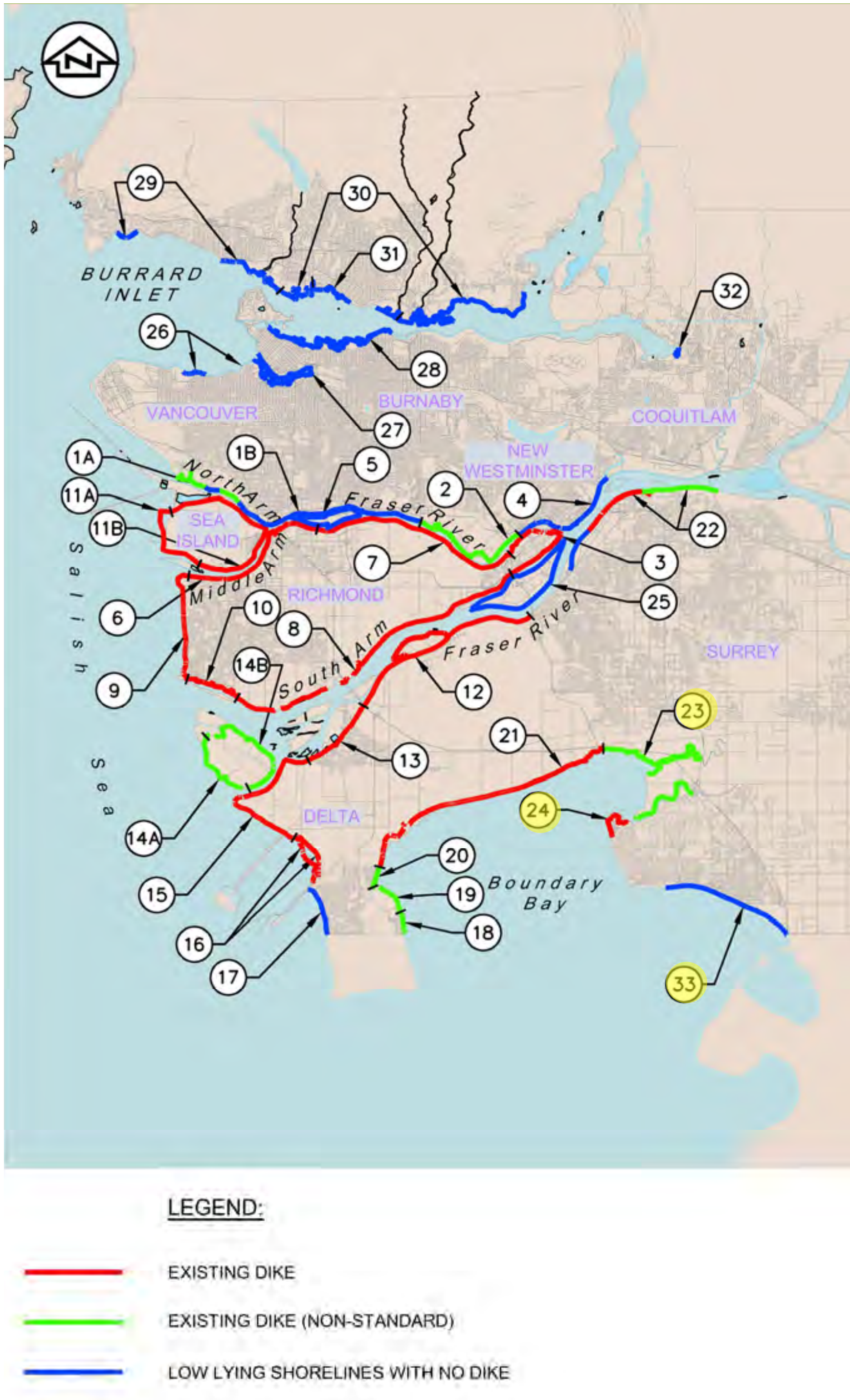

Introduction & Summary

- 2011 Provincial Guidelines on sea level rise published
- Outlined expected sea level rise and flood protection requirements
- 2012 Provincial report estimated the cost to adapt flood protection to meet the rise in sea level predicted by 2100
- $9.5 Billion estimate for Lower Mainland
  - Estimate of works in Surrey, $1.5B
  - $463.5 M for Mud Bay alone

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Surrey's Climate Adaptation Strategy

Working with *ICLEI Canada: Local Governments for Sustainability*

Building Adaptive, Resilient Communities (BARC)

2011

- Council Report
- Advisory Team

2011

- Background Research
- Risk Assessment

2012-2013

- Staff Working Groups
- Strategy Development
- Stakeholder Engagement

2013 -

- Top 10 Actions
- Implementation work plan
- Risk Management Framework

Likely social, economic, and environmental impacts of climate change

Climate Adaptation Actions

Identified lead departments and tools, as well as 11 actions for immediate implementation:

Goal 2: Update Planning and Development Standards for Floodplains						
	Adaptation Action	Sphere of Influence	City Lead	Support	Tools	Cost
FL-2.1	Conduct detailed analysis on Surrey-specific climate impacts, including the timelines and extent of sea level rise and its related effects on flood construction levels and floodplain designations	Municipal Jurisdiction	Eng	P&D; CMO		$$$$
FL-2.2	Develop drainage and flood strategies based on cost-benefit analyses and site-specific needs	Municipal Jurisdiction	Eng	P&D; CMO	OCP (DPAs); NCPs, ISMPs; By-Laws	$$$$
FL-2.3	Incorporate climate change into the City's Integrated Stormwater Management Plans (ISMPs) and other efforts to integrate land use planning and stormwater management	Municipal Jurisdiction	E			
FL-2.4	Review and revise regulatory and design standards to account for and minimize the impacts of climate change	Municipal Jurisdiction	P			

Immediate Implementation

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SURREY COASTAL FLOOD ADAPTATION STRATEGY (CFAS)

- Mayor & Council adopted recommendations to develop a Coastal Strategy Feb 22, 2016 under Corporate Report No. R034;2016
  - Continuing commitment to participatory planning
- CFAS anticipated to be complete by end of 2018
- Large study area with many communities, stakeholders and partners

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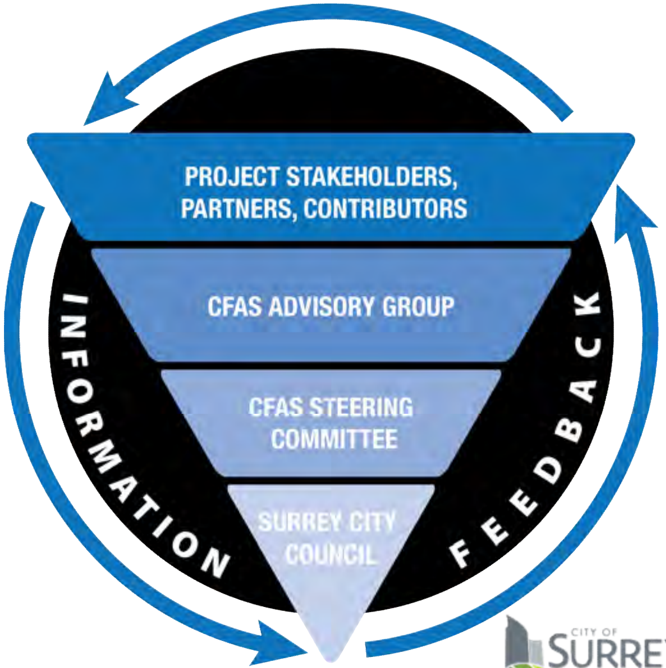
Surrey CFAS Process

- Many stakeholders
  - Farmers and agricultural community
  - Residents, businesses, community groups
  - Environmental and recreational groups
  - Infrastructure operators, owners & emergency service providers
  - Semiahmoo First Nation



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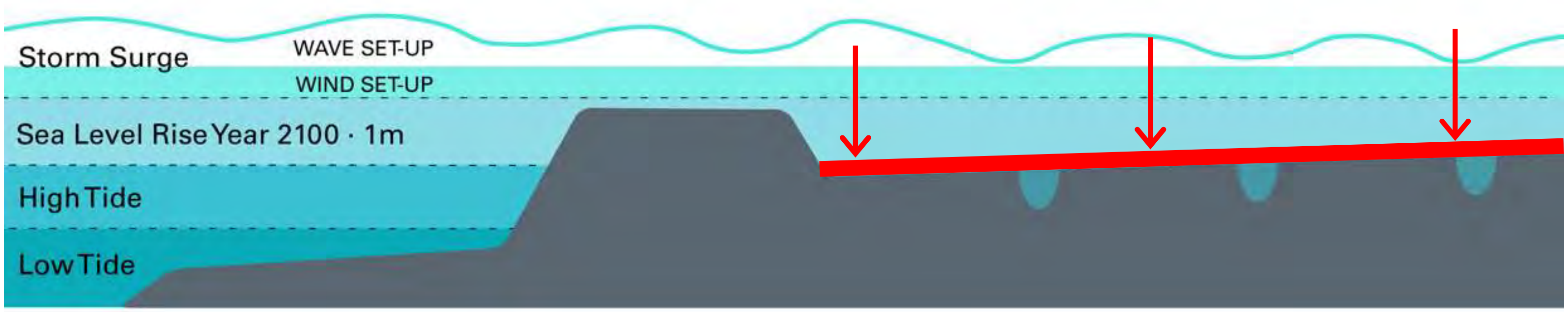
Surrey CFAS Process

Surrey's Coastal Floodplain

- A natural floodplain
- Regularly experiences coastal flooding
- Ocean-driven flooding (storm surges, king tides)
- River-driven flooding (rain storms, rapid snow melt)

Climate Change and Flood Hazards

- Sea level rise and ground subsidence
- Sea level rise combined with more frequent and more intense storm surges increases the risk of dyke breaches – overtopping, failures, and piping



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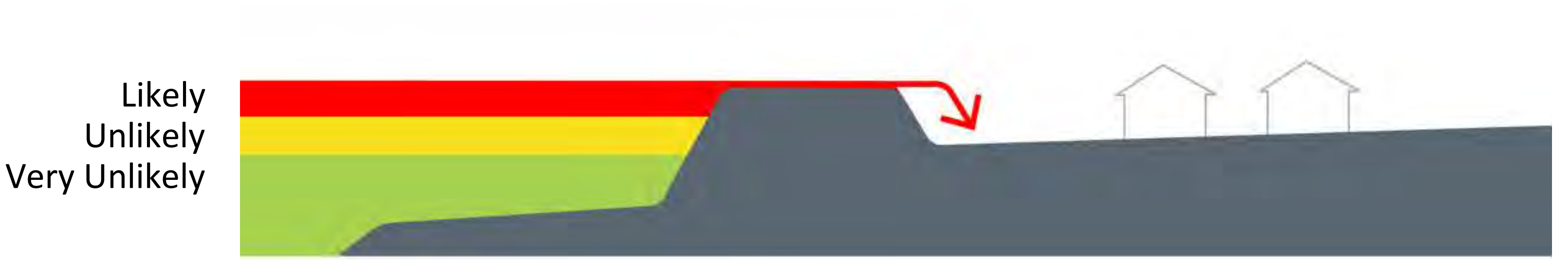
Dyke Breach Risk

Likelihood of Breach



Infrastructure Impact from 200 yr. return Water Level

Sea Dams:	Dry ◆	Compromised ◆	Wet ◆
Bridges:	Dry ●	Compromised ●	Wet ●

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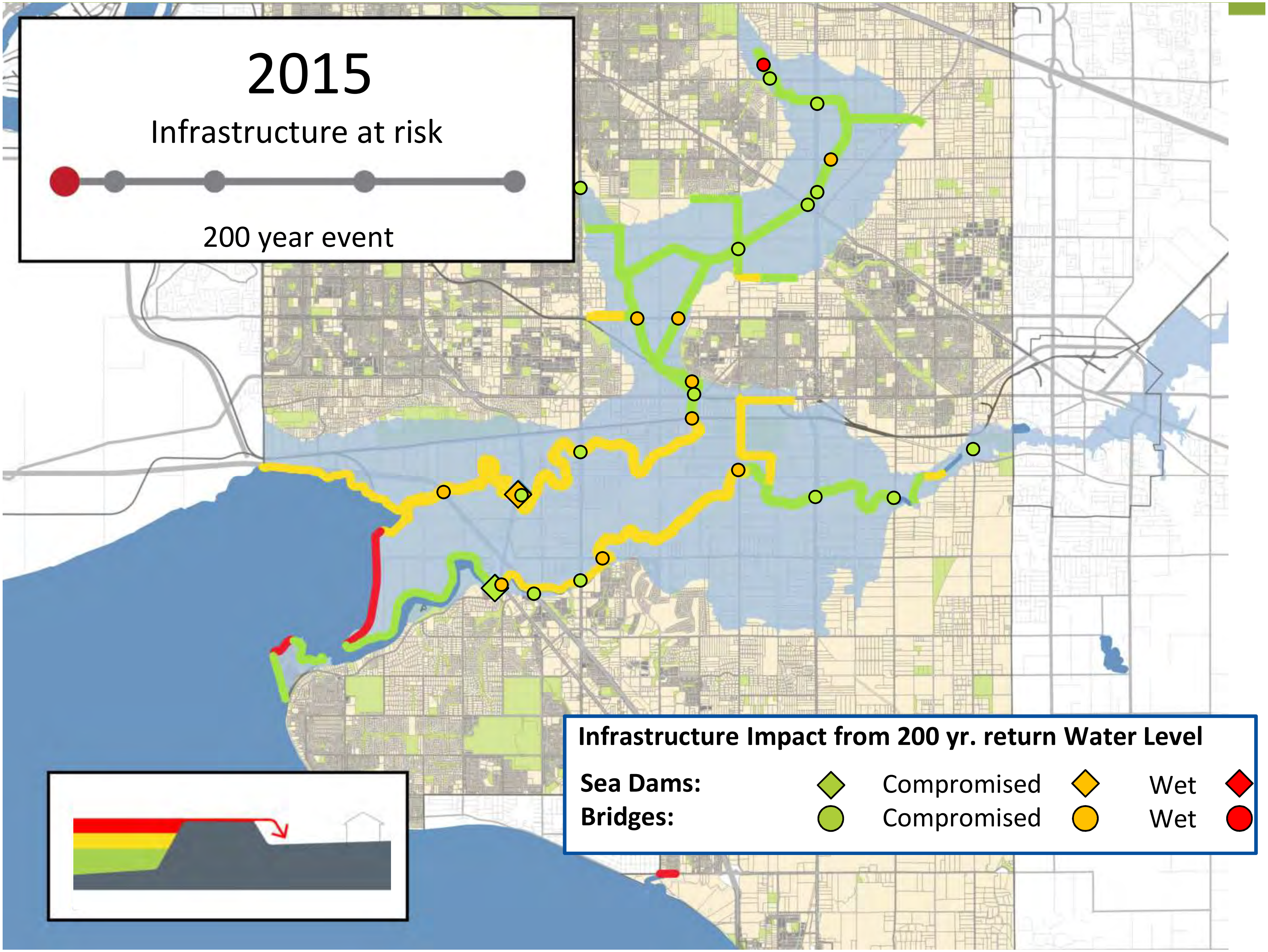
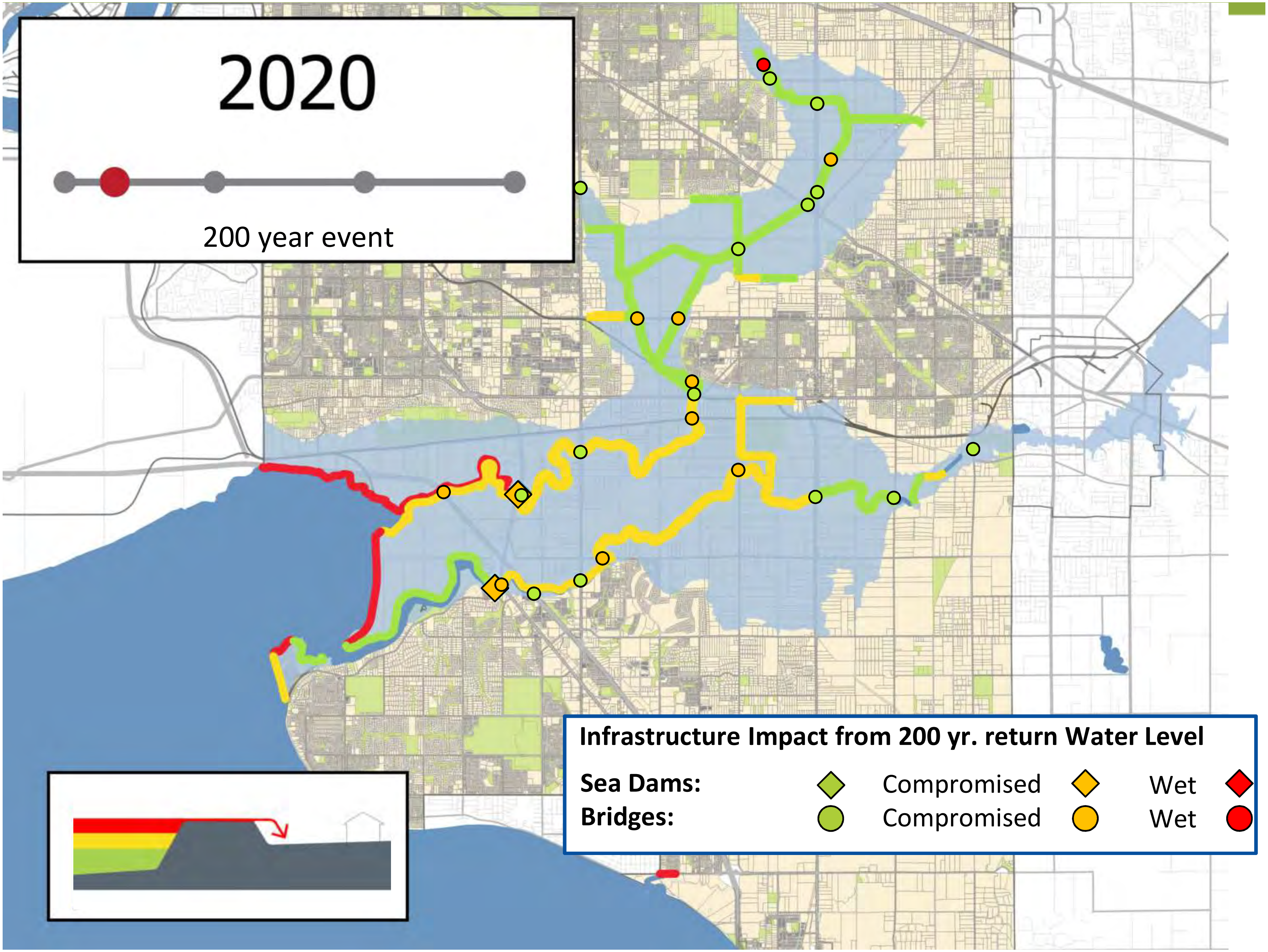
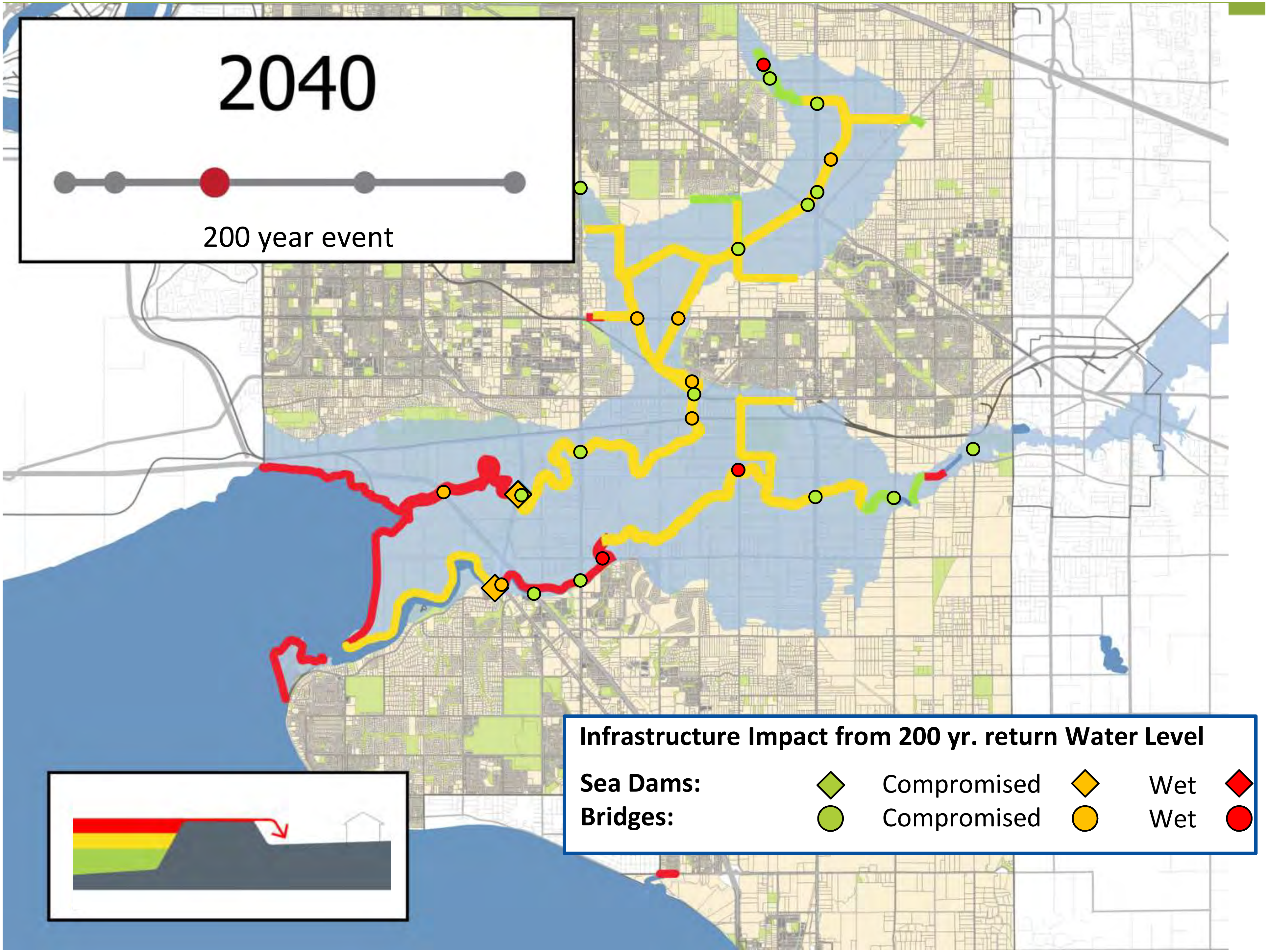
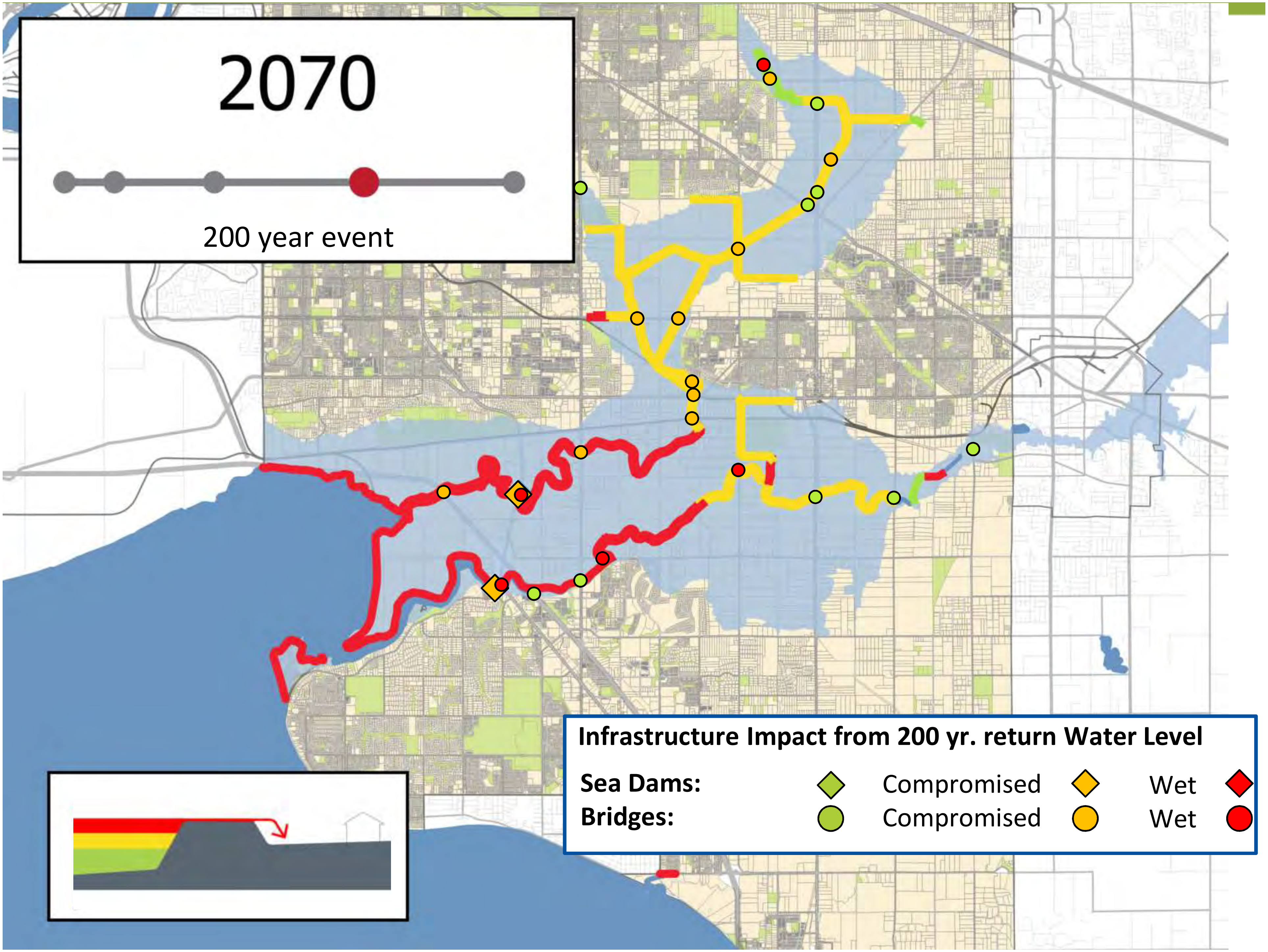
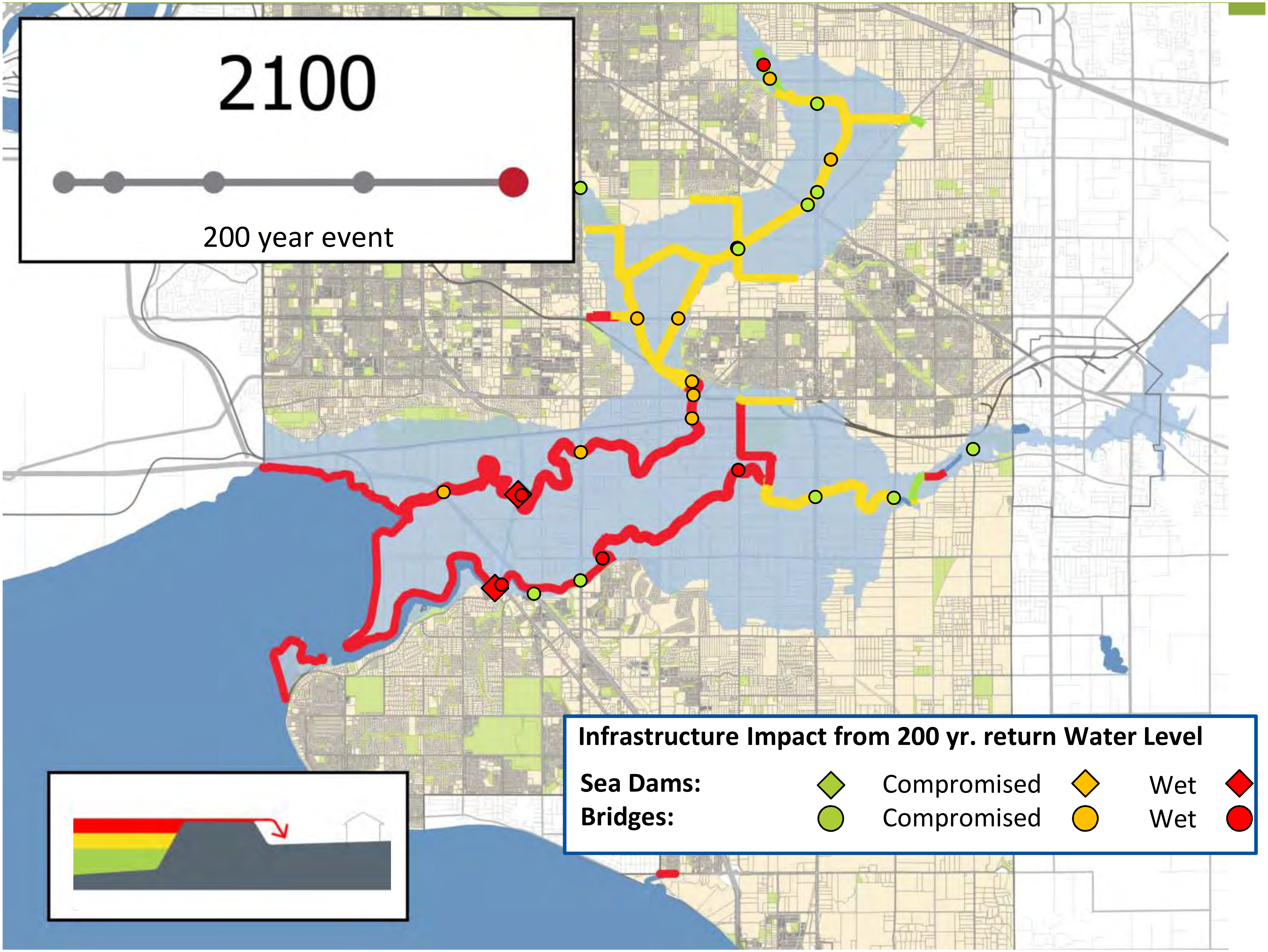

2015
Infrastructure at risk
200 year event
Infrastructure Impact from 200 yr. return Water Level
Sea Dams:
Bridges:
Compromised
Compromised
Wet
Wet


2020
200 year event
Infrastructure Impact from 200 yr. return Water Level
Sea Dams:
Bridges:
Compromised
Compromised
Wet
Wet


2040
200 year event
Infrastructure Impact from 200 yr. return Water Level
Sea Dams:
Bridges:
Compromised
Compromised
Wet
Wet


2070
200 year event
Infrastructure Impact from 200 yr. return Water Level
Sea Dams:
Bridges:
Compromised
Compromised
Wet
Wet


2100
200 year event
Infrastructure Impact from 200 yr. return Water Level
Sea Dams: Compromised Wet
Bridges: Compromised Wet

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HISTORY OF FLOODING

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Flood & Infrastructure Context

- History
  - Dyke construction & operation
  - Sea Dam construction & operation
  - Significant flood events
- Ongoing Infrastructure Challenges
  - Shoreline erosion
  - Ground subsidence & embankment settlement
  - Accelerated corrosion from brackish water

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Dyke History

- A long history of work starting with early European settlers
- 1890's first dykes

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Dyke History

Originally starting in the 1920’s, it wasn’t until the late 1950’s and the acquisition of a drag line that mechanized dredging along the both rivers became a regular project.

Dredging was completed to build up the dykes, and remove silt .

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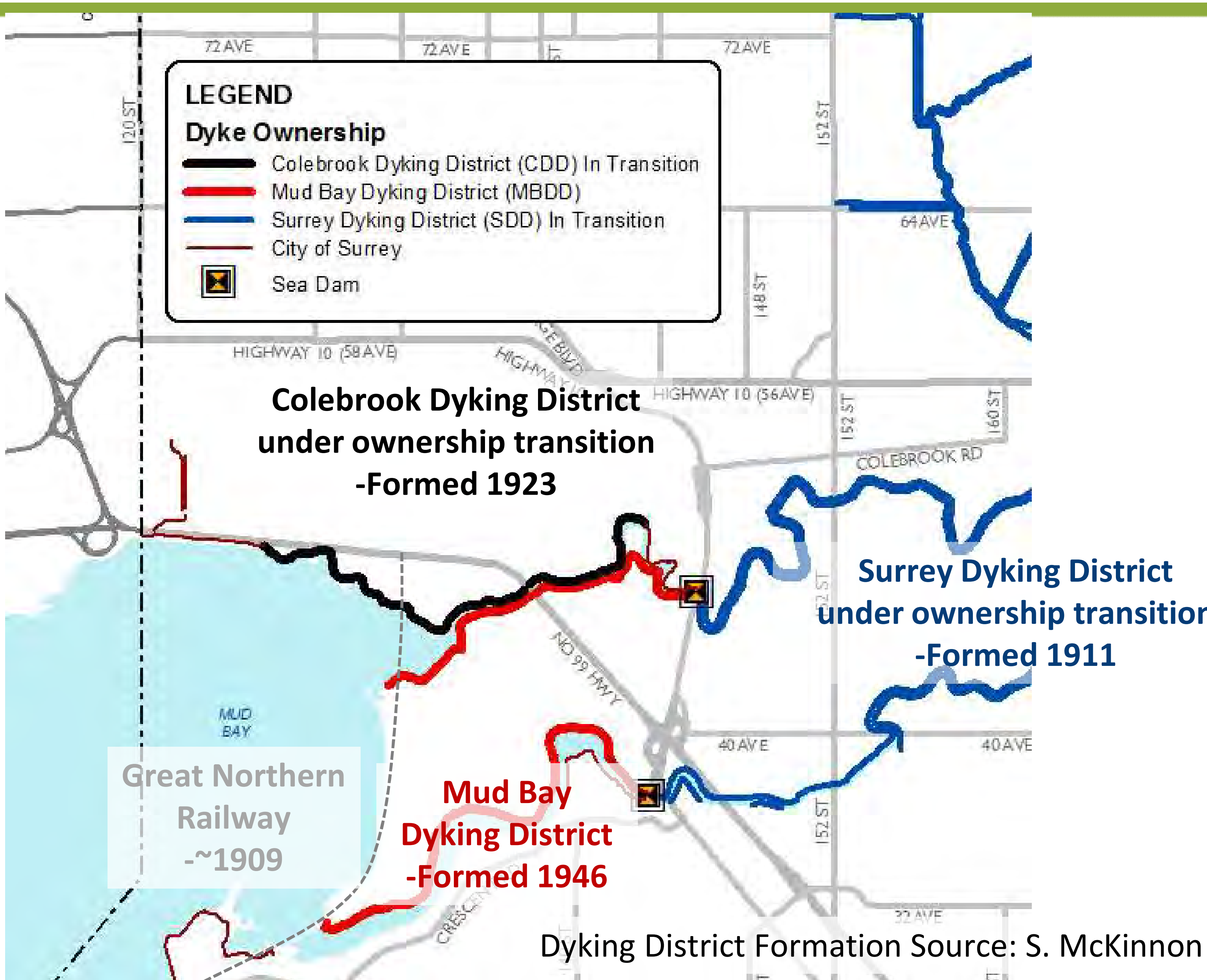

Dyking District Formation Source: S. McKinnon

Sea Dam History

"Another ambitious scheme, begun in 1899, was destined to involve the Municipality of Surrey in a lengthy period of trouble and expensive litigation. Settlers along the reaches of both the Serpentine and Nicomekl rivers early began building dykes along their individual farms in order to bring the rich lowlands under cultivation. As John Stewart put it, they "fought the Pacific Ocean with spades", since the tidal nature of the rivers caused frequent flooding. Some farmers in the area raised a considerable sum of money towards a dyking scheme and offered to turn their funds over to the Municipality if it could be made a public project."

~Surrey Story, Page 38

A- LOOKING NORTH
FROM SOUTH BANK

B- LOOKING SOUTH
FROM RIVER

C-LOOKING UPSTREAM
FROM SOUTH BANK

D-LOOKING NORTH
FROM SOUTH BANK

Source: Surrey Story

PLATE 6.4 – ORIGINAL SERPENTINE
RIVER DAM BUILT IN 1889

Source: Surrey Archives

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In 1922 a hole under the Nicomekl Sea Dam formed, and continually progressed which decreased the level of protection provided, and allowed brackish water to enter the Nicomekl River.

Over the 40-years many several attempts were made to fill the hole including piling, and concrete and earth plugs to no avail.

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Save for Bob Hugh

The Weather

Partly cloudy not much change in temperatures. Thursday's, 76, 57.

The Vancouver News-Herald

Metropolitan Edition

VOL. 13, NO. 74 — VANCOUVER, B.C., FRIDAY, JULY 20, 1945 — ★★★ 85c Month By Carrier — PRICE 5c

7-HOUR FIGHT SAVES DIVER'S LIFE

Air line only contact with trapped diver

Third attempt to rescue trapped man

"He's coming to the surface!"

64 Year Old Worker Rescued From River

By PETER MADISON

Many things can happen to a man during 64 years of life . . . especially if he's a diver for 22 of them.

But when he's trapped for seven hours in 15 feet of water behind the 16-foot steel flood gates of the Nicomekl River dam those hours can be longer than all his previous life span.

That's what happened to Ben Gilbert, the 64-year-old diver. He is still alive to tell about it.

The grim drama of rescue workers battling the surging current at the dam gates to free the trapped man started about 2:30 Thursday afternoon, when the Straits Towing and Salvage Company of Vancouver received an emergency call to rush a diver and equipment to the Nicomekl bridge in Surrey municipality where a diver was trapped.

George Unwin, husky salvage supervisor and diver of the Straits Towing andd Salvage Co., headed a rescue crew and equipment to scene.

Within an hour from the time they left Vancouver, Unwin was down under the flood gates trying to free the trapped man.

EXPLAINS MAN'S PLIGHT

"As soon as I got down to him, I saw that he was trapped. If we tried to pull him back against the current to the surface, we would smash his ribs and limbs. I made him as comfortable as possible, took the weights off him, but that's all I could do then, because I was helpless to aid him," the rescue diver told this reporter.

Unwin explained that the trapped man had been working on the flood gates for about a month, repairing cement bases upon which the swinging gates rested.

It was not a new job for Ben Gilbert, nor a particularly dangerous one so long as everything went on schedule.

Each summer, for many years, he had repaired and replaced some of the six sets of steel

workmen were examining to hook a line onto and wrench open.

He explained, as he was taken out of his diving suit, that to try to pull the seemingly doomed man back against the current would cut the diving suit to pieces.

Spurred on by the hope of rescuing the diver before the tide, which had started to rise, would prevent any chance of saving him, the men working at the third dam gate increased their activity. It would take at least another couple of hours after the gate was opened before the tide would level off enough to make another attempt possible.

The first time the cable was hitched to the third gate it only pulled part of the gate away with it. The workers decided to try pulling from the other side of the bridge on the opposite river bank.

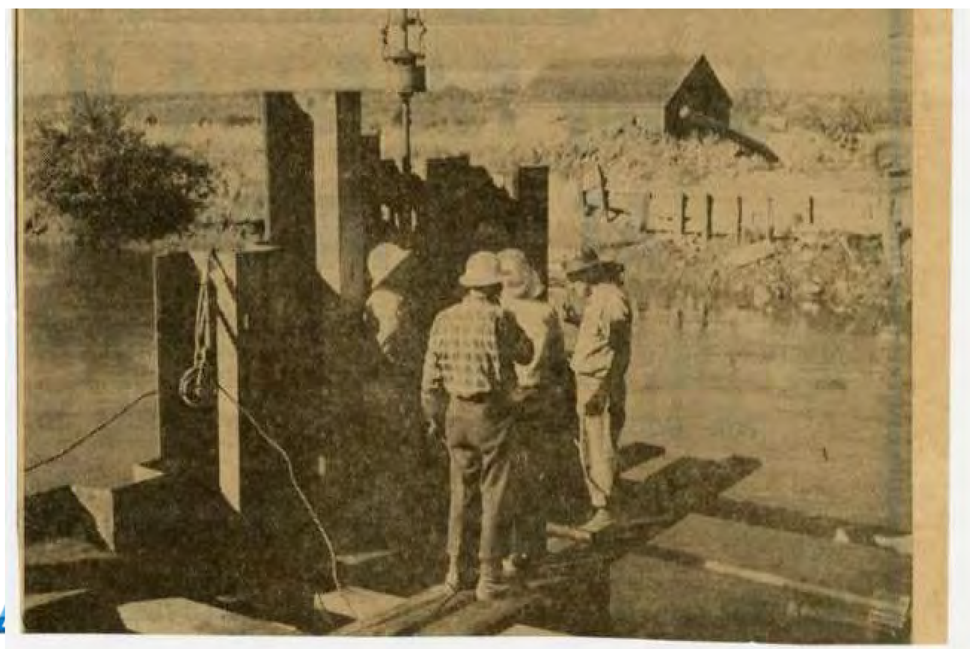
This time, the pull was successful and the gate gradually swung open, allowing a torrent of banked-up water to rush through.

STANDING BY

Sea Dam History

In 1960, steel sheet piles were installed at 25 feet under the sea dam to finally fix the sea dam.

The estimated cost for there works was $32,000 (approximately $230,000 today) but actually cost $92,000 (approximately $660,000 today) as some additional work was required to remove the material from many of the past repair attempts.



Heavy Costs Faced for Dyke Repairs

"We had an estimate of $32,000 and actual costs of $92,000. Who goofed and why?" was the blunt question of B. Graafstra, 5118 Boothroyd Road, at the annual meeting of Surrey Dyking District ratepayers.

The river valley farmers were considering reports and financial statements on the repairs to the Nicomekl River dam at Elgin.

Dyking Commissioner chairman Doug Bose explained that it was not possible to know when repair work started all the difficulties which would be faced.

"We didn't think we'd have to remove the old wooden piling in front of the dam," he stated. Then it was found impossible to seal the new concrete to the old apron, and that had to be removed.

Divers worked under very difficult conditions — they could not see through the murky water, but had to feel with their hands.

Most of the ratepayers were familiar with the difficulties of repair work on an old structure, and also of the difficulty in working in the river. There was not too much argument over the course of action which the Commission had taken.

Big question facing the meeting was how to pay the costs.

BANK LOAN

Commissioner John Lane reported that $55,000 had been borrowed from the bank at 5½ per cent interest. Surrey Municipality has provided $8,000 and Hon. Frank Richter, the new Minister of Agriculture, has given sympathetic hearing to the Commission at the provincial level.

A special levy of around $2 an acre over three years may be necessary.

Keith Douglass, engineer with Hunter, Douglass & Crockford, reported on the development of Elgin dam and on the repair job.

This dam on the Nicomekl was built in 1912, and a serious blowout occurred in 1922. A wooden pile wall was installed on the seaward side of the dam, and concrete poured into the break under the dam.

The current, however, carried the cement away. Recently the dam began to leak seriously and cracks were opening in the old concrete apron protecting the face of the dam.

A pile wall of interlocking sheet steel was driven six feet in front of the apron, Mr. Douglass explained. Then the old wooden pile wall had to be removed, which proved very difficult.

Concrete was laid through pipe, to avoid having it washed away.

"There are still voids of varying thickness under the old structure," he reported, varying from 1½ inches to 3 feet. These need to be filled, and then the work will be complete.

All doors on the dam are now secure; the river bed is in very good condition; and concrete is 5 feet deep along the sheet pile wall, the engineer stated.

Commissioner W. L. Heppell reported on the District's shovels and machinery, which is in good condition.

John Lane gave the report on the dykes. With the gates on the dam propped open during the months of repair work, there were between 20 and 25 breaks when high tides combined with heavy

S. T. Feb 2/61

Nicomekl Sea Dam

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Historic Flooding

1935

On January 20th it began to snow, which wasn't unusual for the time of year. Only this it kept on until the snow lay four feet deep over Surrey. The ground had frozen hard that winter before the snow started. After the great snowfall it rained for another two days. The water couldn't get away through the frozen ground and an icepack rose to the top of the water. The Serpentine flats around Cloverdale were badly flooded. The B.C. Electric rails were just showing. Dr. Sinclair carried a canoe on top of his car and paddled his way to patients.

George Lane and Cec. Heppell on duty for the Municipality, took a boat down the Coast Meridian Road [now 168 St], hauled it over a bridge that still showed above water, and then rowed on to take supplies to people marooned in their homes.

An old man stayed with his incubators till the water was almost up to the lamps, as he tried to save his hatching chicks. At the Keery farm they had both the piano and the cows up on bales of hay to keep them out of the water. The old Collishaw place was on higher ground and neighbors gather there.

As Lane and Heppell tried to bring their boat back along the road the wind had risen, causing ice cakes to block their way. They had to chop themselves free. Today's 'Oldtimers' of the Thirties have many stories to tell of the Big Flood…

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Source: Surrey Story

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1951

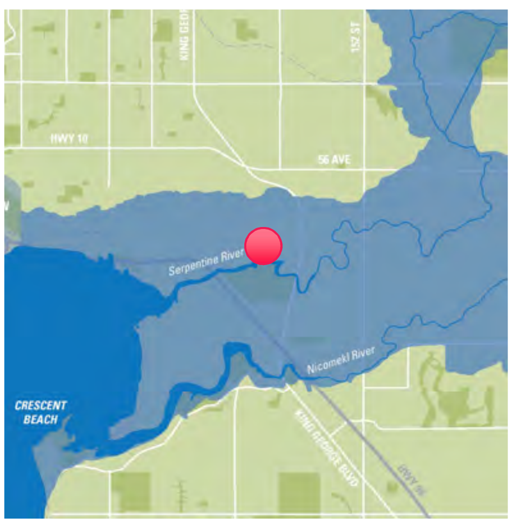
"In December the highest tides in months, combined with gale-force winds, sent water roaring through a 60-foot break in the dyke along the Serpentine River, in the Mud Bay Dyking District. Five feet of water covered about 1,200 acres of farm land from the south bank of the Serpentine to the north dyke on the Nicomekl.

Repairs were estimated at twenty thousand dollars and the productivity of the land was down for the next few years from the effects of the salt water.

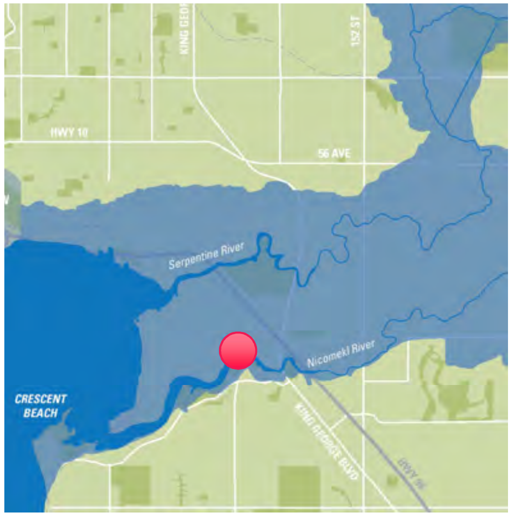
~Account of 1951 flood in Surrey Story

Major Coastal Floods 1951 created 60 foot gap in the dyke. One month of repairs unsuccessful. By Feb 28, 1952 subsequent repair attempt unsuccessful. Dyke moved back 300 ft.

Source: S. McKinnon, 1996



Major Coastal Floods 1951 created major change in lands at current Nicowynd site



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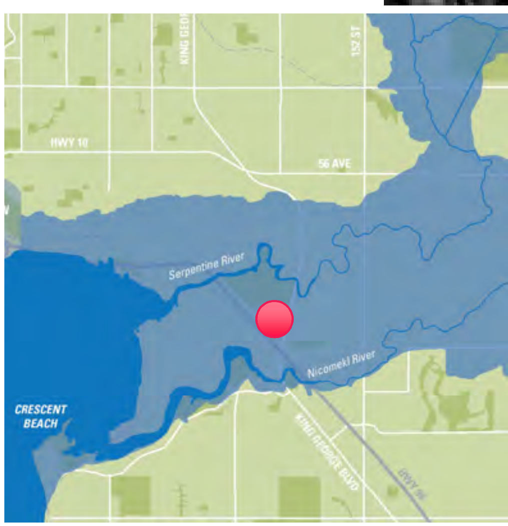
1951 United Church Flood (Mud Bay, near 48 Ave and King George Blvd)



1952 Flooding

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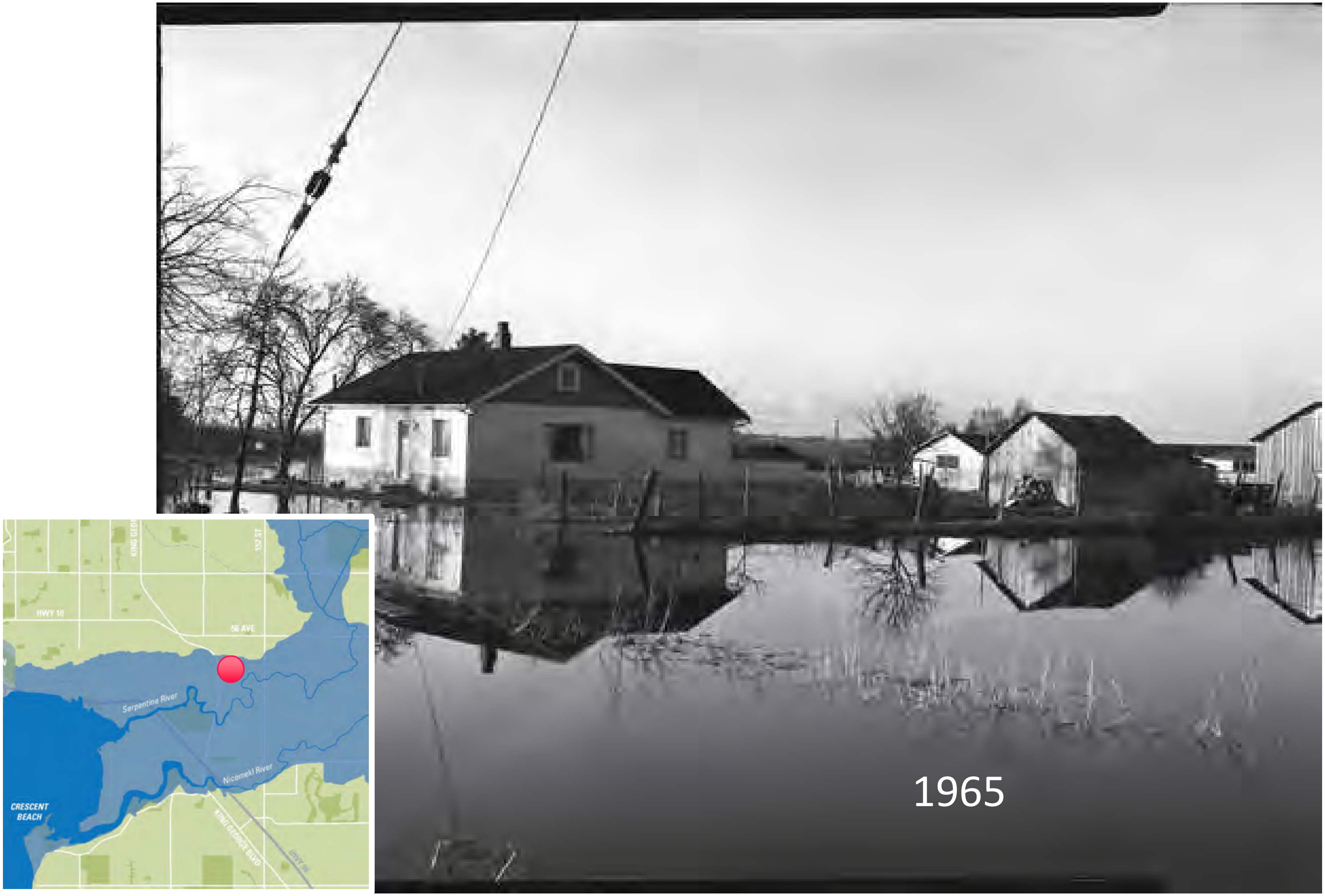
1965 Flood


1965
152 ST
HWY 10
56 AVE
Serpentine River
Nicomekl River
CRESCENT BEACH
KING GEORGE BLVD

1968 Flood

1968 Major flood impacting Crescent Beach, NicoWynd and Mud Bay

Crescent Beach Flood Protection by Wooden Wall

Flooding in Mud Bay district

ese recreational vehicles parked on the lot Nico Wynd Golf Course were literally omped by high water Thursday. The Nico-nd golf course was completely flooded, with water even entering the pro shop building, which doubles as a recreation centre for the luxury townhouse development on Crescent Road.

Rather noncholant about flooding of his home, this old-timer has rowboat moored to his house, on King George Highway just north o Nicomekl River.

e Nicomekl River breached the dikes west of e dam at Elgin on Thursday morning. Heavy inds, combined with a 15.4-foot tide, caused serious damage to the dikes. This photo, taken about 10 a.m., shows the already-subsiding waters dangerously near the top of the dike.

Surrey MLA Bill Vander Zalm met with Mud Bay and Surrey dykin commissioners on Saturday, and inspected the flooding in Mud Bc district. Here he checks on the water being discharged from temporary tractor-powered pump on the big ditch alongside Elg Road, at Nicomekl River.

The clubhouse at Nico Wynd golf course had salt water over the floors and carpets.

Frank Bucholtz photos

The windstorm and high tide in the early hours of last Thursd battered Crescent, dumping logs on the beach and boulevard. Here i. pile of these logs gathered by municipal crews and equipment, ne the end of Sullivan Street.

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1968 Flood

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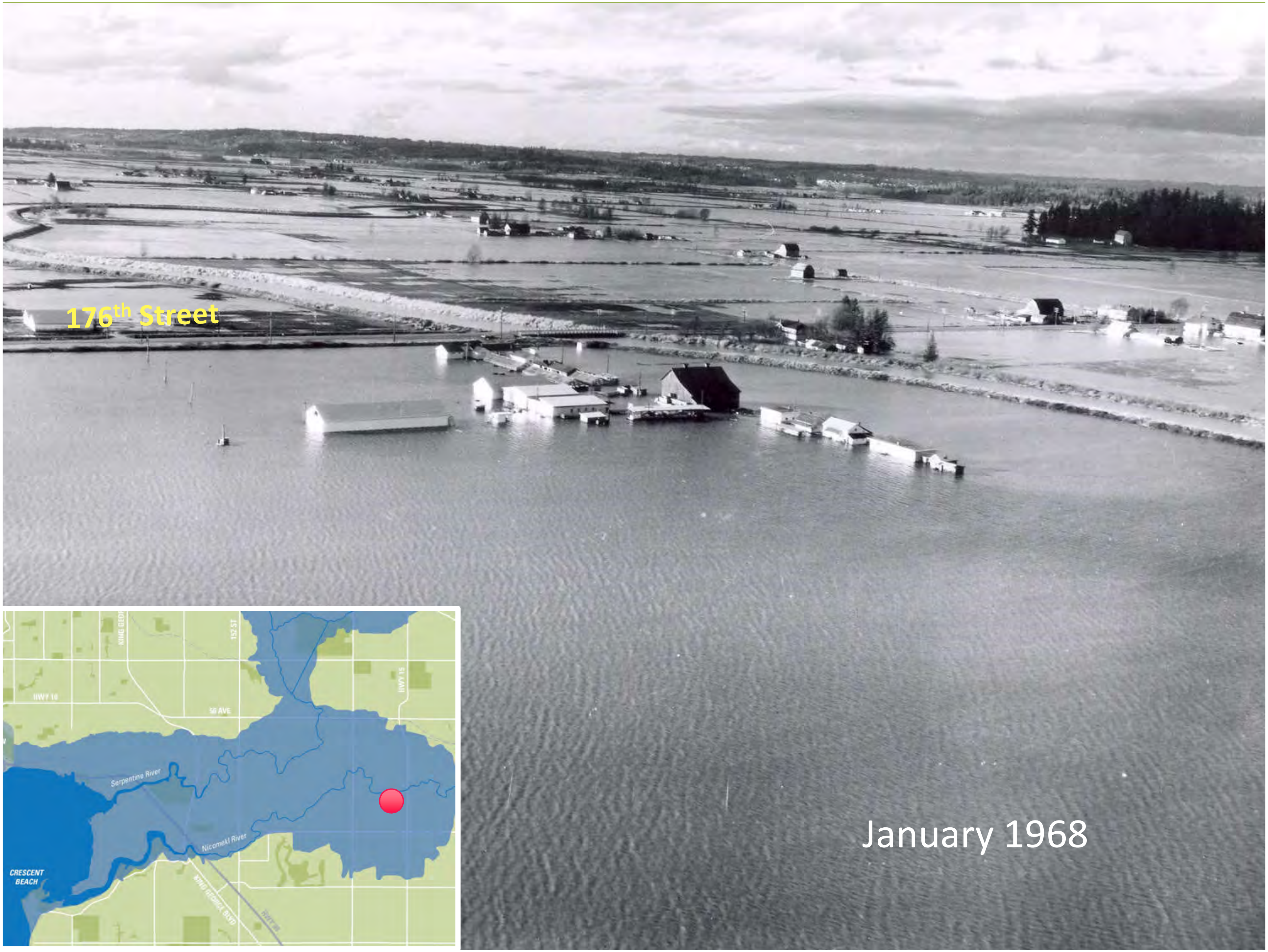

176th Street
HWY 10
152 ST
56 AVE
HWY 15
Serpentine River
Nicomekl River
CRESCENT BEACH
KING GEORGE BLVD
January 1968

Floods: A race against time

Columbian 17 Dec '82

Columbian photo by Tom Braid

…r Zalm of Lonnie Vander Zalm during cleanup at hard-hit Art Knapp's Nursery in Mud Bay.

Delta and Surrey work crews are rushing to repair and strengthen dikes against a repeat of Thursday's flooding which caused millions of dollars of damage to farms and homes.

It is too soon to fix a damage figure, Delta Mayor Ernie Burnett said today. "It's going to be high and without

By DEE FITTON
Columbian Staff Reporter

doing any costing at all, it looks like a million dollars damage to one section in East Delta alone," Burnett said.

"There was minimal damage to the farmland and property there, but the whole face of the dike is gone."

Municipal work crews are working on Westham Island, rushing to repair dikes before high tides, which will continue for the next few days, can do more damage.

"Philosophically," Burnett said, "what we've got to do . . . is make sure the dikes are repaired and relieve the situation before it gets any worse. Then next week, we can assess what happened."

In Surrey, farmer Stan Van Keulen said about three-quarters of his 120-hectare Mud Bay farm is under water.

"It came over the dike again this morning," Van Keulen said. "You should see it. You should see the damage yourself. It's major damage, but we weren't as badly hit as our neighbors. Their houses are under water — just floating around.

"The problem is that it's salt water. We can lime it and the heavy rains will leach it down about a foot into the soil, but by next spring it will come to the surface again and kill all the plants," he said.

Art Knapp's Nursery, on the King George Highway in Mud Bay, suffered extensive damage.

"The water was four or five feet up the walls," said manager Art Vander Zalm. "Everything was sort of floating around.

"It's really a mess. You couldn't see any plants or trees. Everything was under water."

Vander Zalm said the plants will survive more or less intact if flooding

debris, sent crashing into them by tides and strong winds.

Provincial officials said farmers in the area are not eligible for crop insurance because they do not belong to the plan offered by the government.

B.C. Hydro crews expect to finish today the last of a long list of repairs to lines and equipment caused by Wednesday night's storm.

Hydro spokesman Peter Fricker said 12 distribution feeder lines in the Fraser Valley were knocked out, affecting 25,000 users in Maple Ridge, South Surrey, White Rock, Matsqui and Langley. Most were back in service Thursday evening.

On the southern half of Vancouver Island, widespread power outages were reported at the height of the storm Thursday morning and police and civic officials rushed to deal with problems caused by trees falling across houses and roads, as well as some marine incidents.

Flooding was most extensive in Delta.

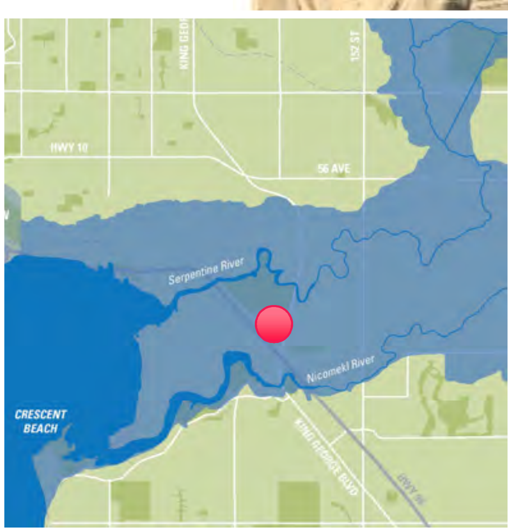
Boundary Bay resident Agnes Morrison said she was awakened at 7:30 a.m. by a neighbor concerned that the rising water might seep in from under the house.

Morrison called herself "fortunate" that only the crawl space was flooded. She said she and her husband Oscar built their home in the community near Tsawwassen about one metre above ground after their old summer cabin, replaced in 1969 by the house, was flooded in the 1950s.

Neighbor Harry Berry, however, wasn't so lucky.

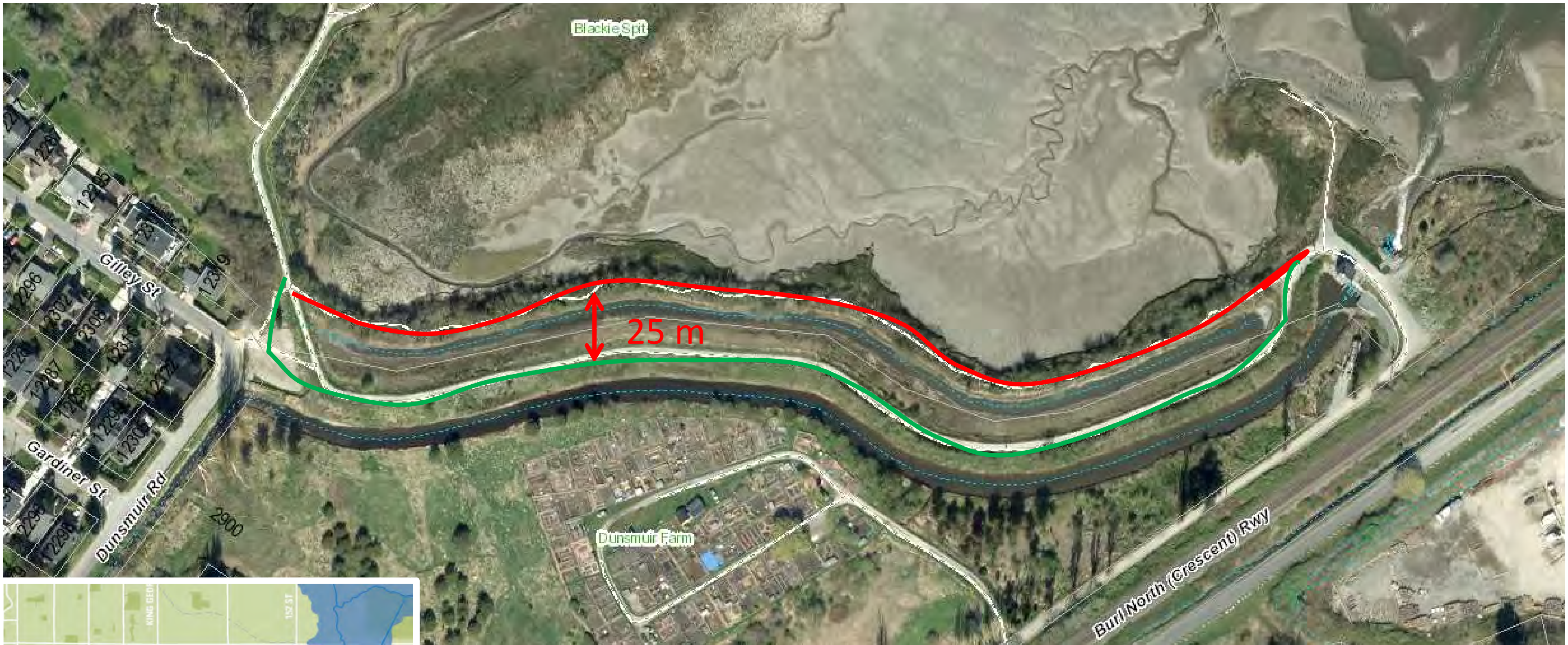
At 6 a.m., Berry's rugs were floating in 30 cm of water. Much of the furniture was removed to high ground but the carpets and drapes were ruined.

"We were horrified at first," Mrs. Berry said. "But it's one of those things. I guess it's just an act of God."



1982 Flood

Dyke Reconstruction after 1982 Flood



425m section of Crescent Beach Dyke relocated 25m in '90s

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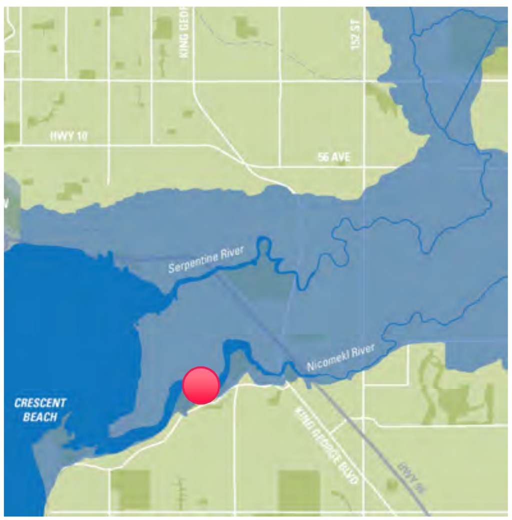
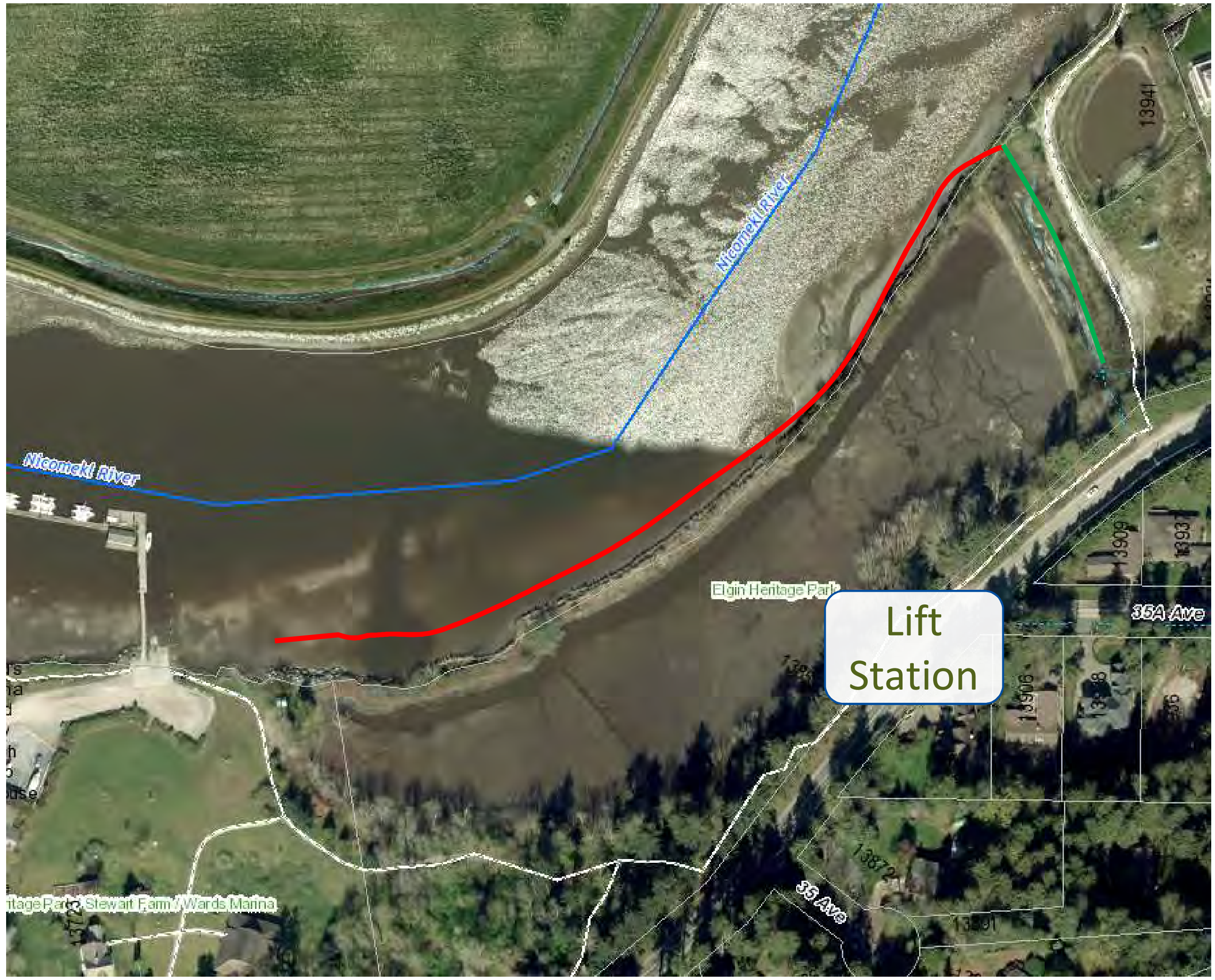
1982 Flood - Dyke Retreat



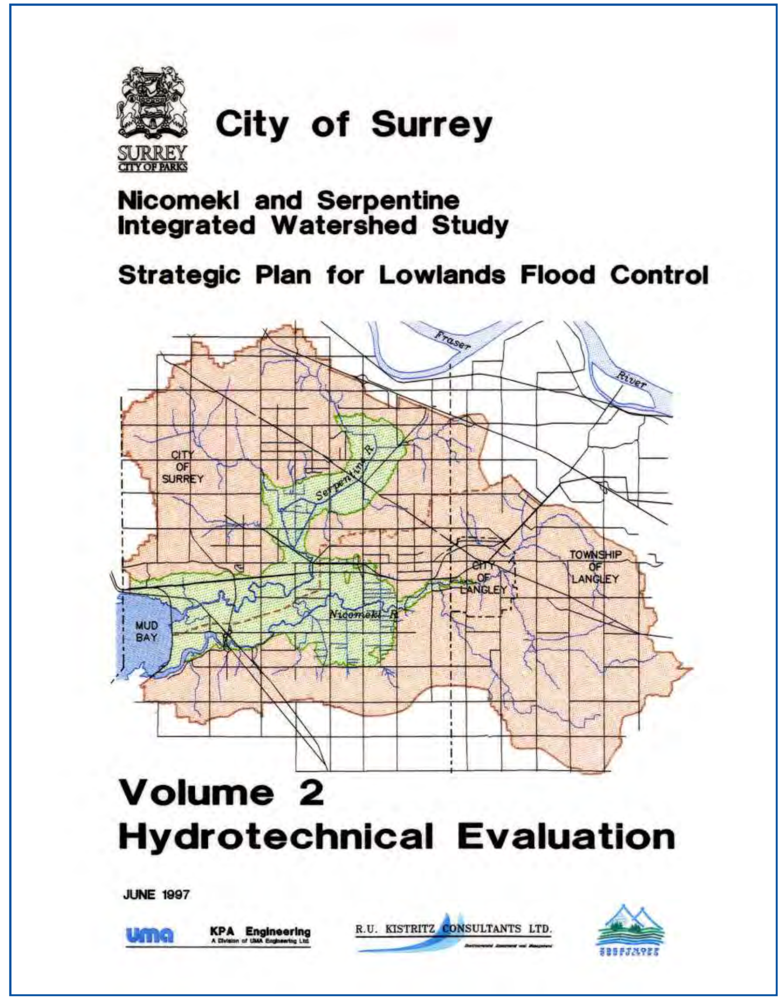


350 m section of dyke at Elgin Heritage Park replaced by 100m to the east - retreat

Strategic Plan for Lowlands Flood Control

- While flooding is controlled in both depth and duration, the Nicomekl and Serpentine Lowlands remain an active floodplain, subject to standing water for multiple days

- Existing dykes were upgraded and new dykes were established, all upstream of the sea dams to control flooding



Municipal History

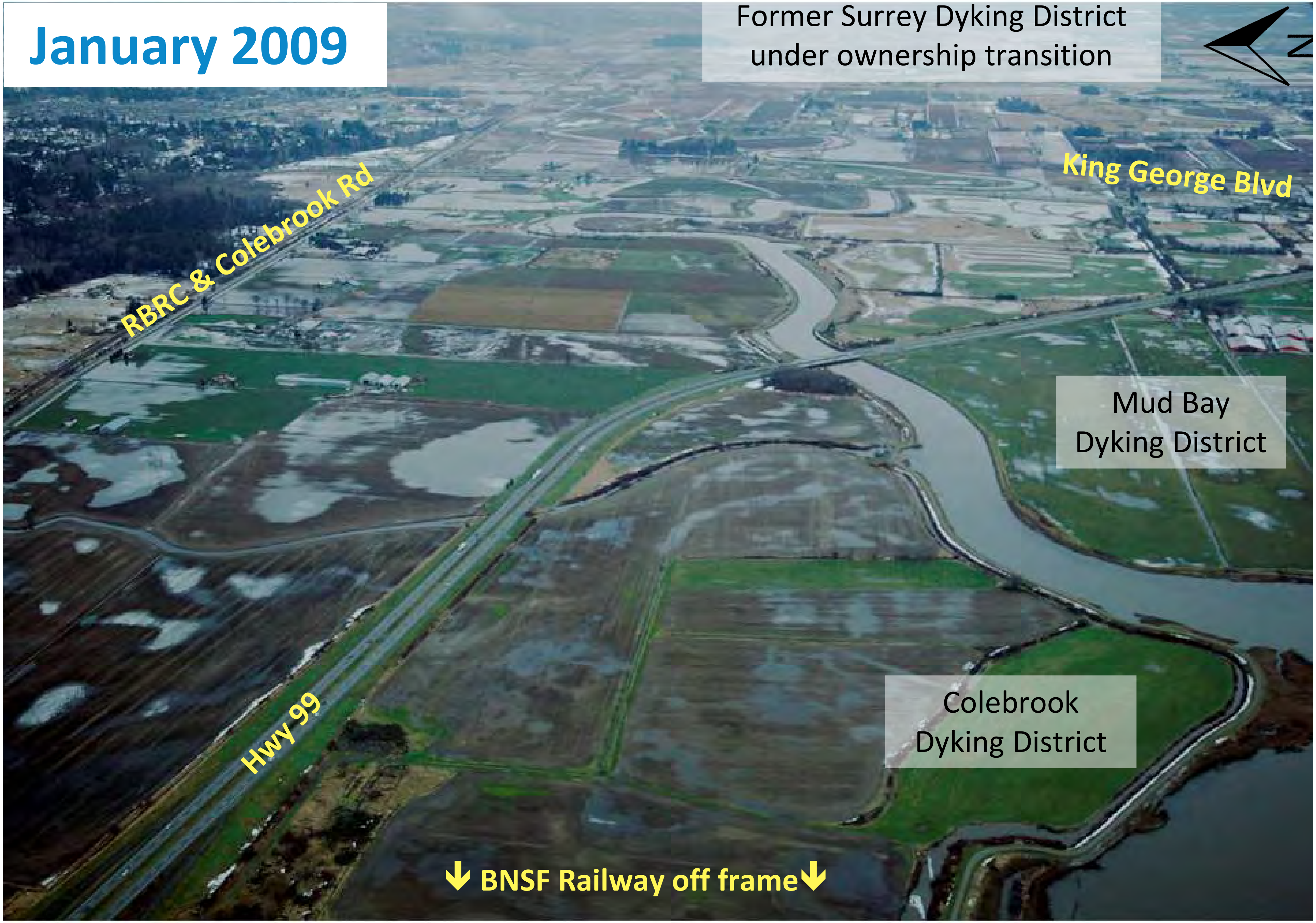
- Since 1998 City has invested over $50 million on flood control and to improve drainage to the lowland farming community (Serpentine/Nicomekl rivers upstream of Sea Dams)
- Where right-of-ways exist:

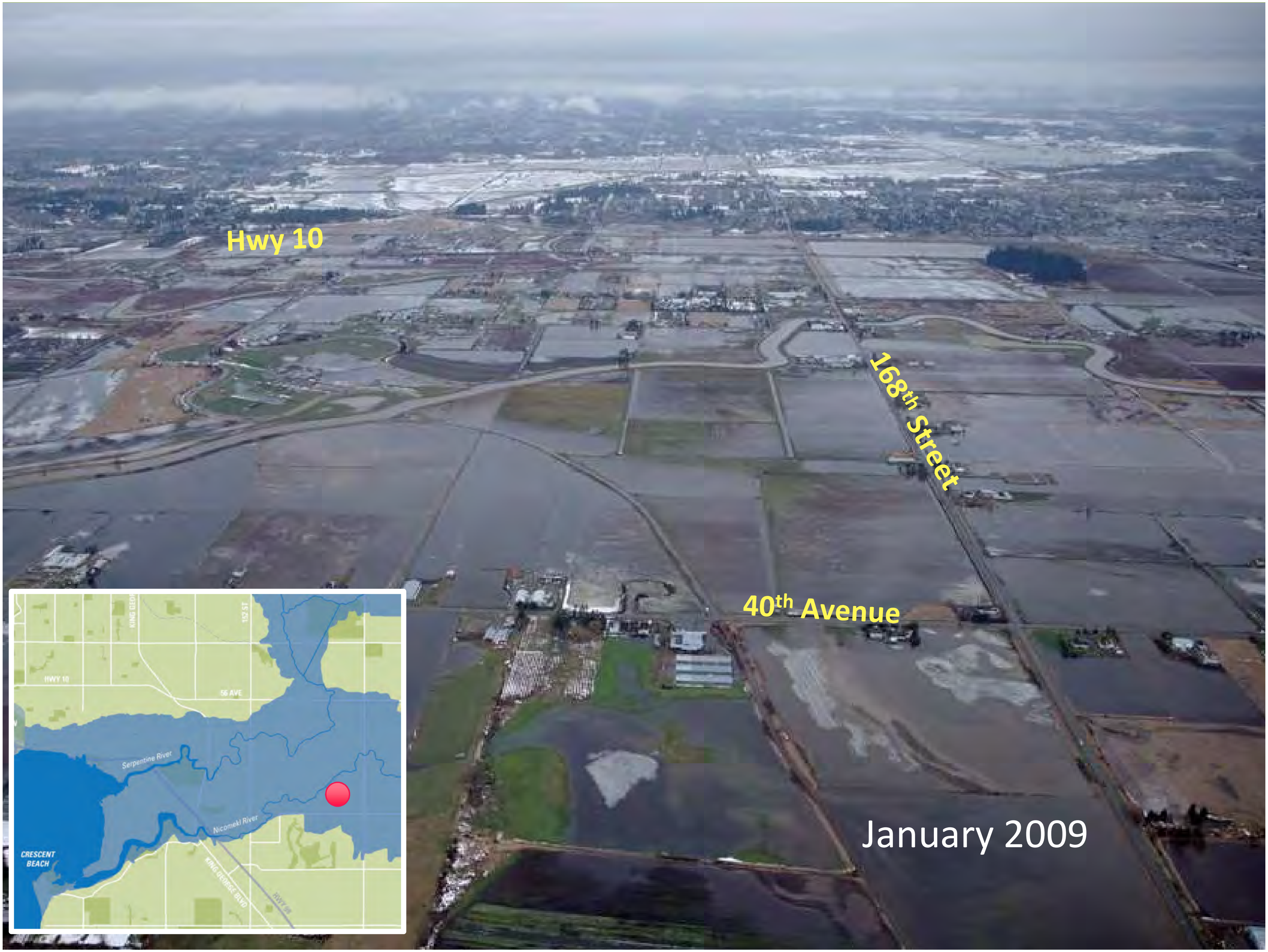
  -In 2013 City took over the Surrey Dyking District Responsibilities

  -In 2016 City took over Colebrook Dyking District Responsibilities

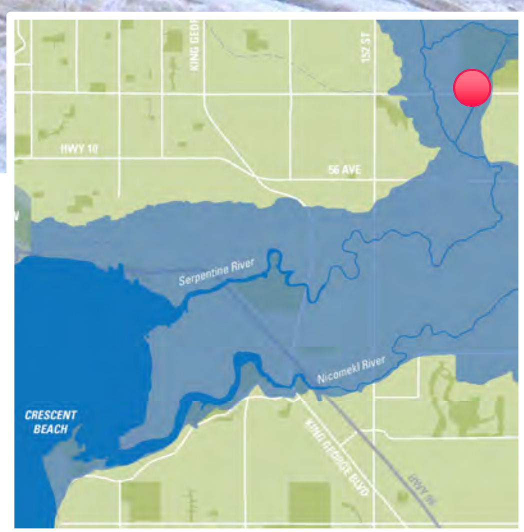
Scene on a Cloverdale street during the disastrous flood of 1935. The tow truck belonged to the Hamre Garage.

May 20 - 1981 (Photo from the Hastings collection.)


January 2009
Former Surrey Dyking District
under ownership transition
N
King George Blvd
RBRC & Colebrook Rd
Mud Bay
Dyking District
Hwy 99
Colebrook
Dyking District
BNSF Railway off frame


Hwy 10
168th Street
40th Avenue
January 2009
HWY 10
56 AVE
152 ST
Serpentine River
Nicomekl River
CRESCENT BEACH
KING GEORGE BLVD
HWY 99

2009 flood – dyke repairs



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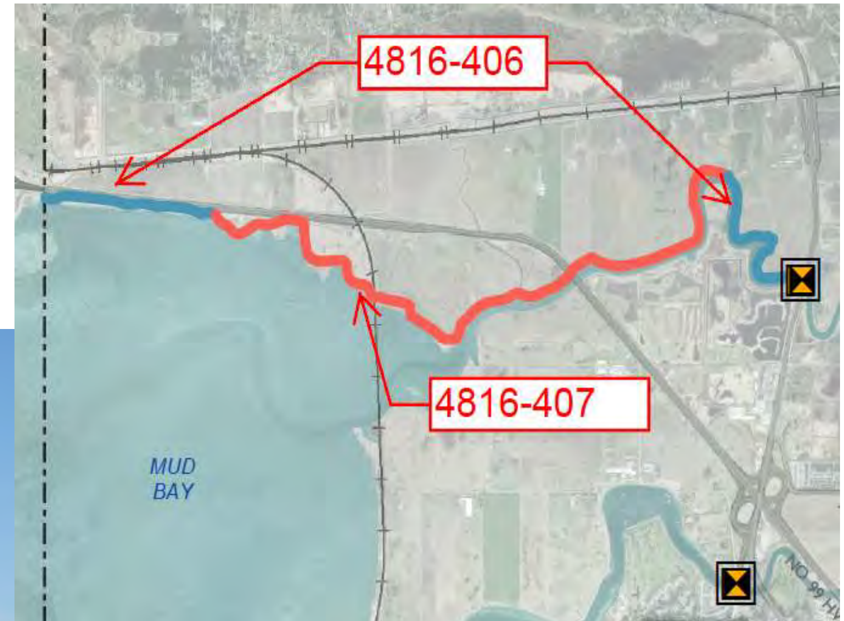
Winter 2016
HWY 10
56 AVE
Serpentine River
Nicomekl River
CRESCENT BEACH
KING GEORGE BLVD

Colebrook Dyke $10.4M Provincial Funding Announcement

July 6, 2016

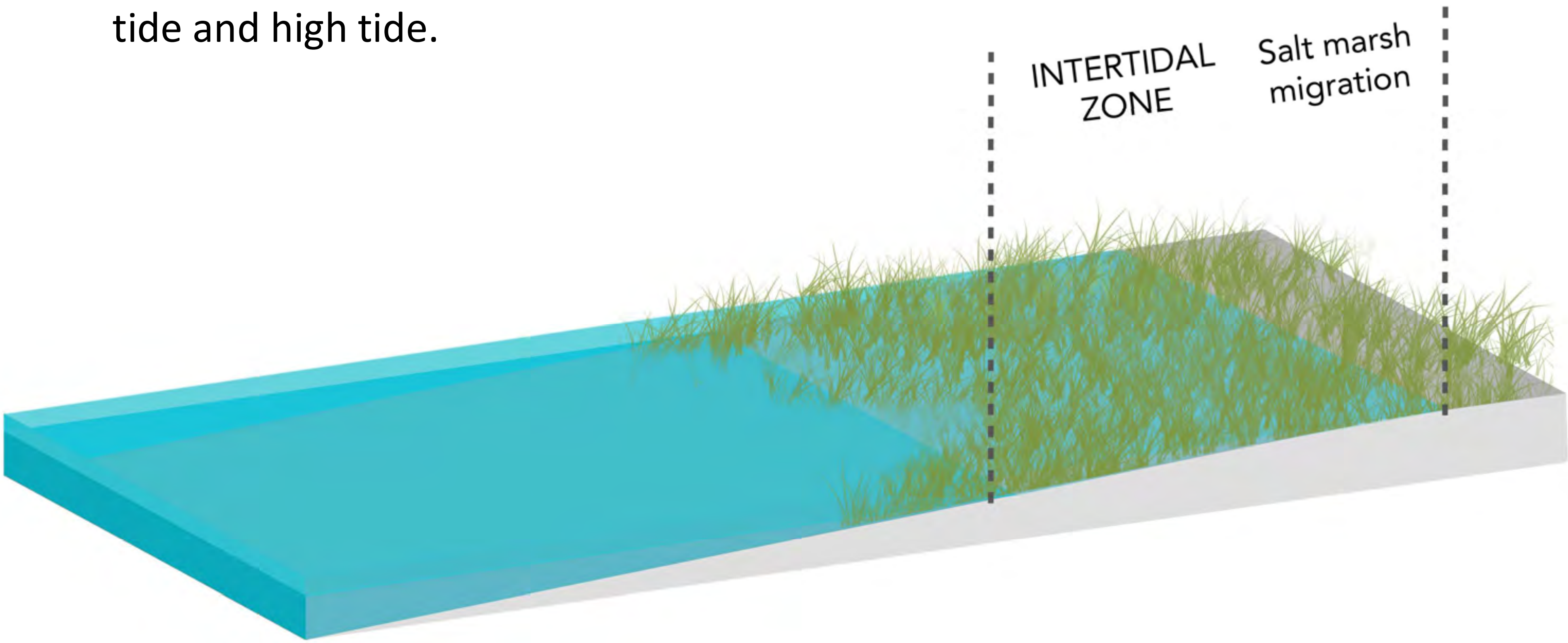


Other Impacts to Shorelines

- Other challenges will include more erosion of coastlines, impacts to infrastructure and ecosystems, changes to beaches, higher groundwater levels and potential salinization
- Habitat loss and changes in biodiversity
- Coastal squeeze

Natural Shoreline

The Intertidal zone occurs between the low tide and high tide.



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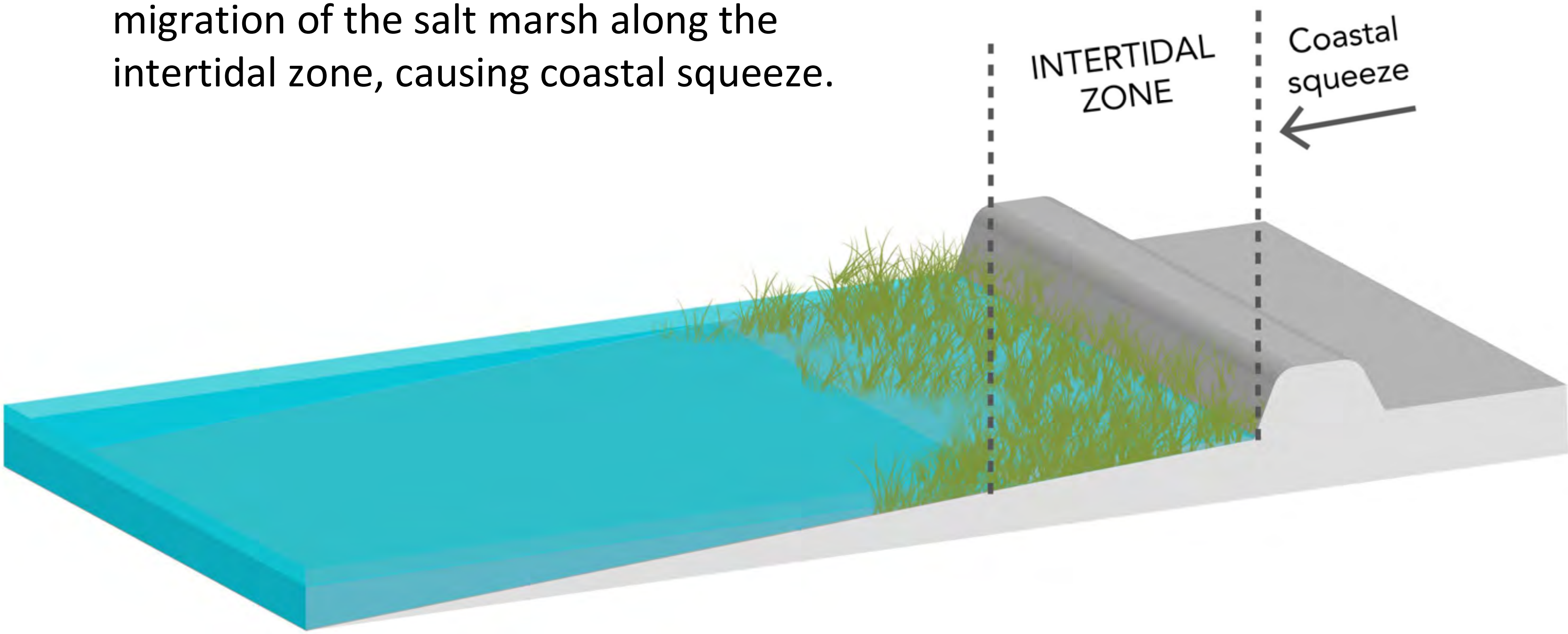
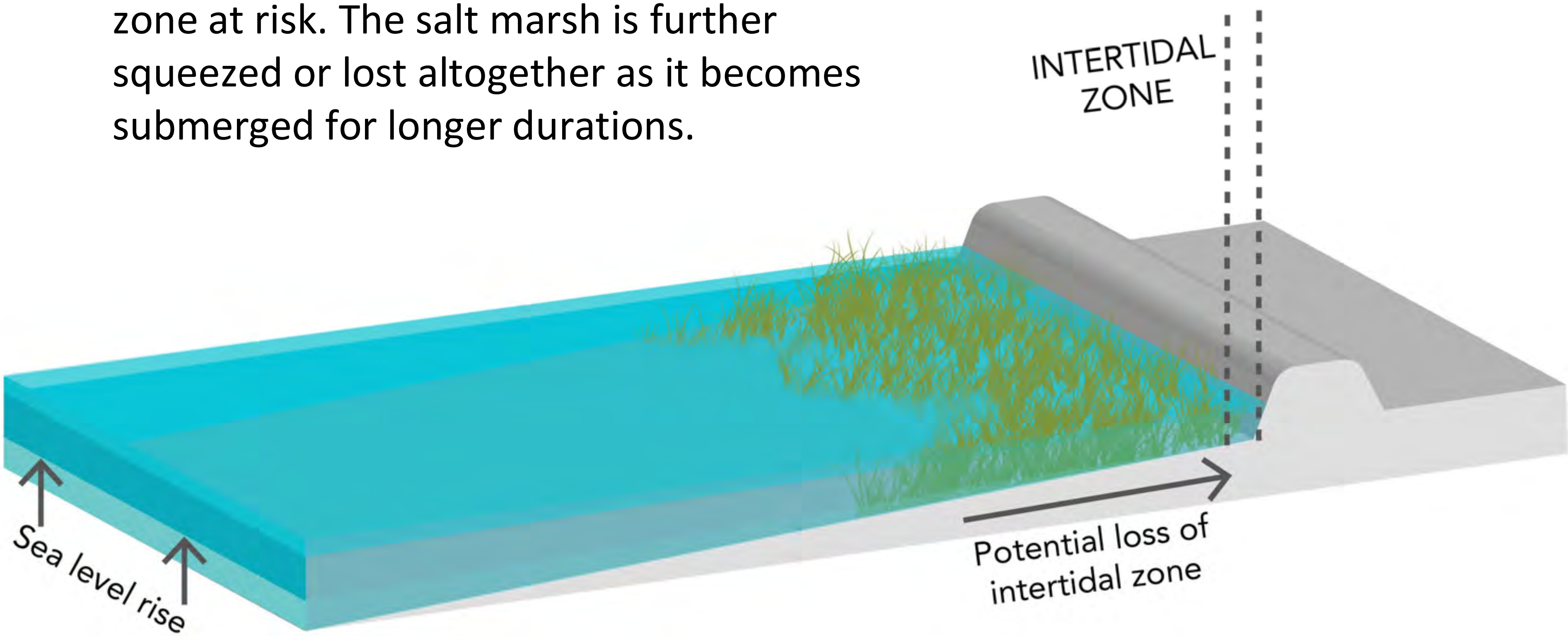
Shoreline with Dyke

The placement of a dyke prevents natural migration of the salt marsh along the intertidal zone, causing coastal squeeze.



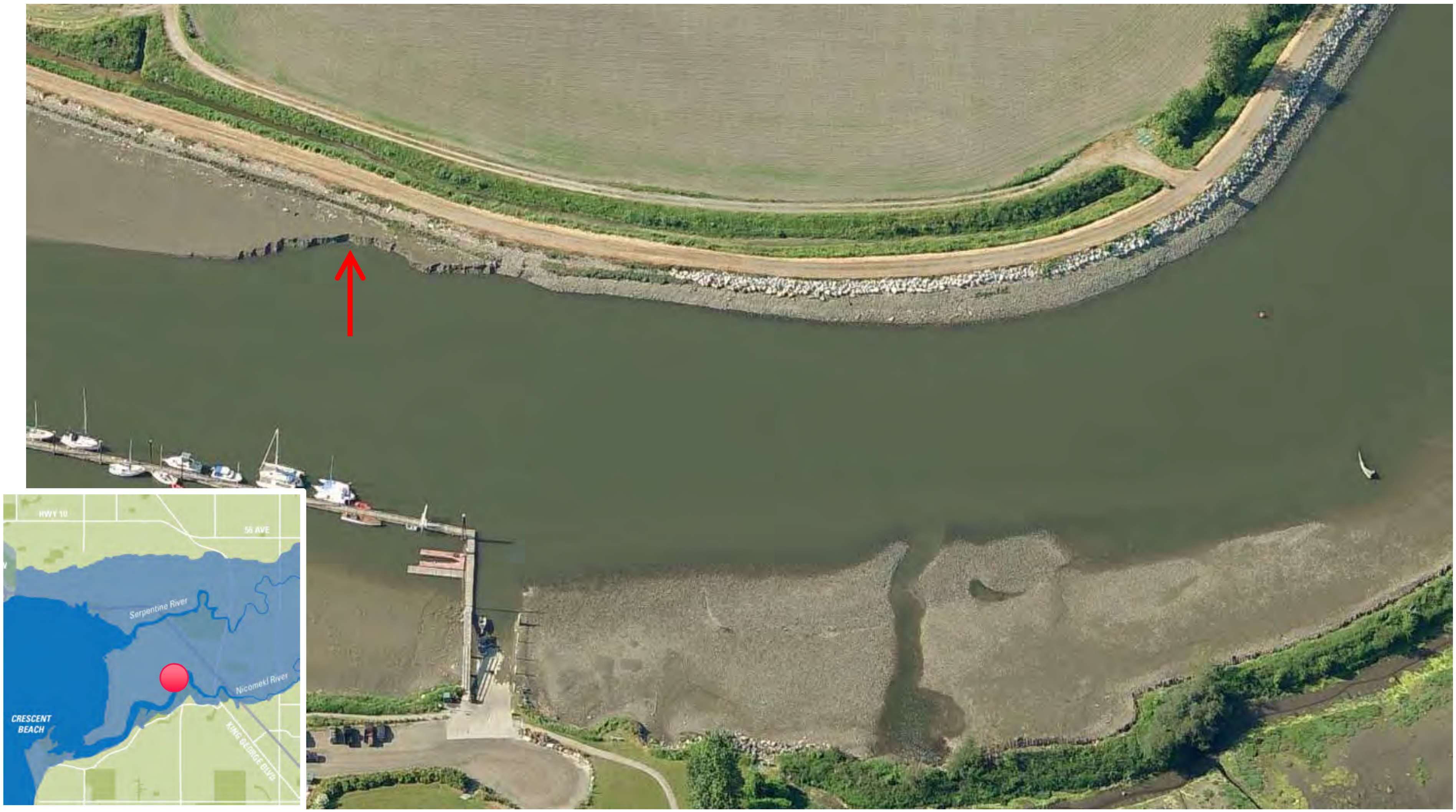
Sea Level Rise

Sea level rise further places the intertidal zone at risk. The salt marsh is further squeezed or lost altogether as it becomes submerged for longer durations.



Coastal Erosion History

- June 19, 2007



July 31 '08

Aug 29 '08

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July 31 ‘08

Aug 20 ‘08

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July 31 ‘08

Aug. 29 ‘08

Aug. 29 ‘08   Jan. 16 ‘09

Between 0.1 and 1.8m of erosion over 16 months


Apr. 9 '09
KOMATSU

Before Repairs
Aug. 20 '08

Post Repairs
Apr. 27 '09

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Post Repair
Apr. 27 ‘09

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Coastal Erosion History

- April 20, 2009

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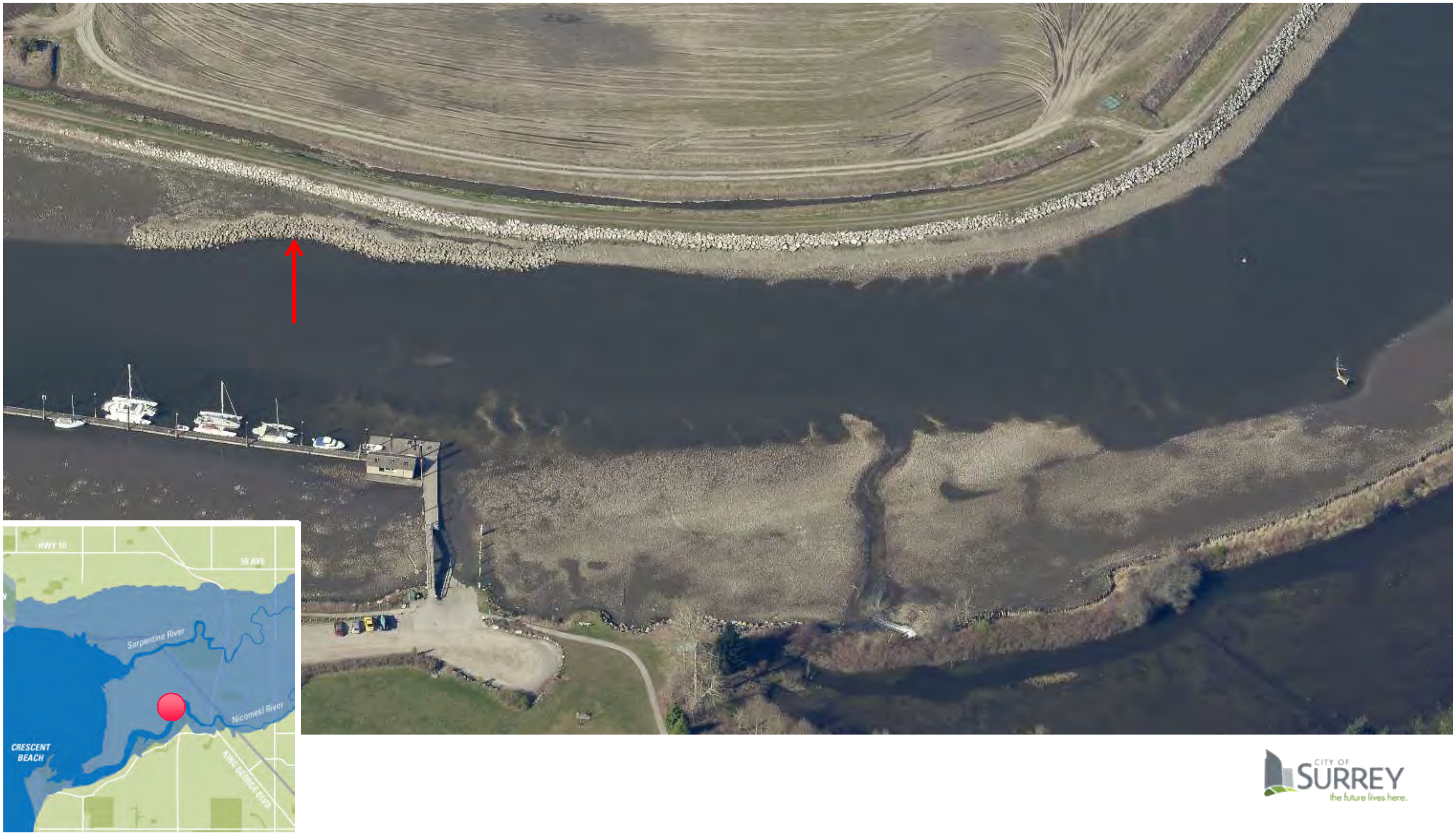
Coastal Erosion History

- April 1, 2013



Railway Maintenance

Illustration 8-28

Barrie Sanford

Source:
Surrey Story

Ongoing Infrastructure Challenges

- In the Surrey lowland area, we have also seen considerable subsidence – sinking of lands

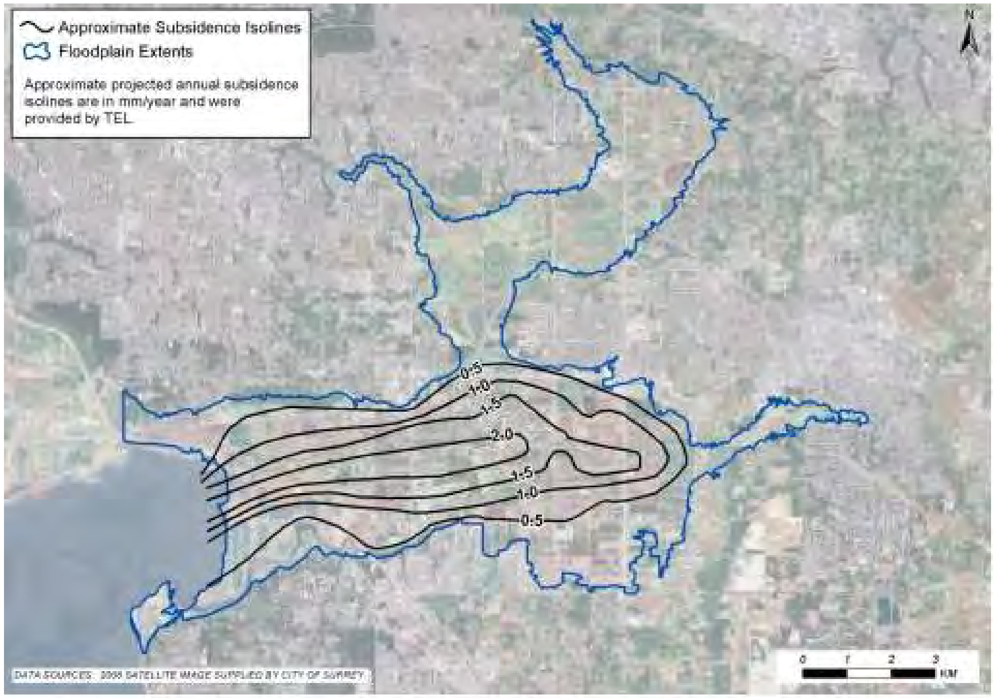


Figure 2. Approximate projected annual subsidence isolines.

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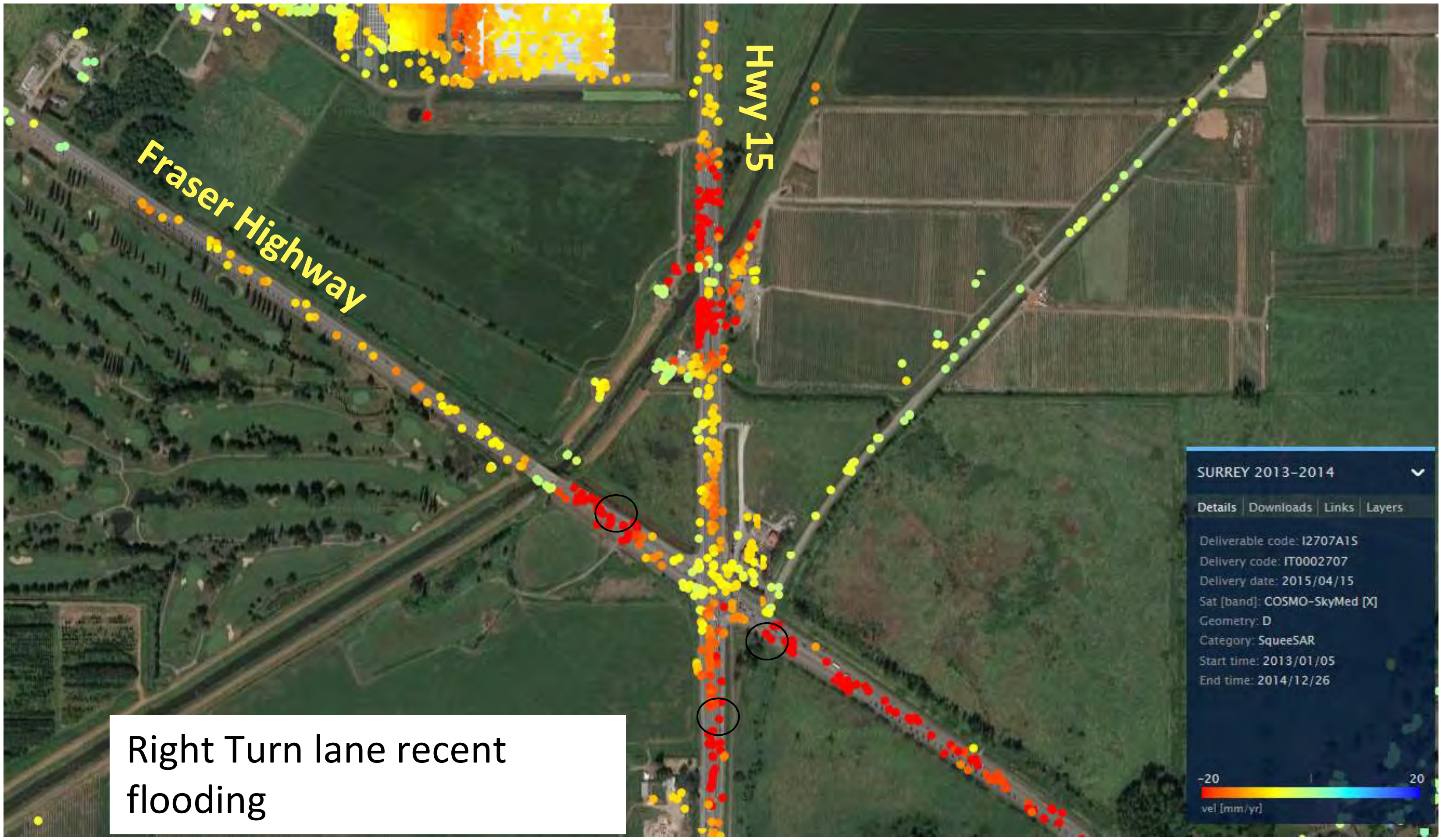
Highway 15 Example

Ground Movement Velocity ('14-15)



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Mud Bay Ground Movement Velocity

Ground Movement recorded between 2014 and 2015

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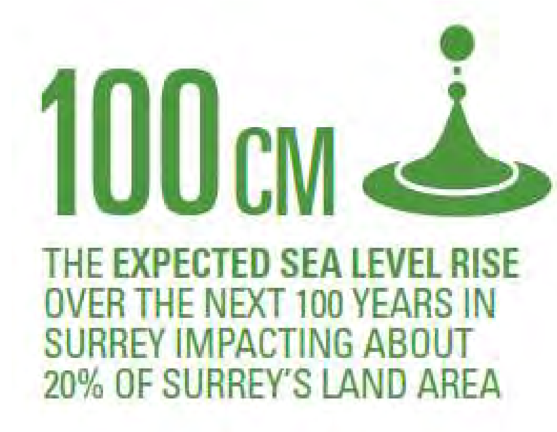
Dyke Construction

Dyke Construction

Accelerated Erosion Brackish Water

Climate Change and Coastal Floods

- Coastal cities around the world are facing same challenges
- Province directed municipalities to plan for at least 1 m sea level rise by 2100
- In Surrey and elsewhere, most drainage systems are not designed for projected changes



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CFAS PIEVC Workshop

FLOOD SCENARIO A - COASTAL FLOOD WITH DYKE BREACH - CURRENT AND FUTURE

nhc northwest hydraulic consultants

epi

Associated Engineering | GLOBAL PERSPECTIVE. LOCAL FOCUS.

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SURREY COASTAL FLOOD ADAPTATION STRATEGY (CFAS)

PIEVC Workshop

Coastal Flooding - Scenario A

nhc northwest hydraulic consultants

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epi

Presentation Outline

- Study area and background information
- Past, present and future floods
- Implications for infrastructure

Study Area

- Serpentine / Nicomekl Floodplain
- Southeast Delta
- Crescent Beach
- Semiahmoo Bay/ mouth of Campbell River

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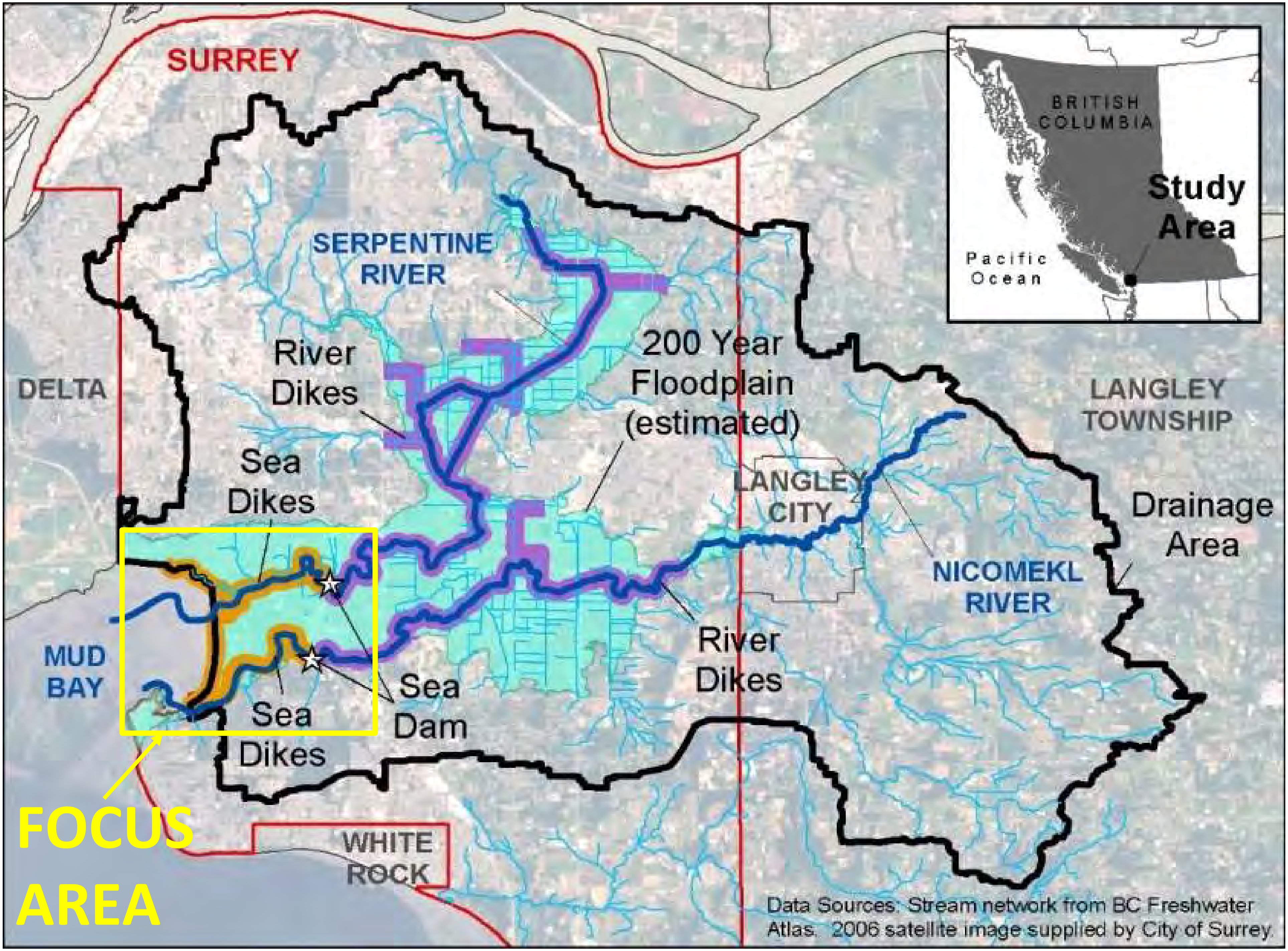
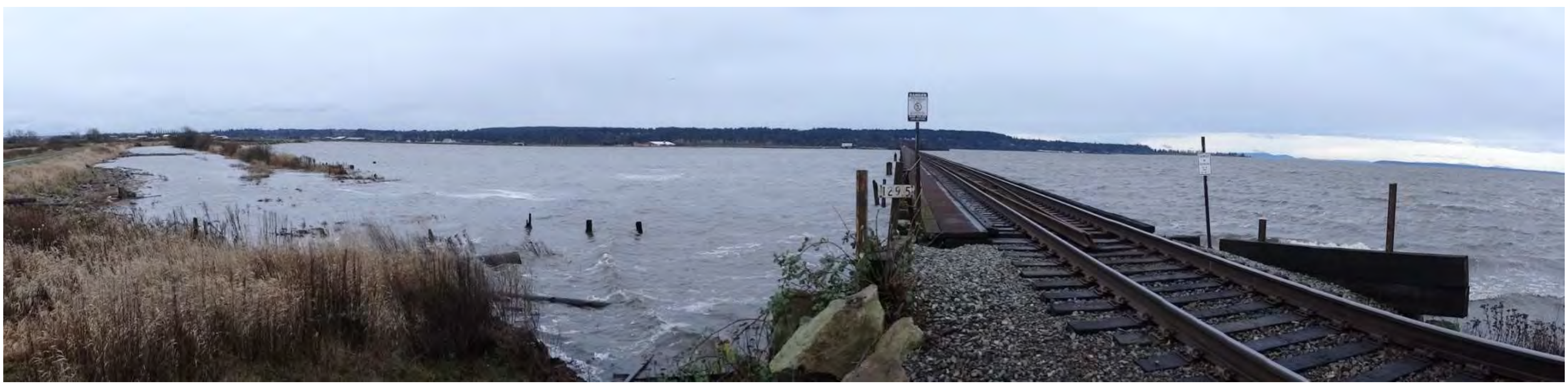

SURREY
BRITISH COLUMBIA
Study Area
Pacific Ocean
SERPENTINE RIVER
River Dikes
200 Year Floodplain (estimated)
DELTA
LANGLEY TOWNSHIP
Sea Dikes
LANGLEY CITY
Drainage Area
NICOMEKL RIVER
MUD BAY
River Dikes
Sea Dam
Sea Dikes
FOCUS AREA
WHITE ROCK
Data Sources: Stream network from BC Freshwater Atlas. 2006 satellite image supplied by City of Surrey.

Flood Hazards

- Coastal:
  - ➢ High tides
  - ➢ Storm surge
  - ➢ Wind + wave setup

- Riverine:
  - ➢ Heavy precipitation
  - ➢ Rain on snow, snow melt
  - ➢ Long-duration relatively high tides



Flood Protection Infrastructure

- Coastal:
  - ➢ Sea dikes & sea dams

- Riverine:
  - ➢ River dikes with spillways, 200 flood-boxes, 30 pump-stations, complex network of flow storage areas, canals, ditches and culverts

Sea dams

SURREY
Hwy 10
King George Blvd
Hwy 10
152 St
Hwy 15
STUDY AREA BOUNDARY
BCR
CPR
Serpentine River
Mud Bay
BNSF
Nicomekl River
STUDY AREA BOUNDARY

Ocean Dykes

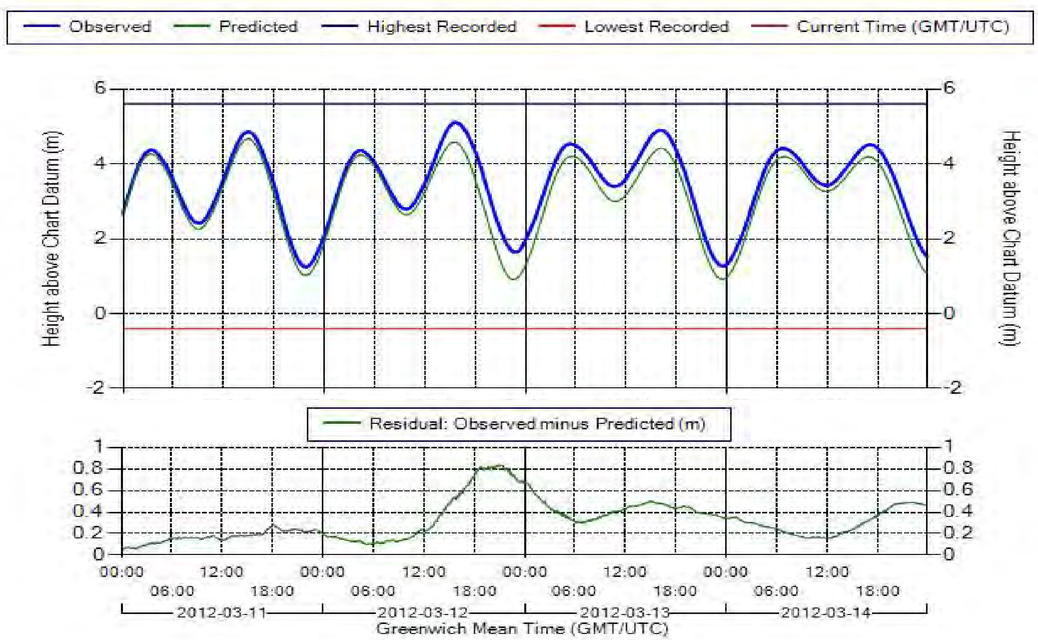
91
DELTA
SURREY
King George Blvd
Hwy 10
Hwy 10
10
99
BCR
CPR
Serpentine River
STRAIT OF GEORGIA

Previous Studies

- Climate Change Floodplain Review Phase 1 (NHC 2012)
- Climate Change Floodplain Review Phase 1 (NHC 2015)
- Spin-off studies (NHC 2015 - 2016)
- CFAS (NHC/EPI 2016 – 2018)

Ocean Levels

- Deterministic component (tide)
- Probabilistic or residual component (storm surge, wind and wave set-up)
- Must consider joint probability



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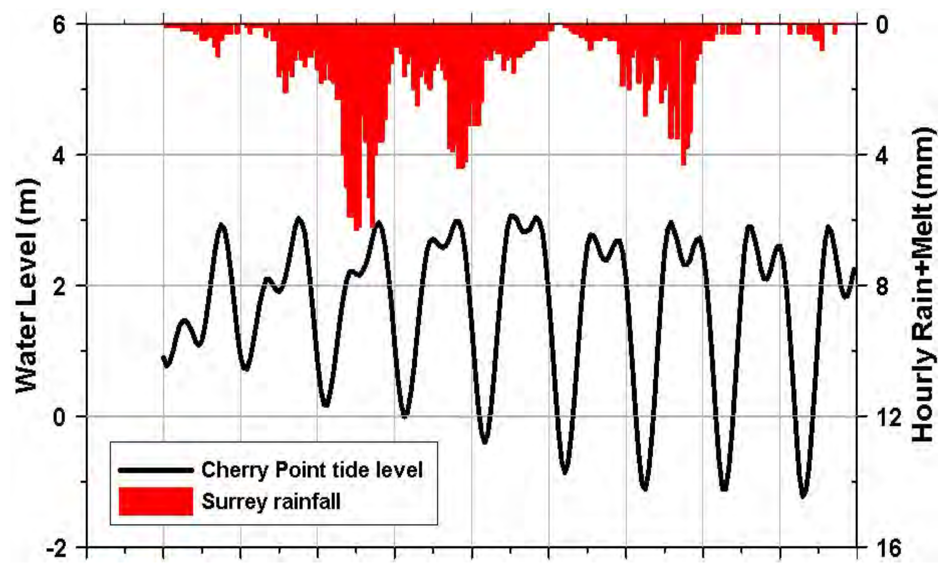
Continuous Simulation Approach

- Develop 50 year ocean level hind-cast
- Assemble 50 year precipitation record
- Generate 50 year flow records (HSPF)
- Generate 50 year water level record at various locations (HEC-RAS)
- Frequency analyses for each location & extract 200 year WL



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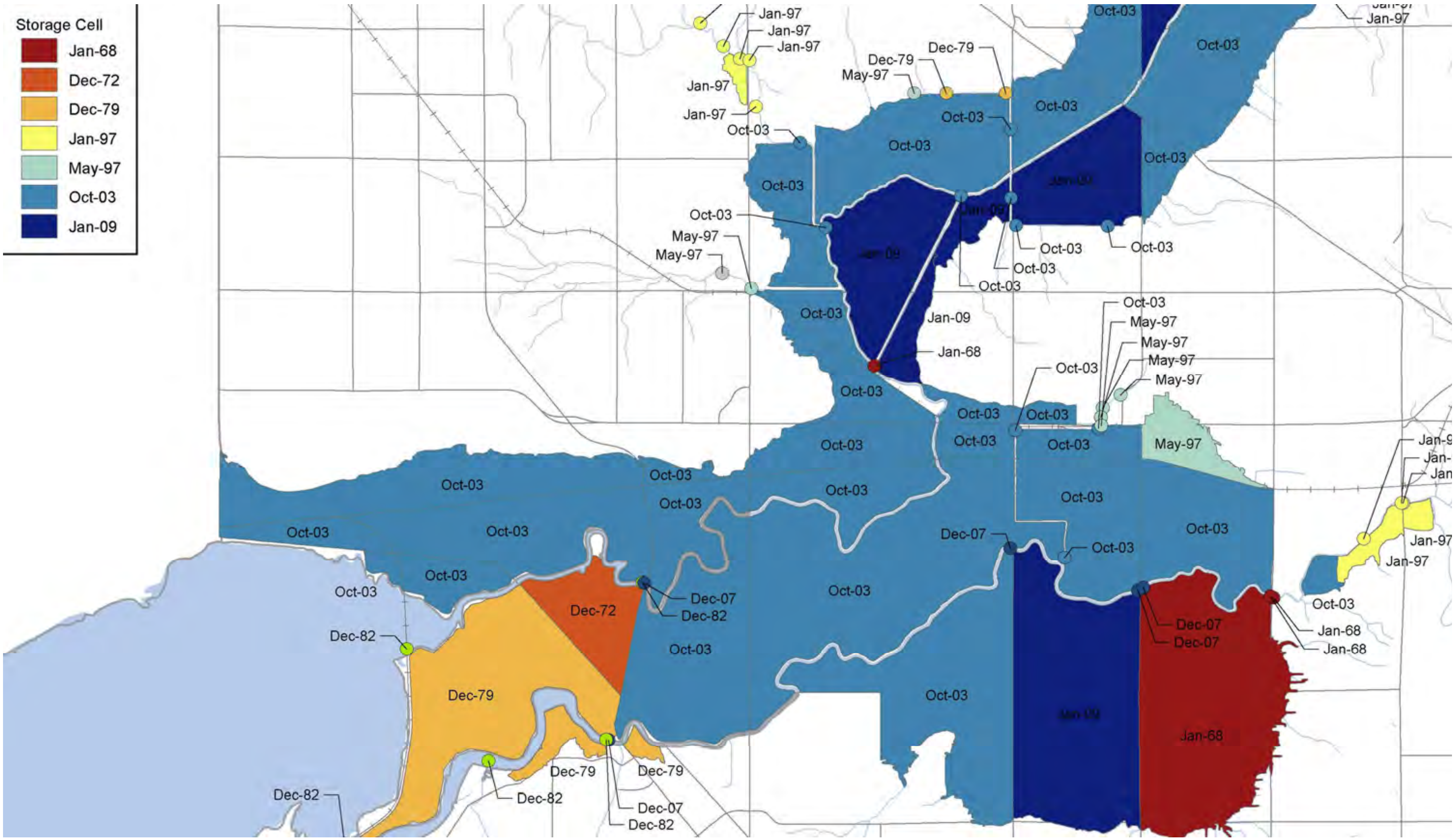
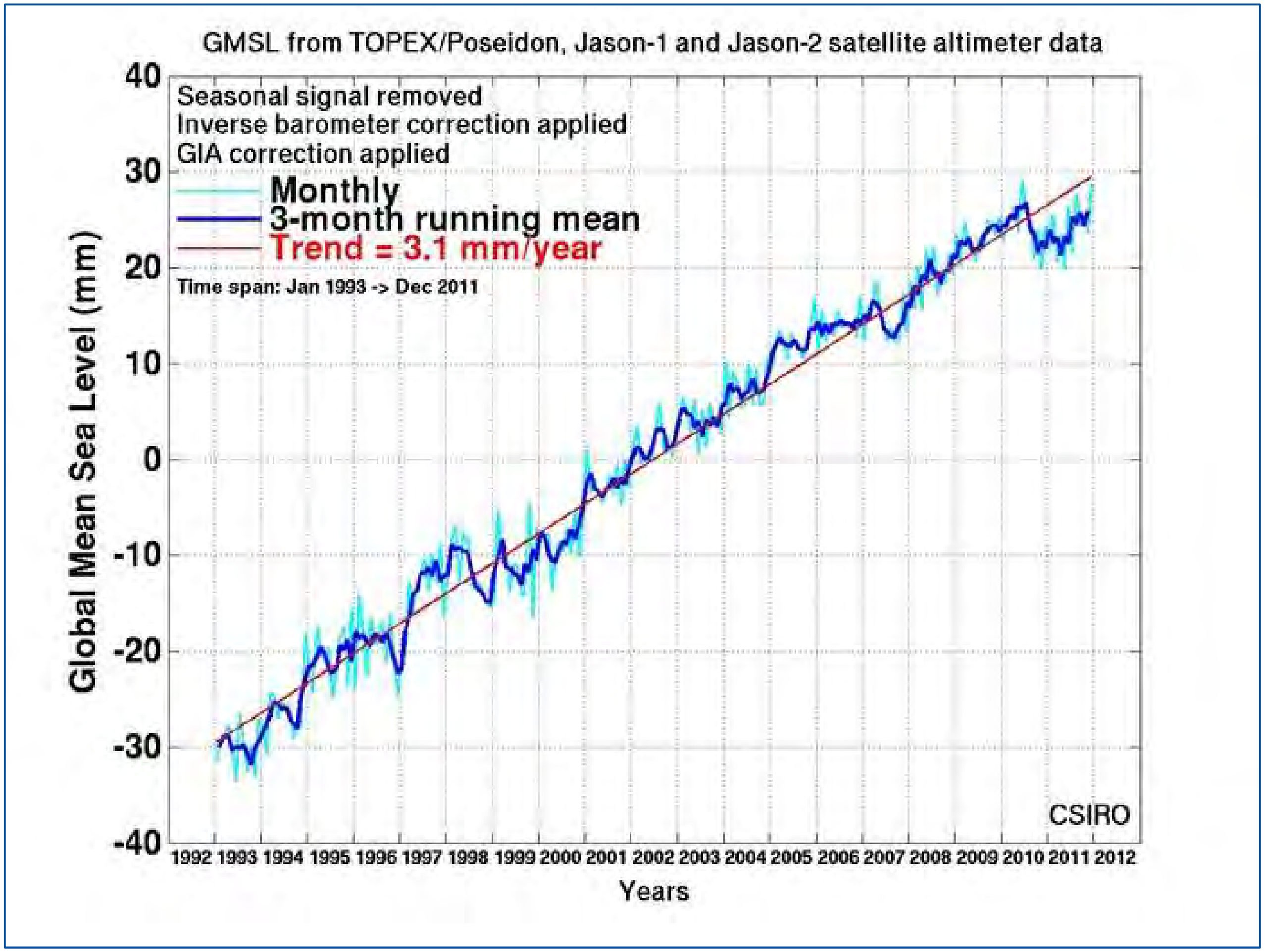
Past Floods



Observed Sea Level Rise



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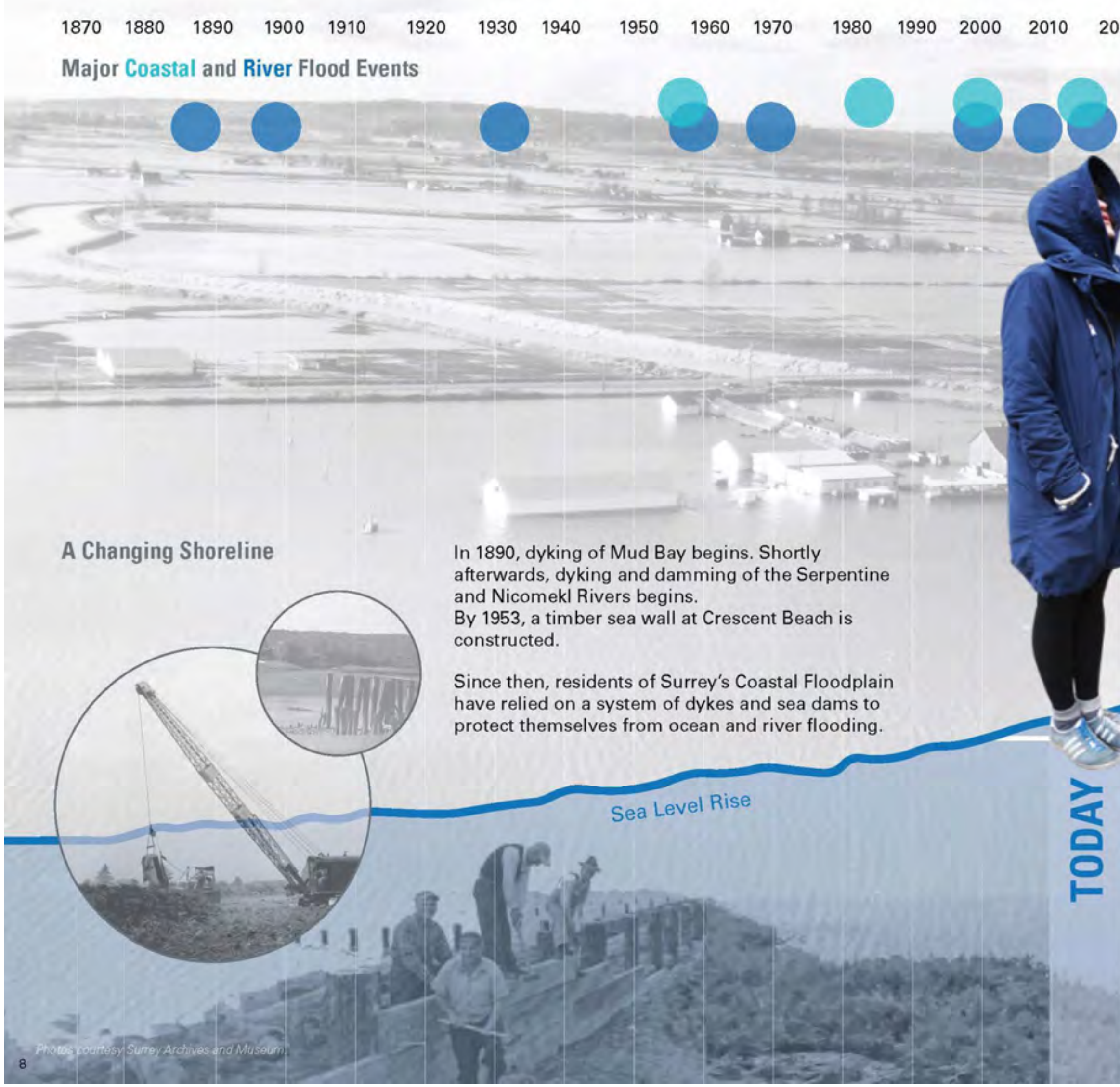
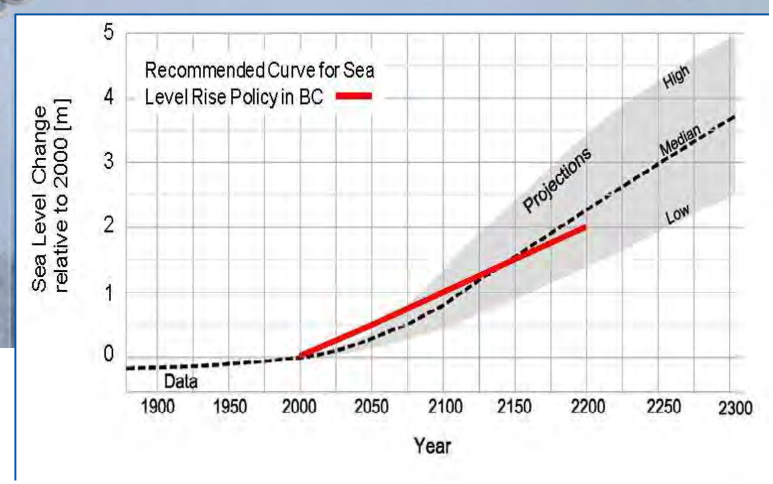
COASTAL AND RIVER FLOODING



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.



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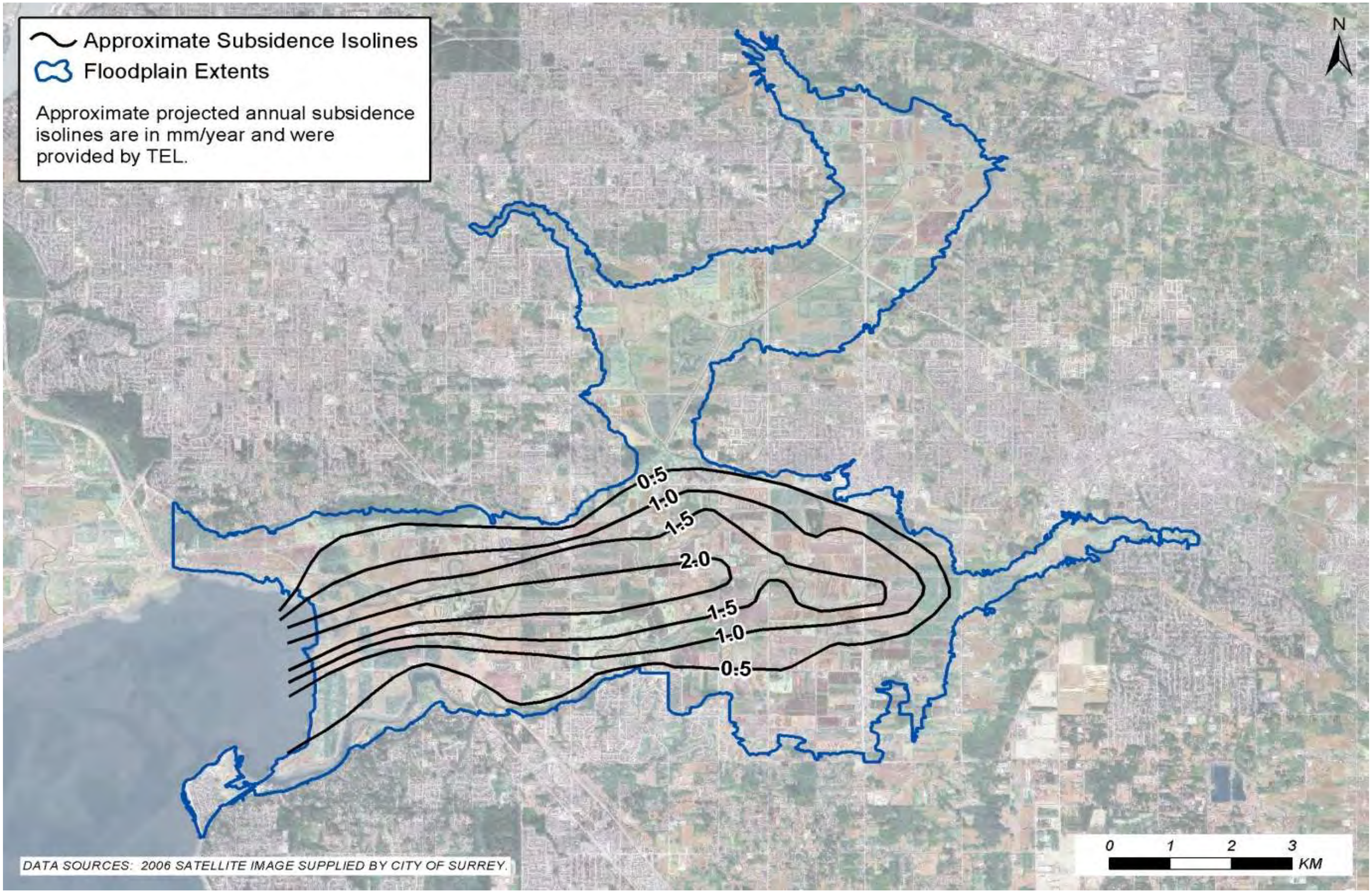
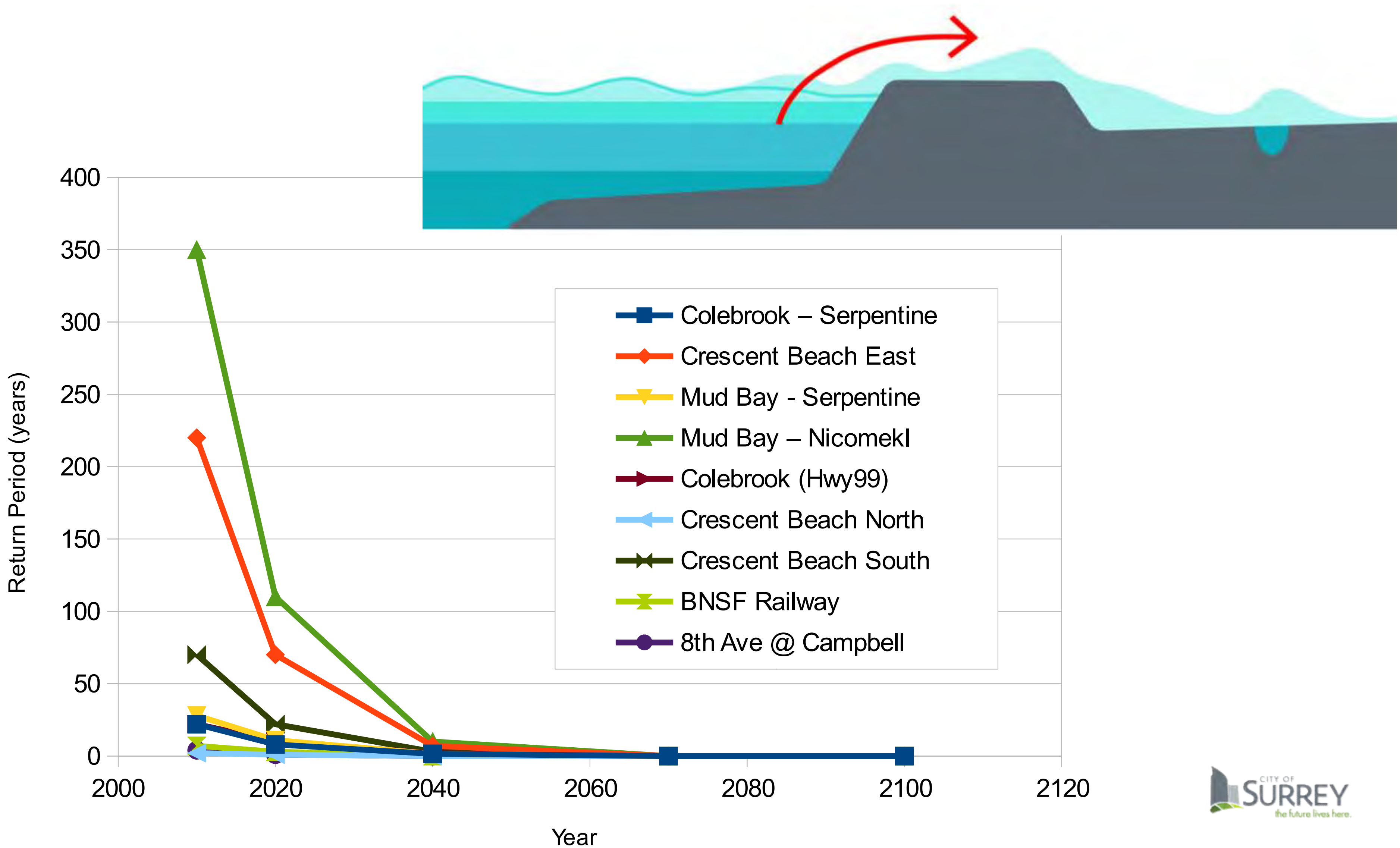
Subsidence


Approximate Subsidence Isolines
Floodplain Extents
Approximate projected annual subsidence isolines are in mm/year and were provided by TEL.
0.5
1.0
1.5
2.0
1.5
1.0
0.5
N
0
1
2
3
KM
DATA SOURCES: 2006 SATELLITE IMAGE SUPPLIED BY CITY OF SURREY.

Future Floods



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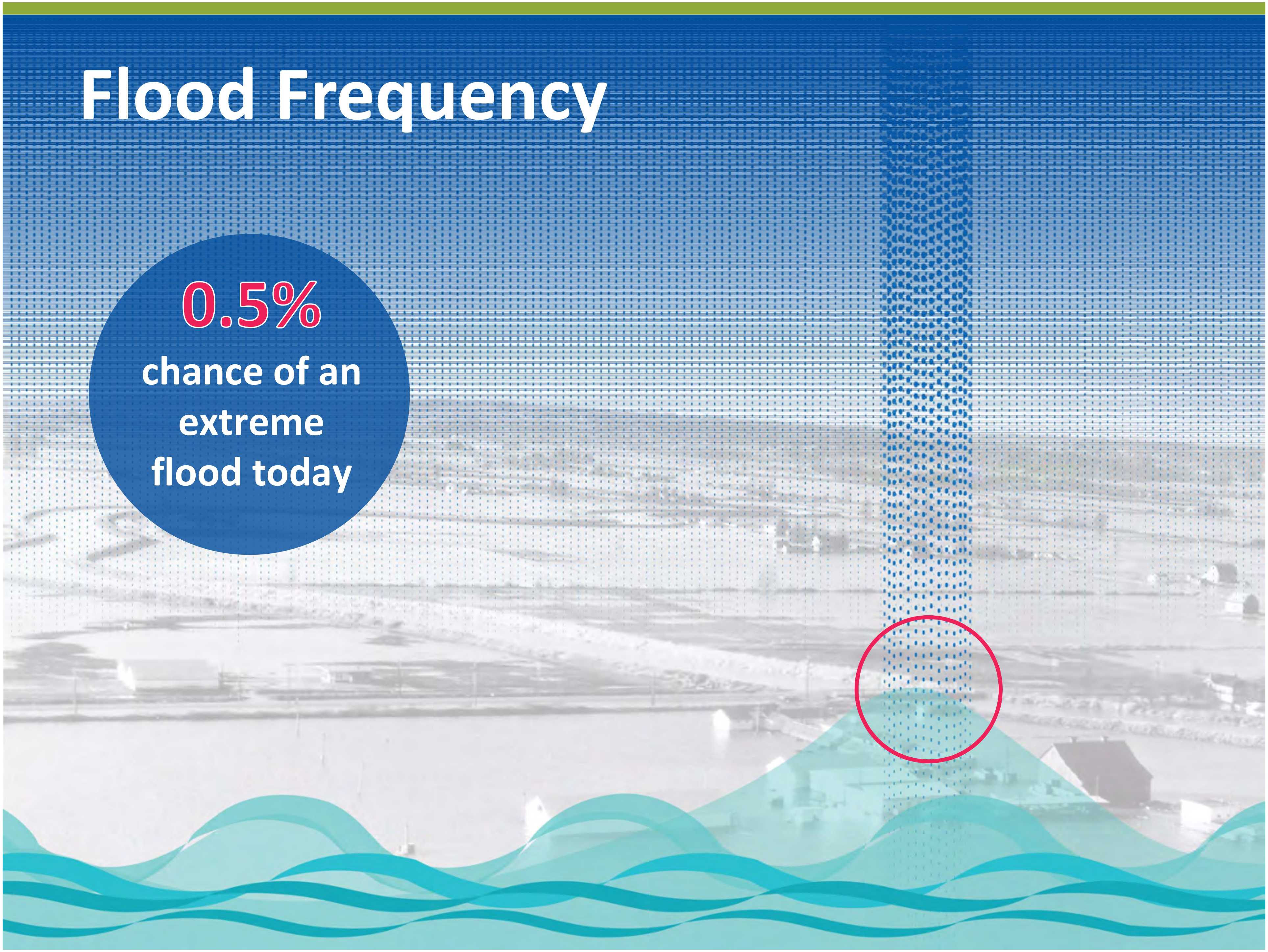
Extreme Floods

- Climate change is affecting intensity and frequency of storms and flood events
- Extreme floods of today become more frequent in the future

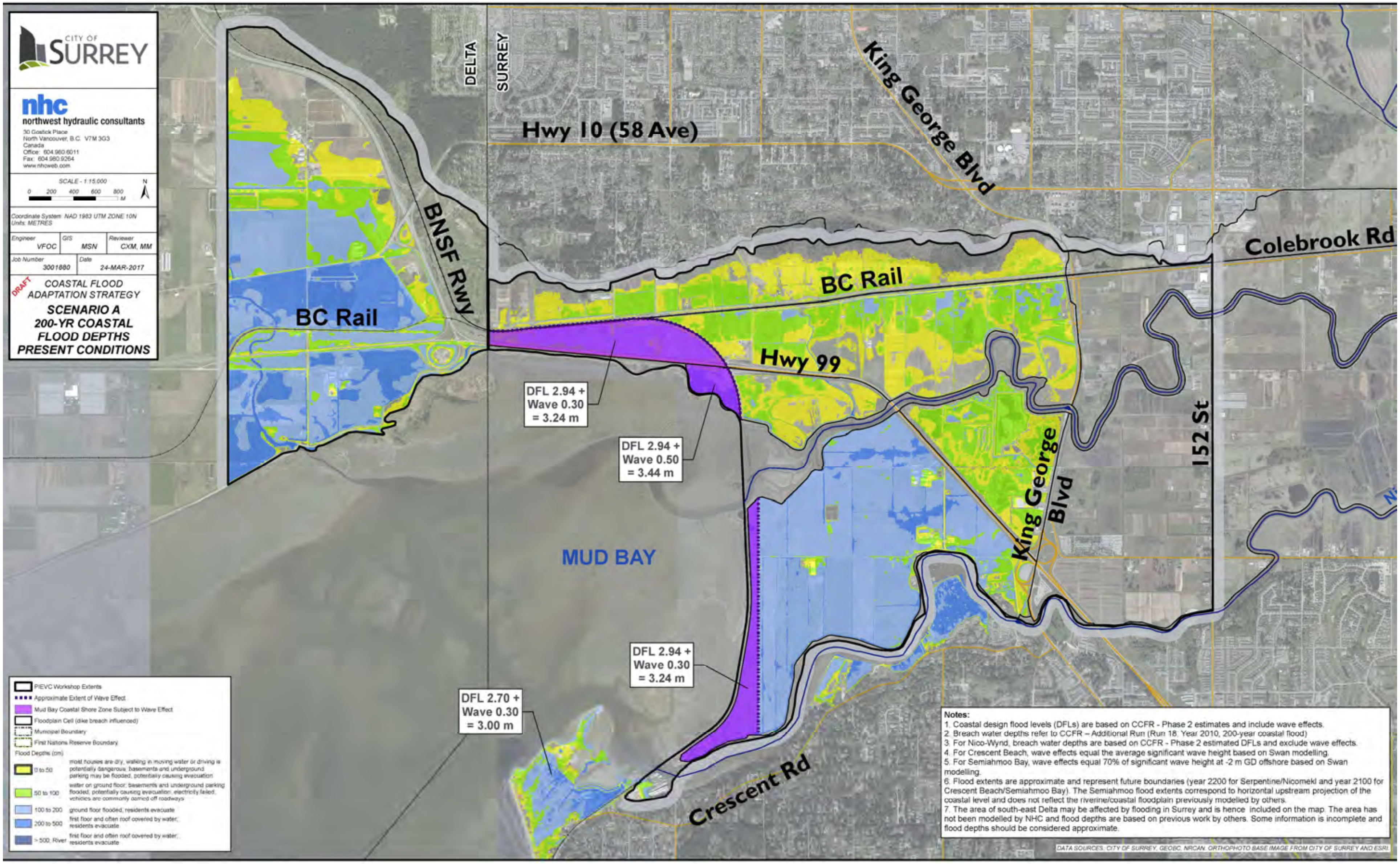

Flood Frequency
0.5%
chance of an extreme flood today

Flood Frequency

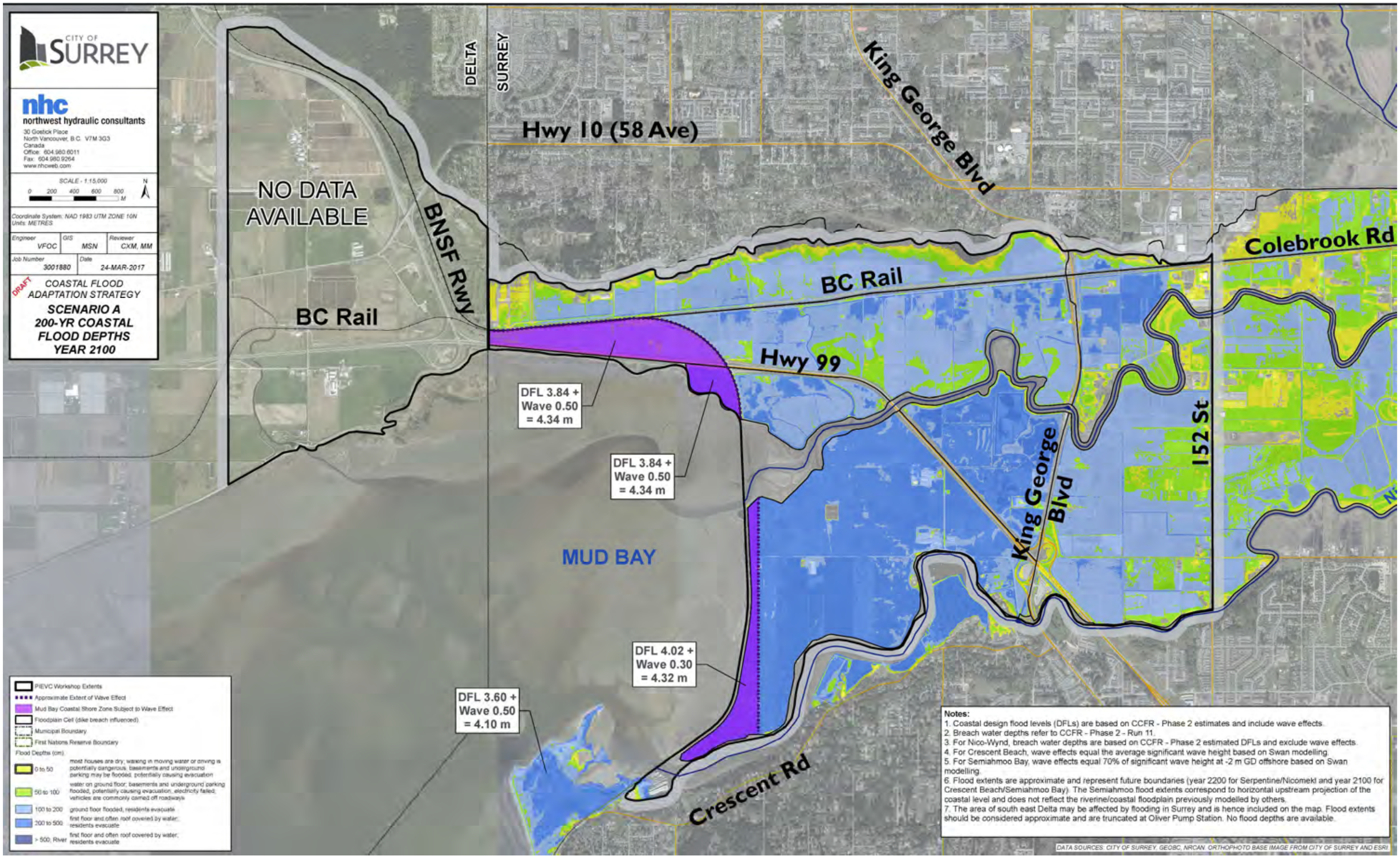
50%

chance of an extreme flood in 2100

Scenario A - Present



Scenario A – Year 2100



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Water Surface Elevation, T = 00:15:00

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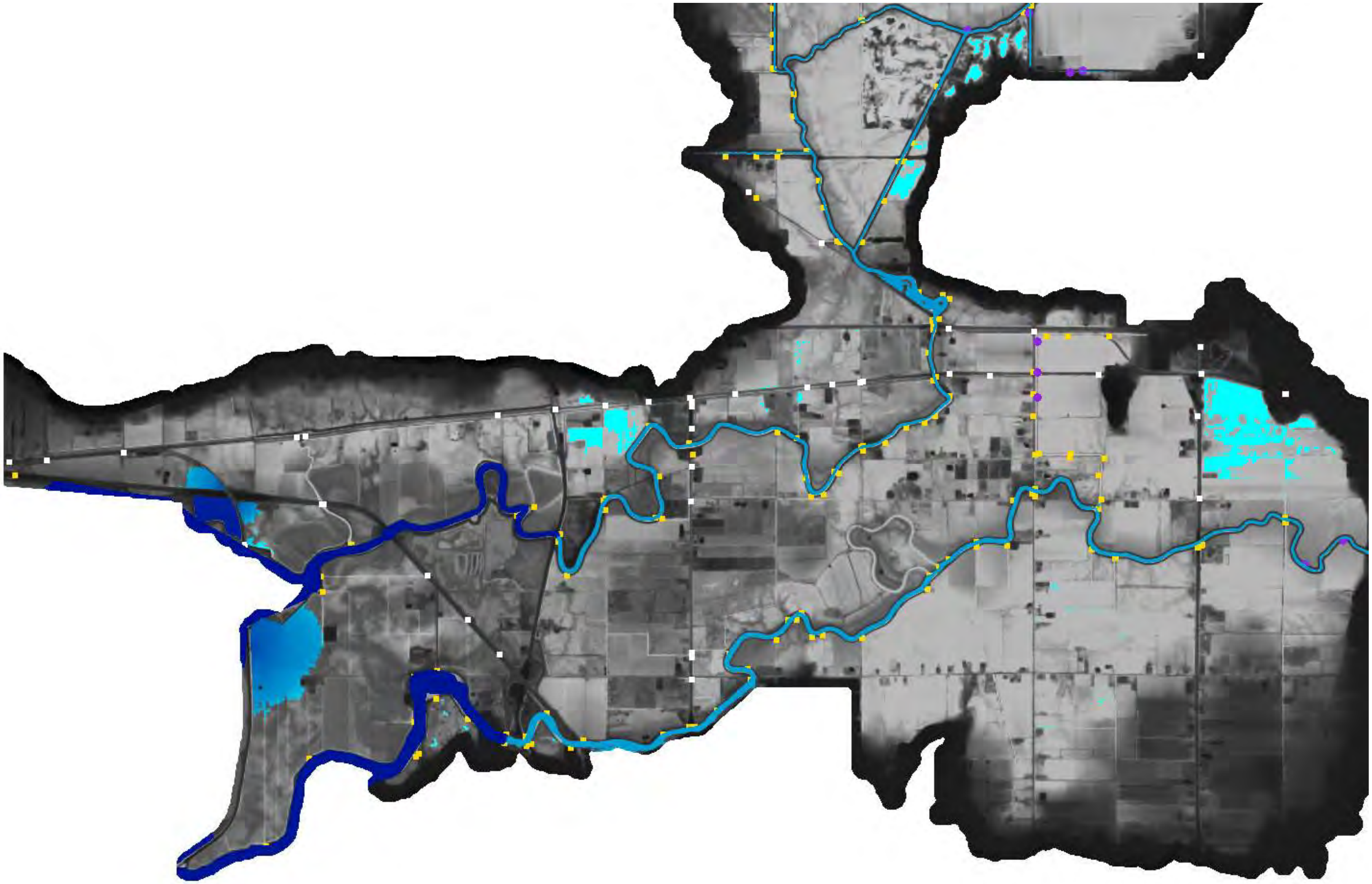

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Water Surface Elevation, T = 00:30:00

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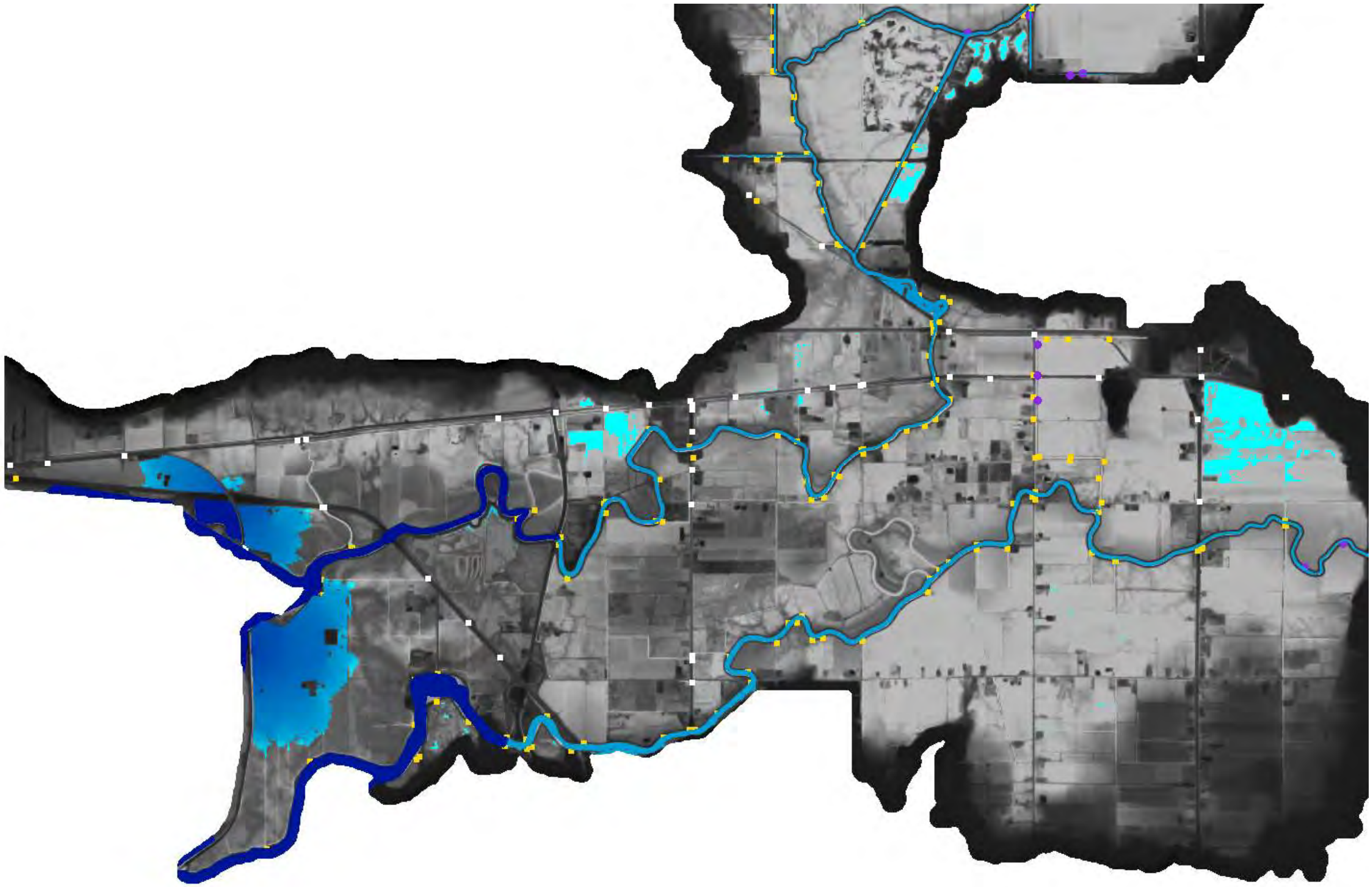

CFAS

Water Surface Elevation, T = 00:45:00

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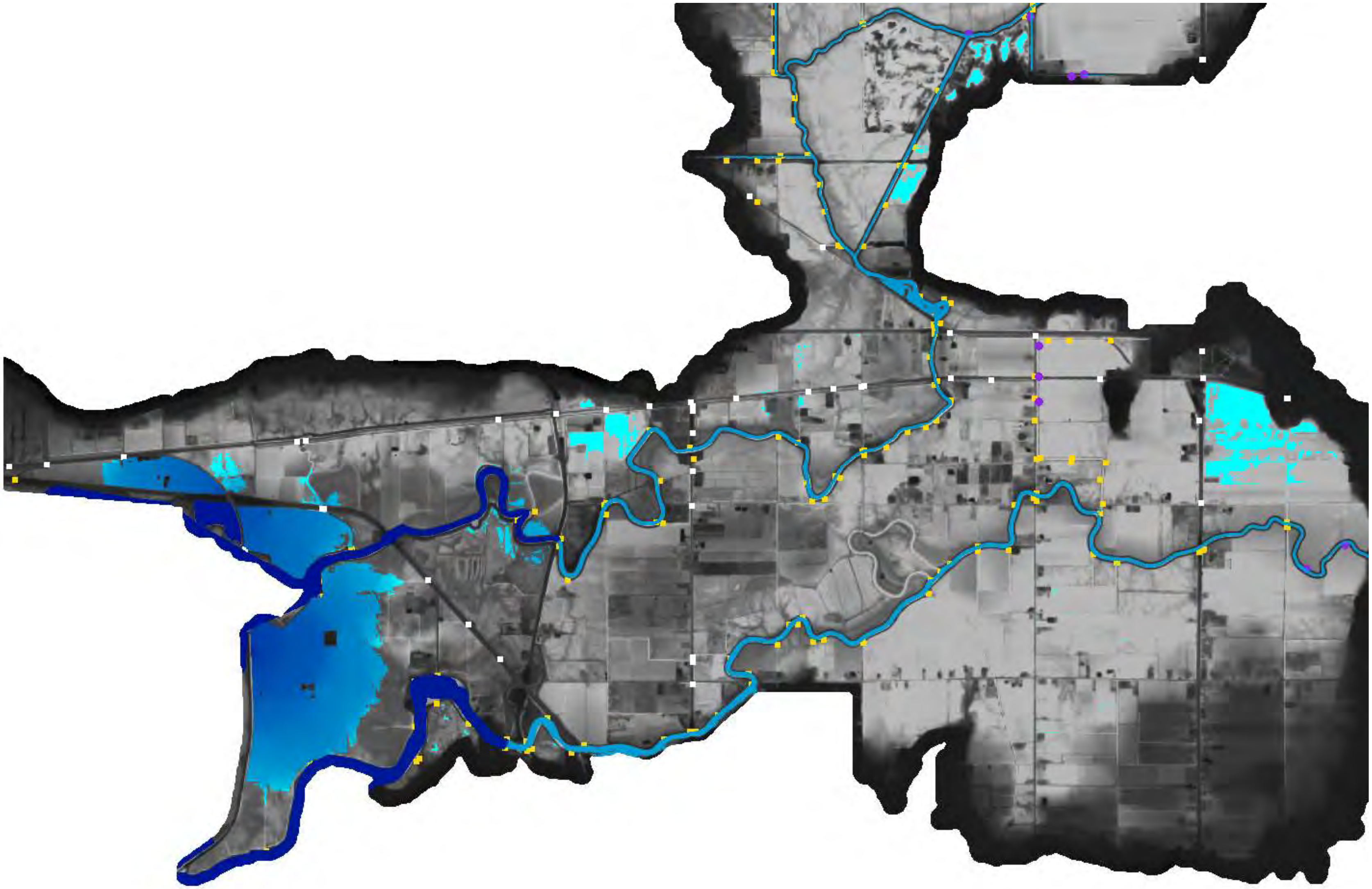

CFAS

Water Surface Elevation,   T = 01:00:00

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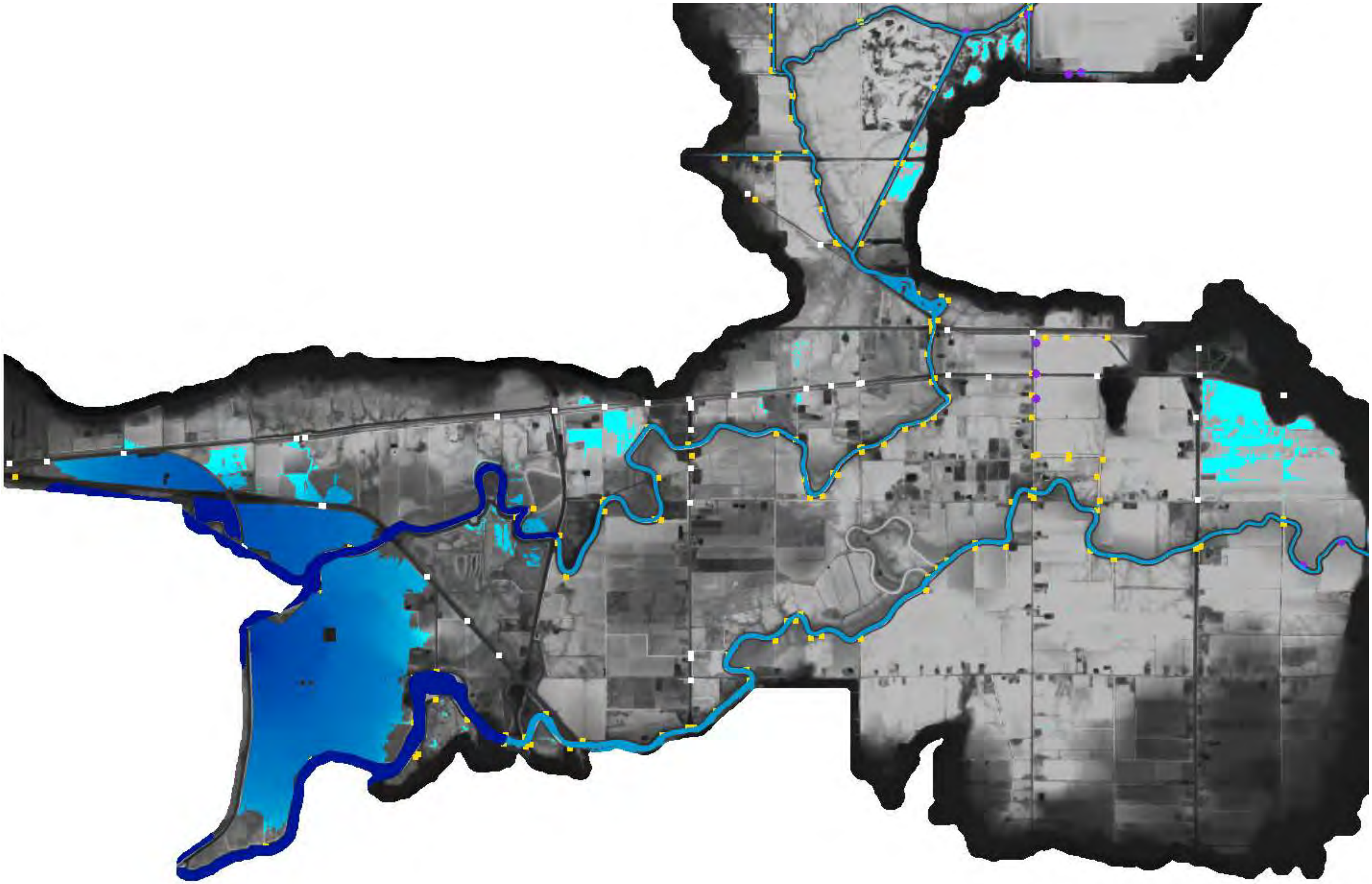
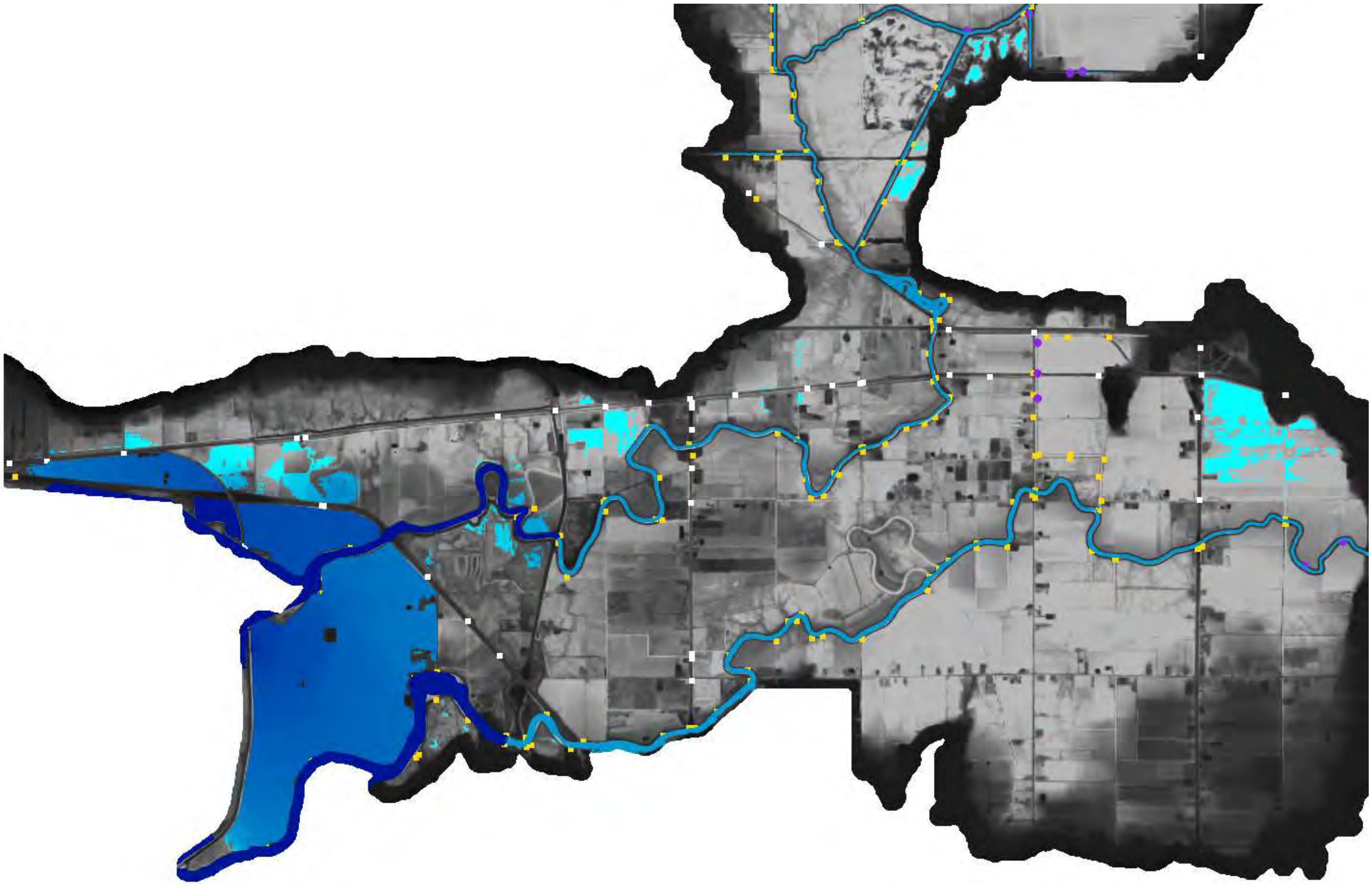


CFAS

Water Surface Elevation, T = 01:15:00



CFAS

Water Surface Elevation, T = 01:30:00

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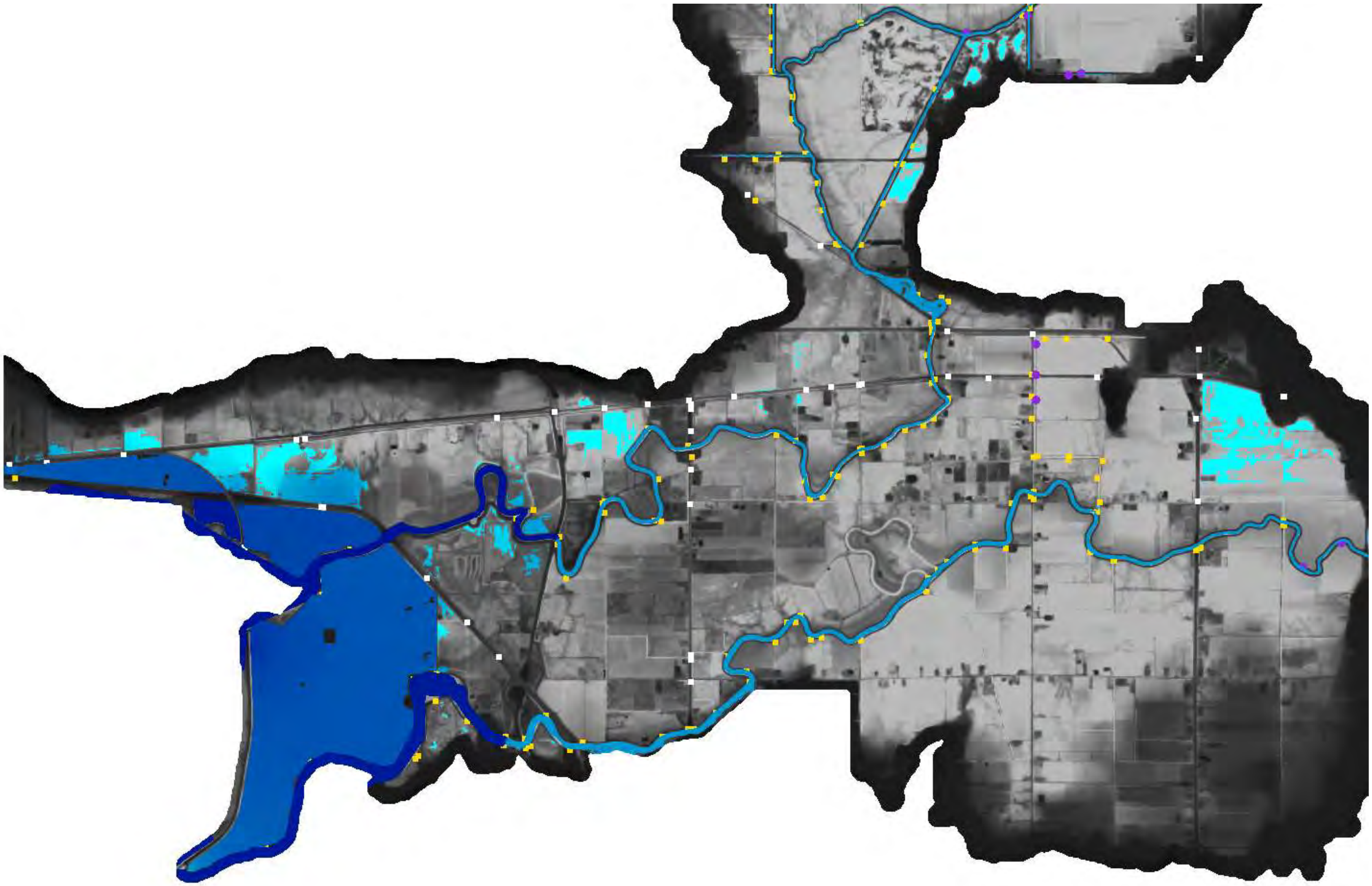

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Water Surface Elevation, T = 01:45:00

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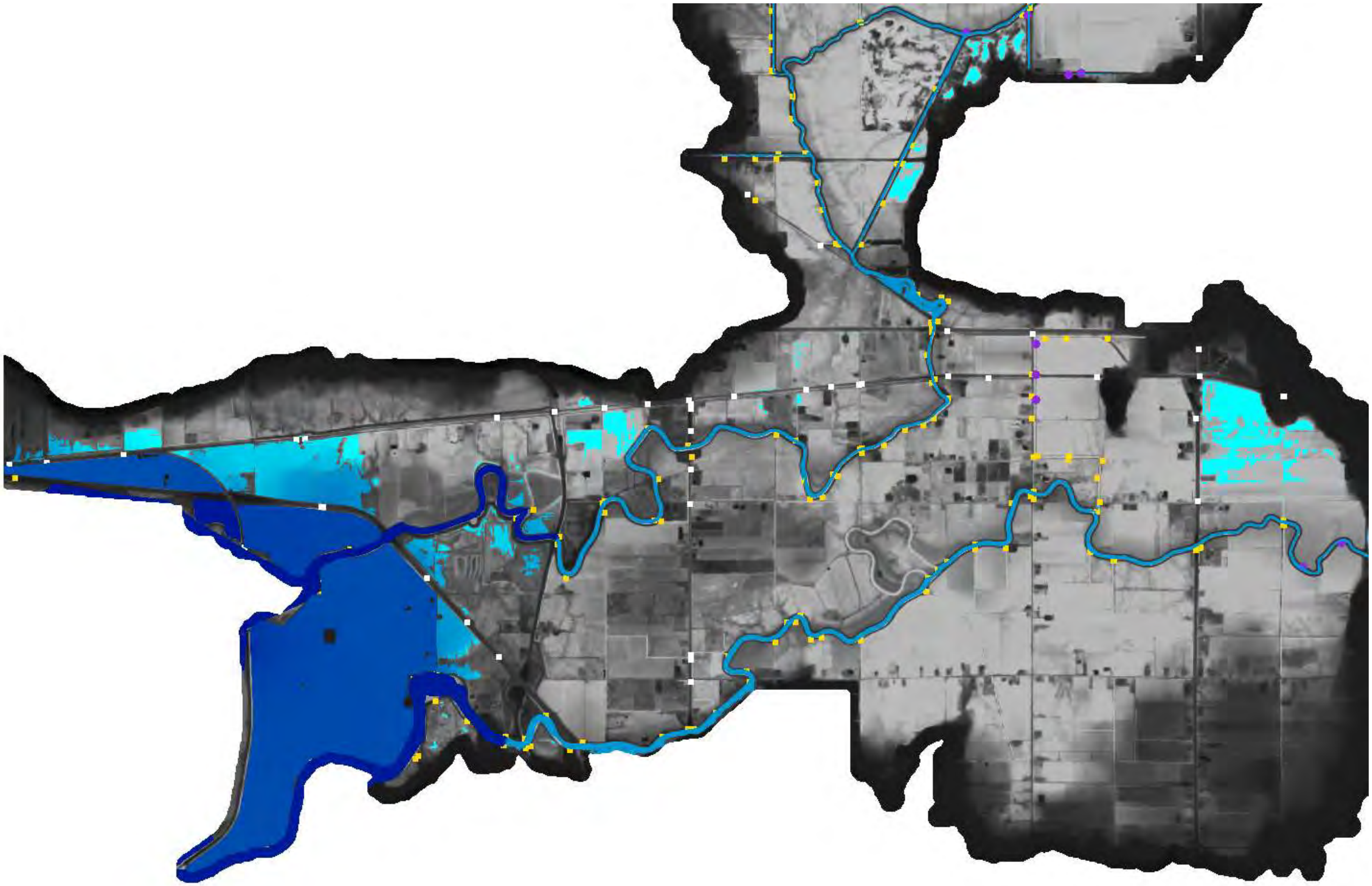

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Water Surface Elevation, T = 02:00:00

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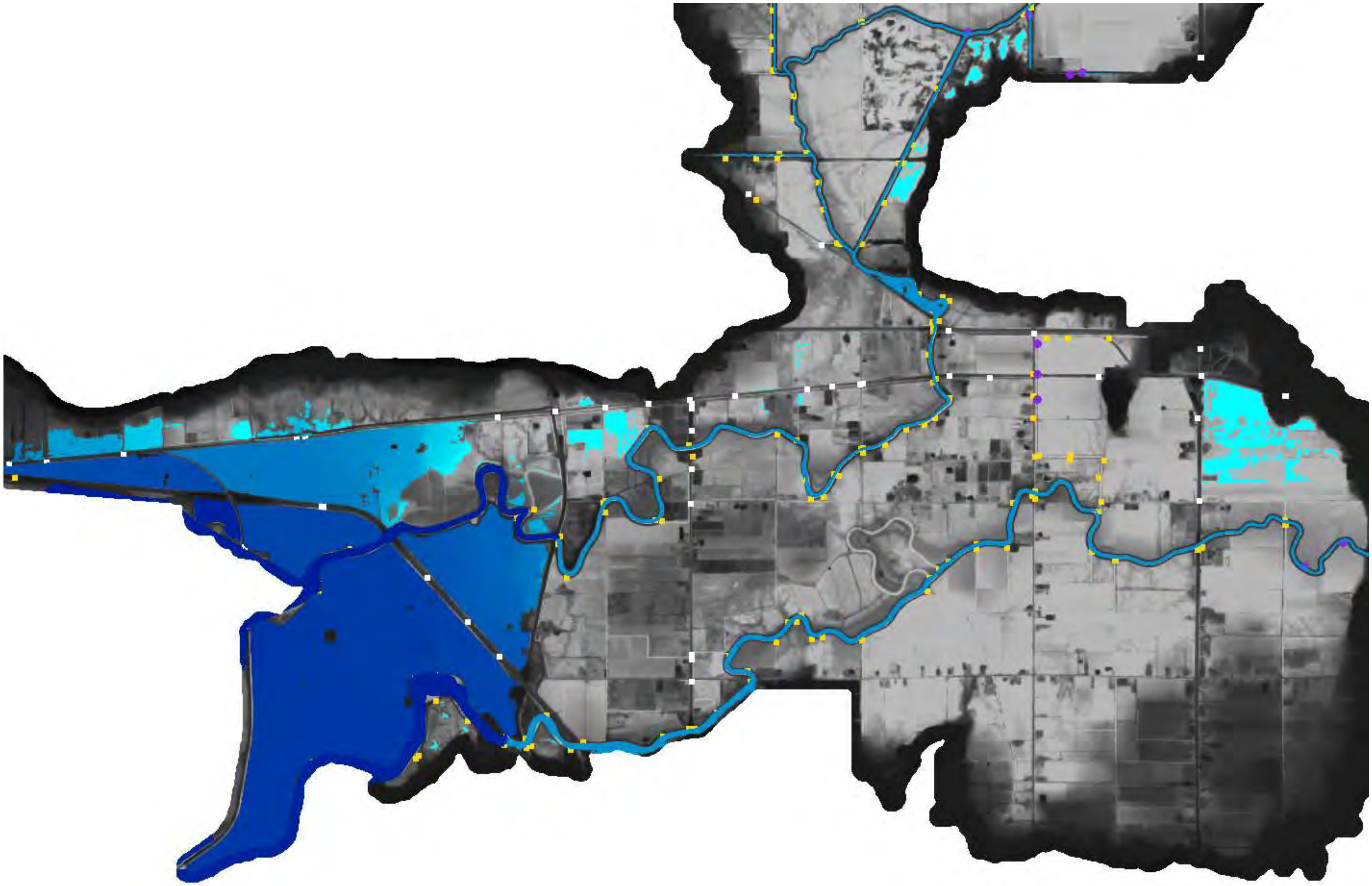

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Water Surface Elevation, T = 03:00:00

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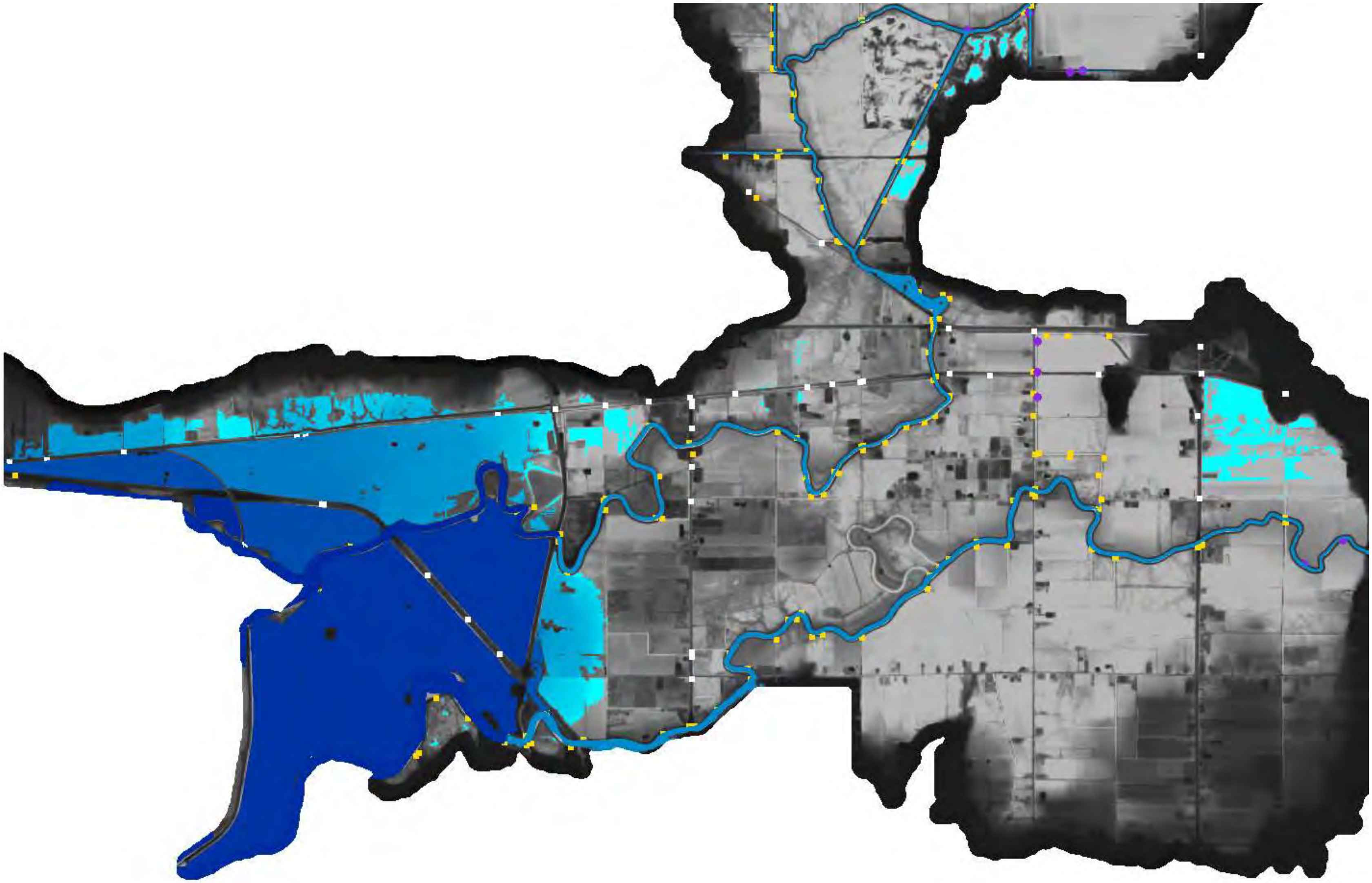

CFAS

Water Surface Elevation, T = 04:00:00

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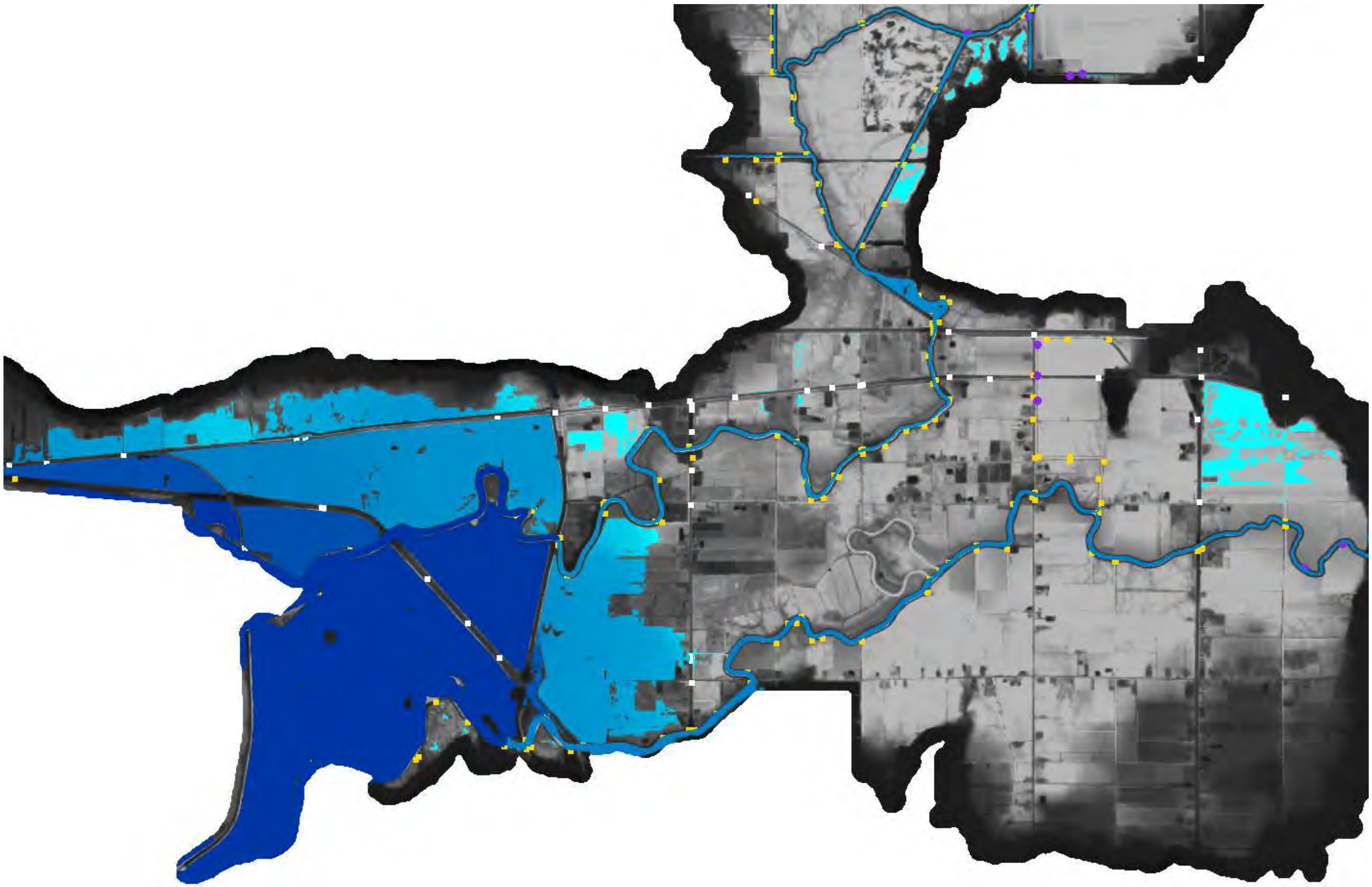

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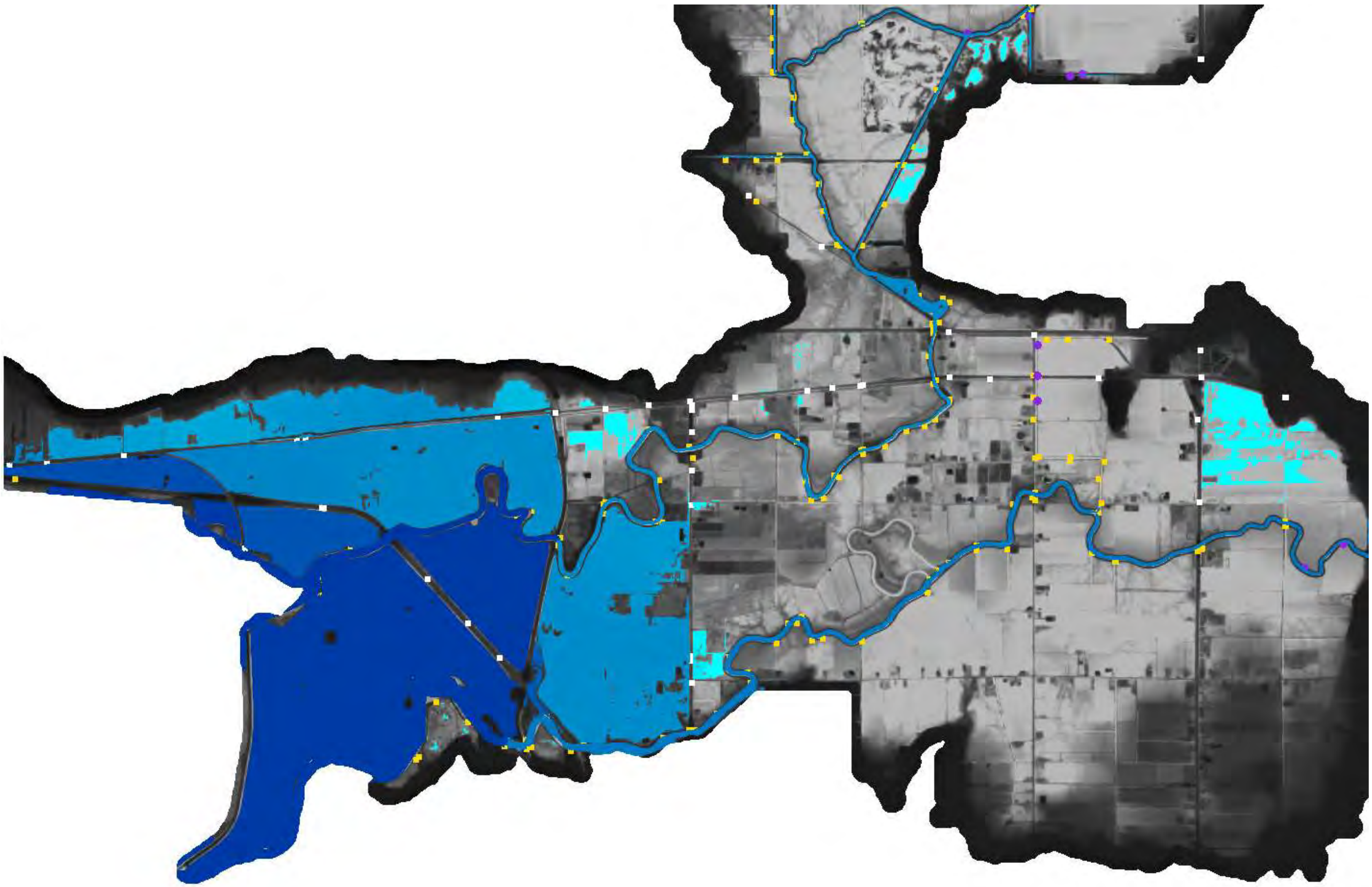
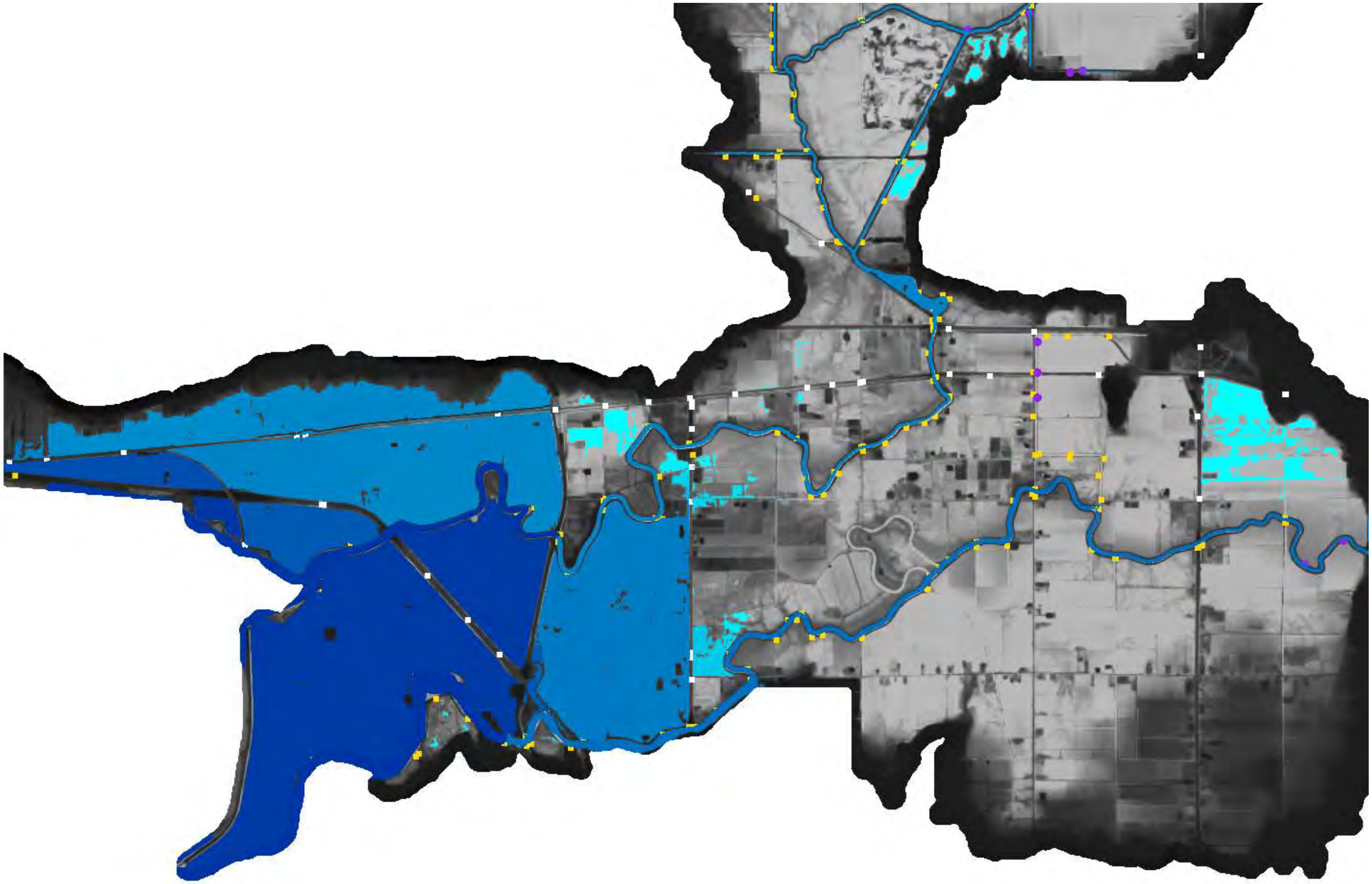
Water Surface Elevation, T = 05:00:00

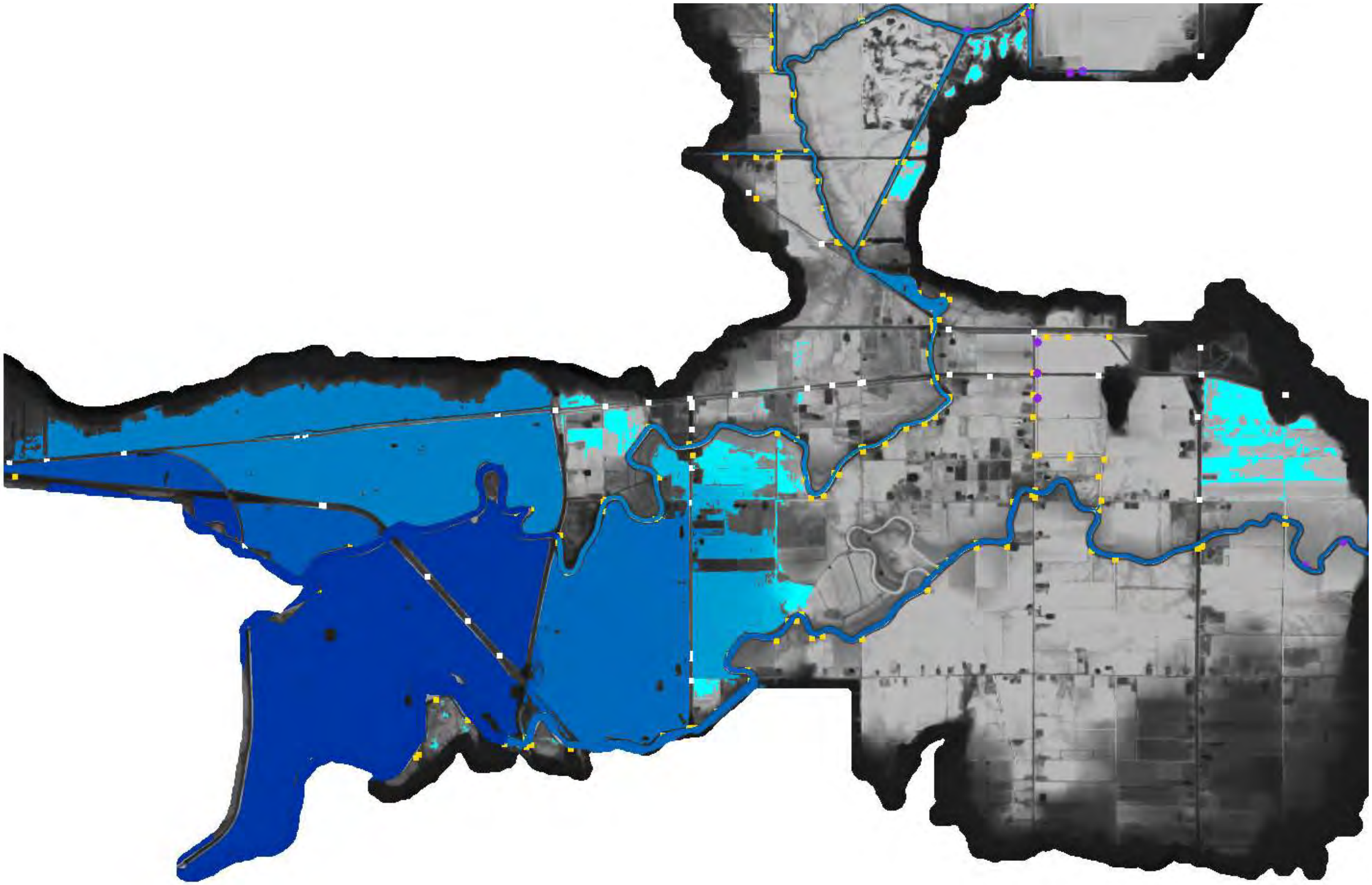
SURREY



Water Surface Elevation, T = 06:00:00



Water Surface Elevation, T = 08:00:00



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Water Surface Elevation, T = 10:00:00

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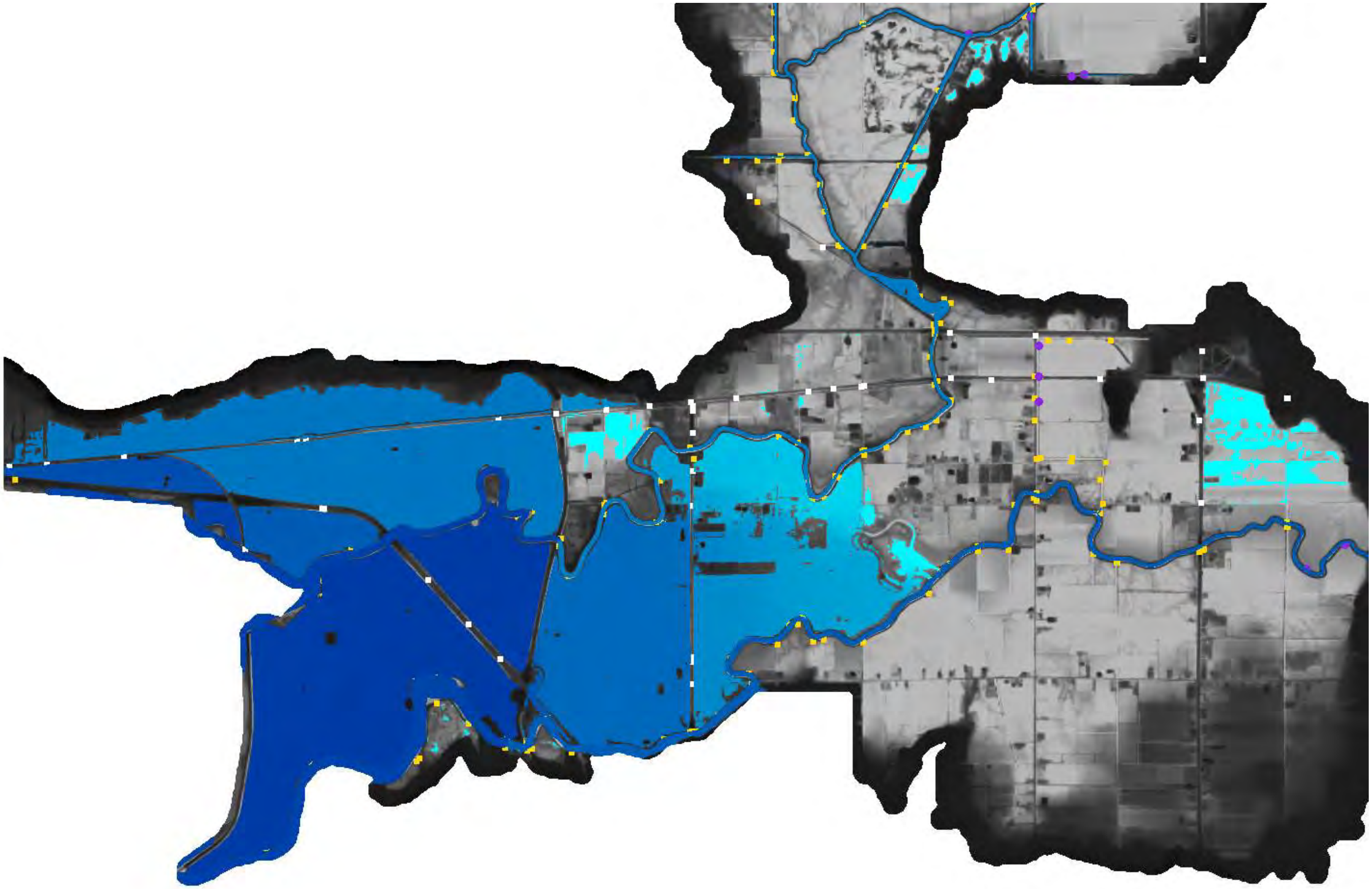

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Water Surface Elevation, T = 12:00:00

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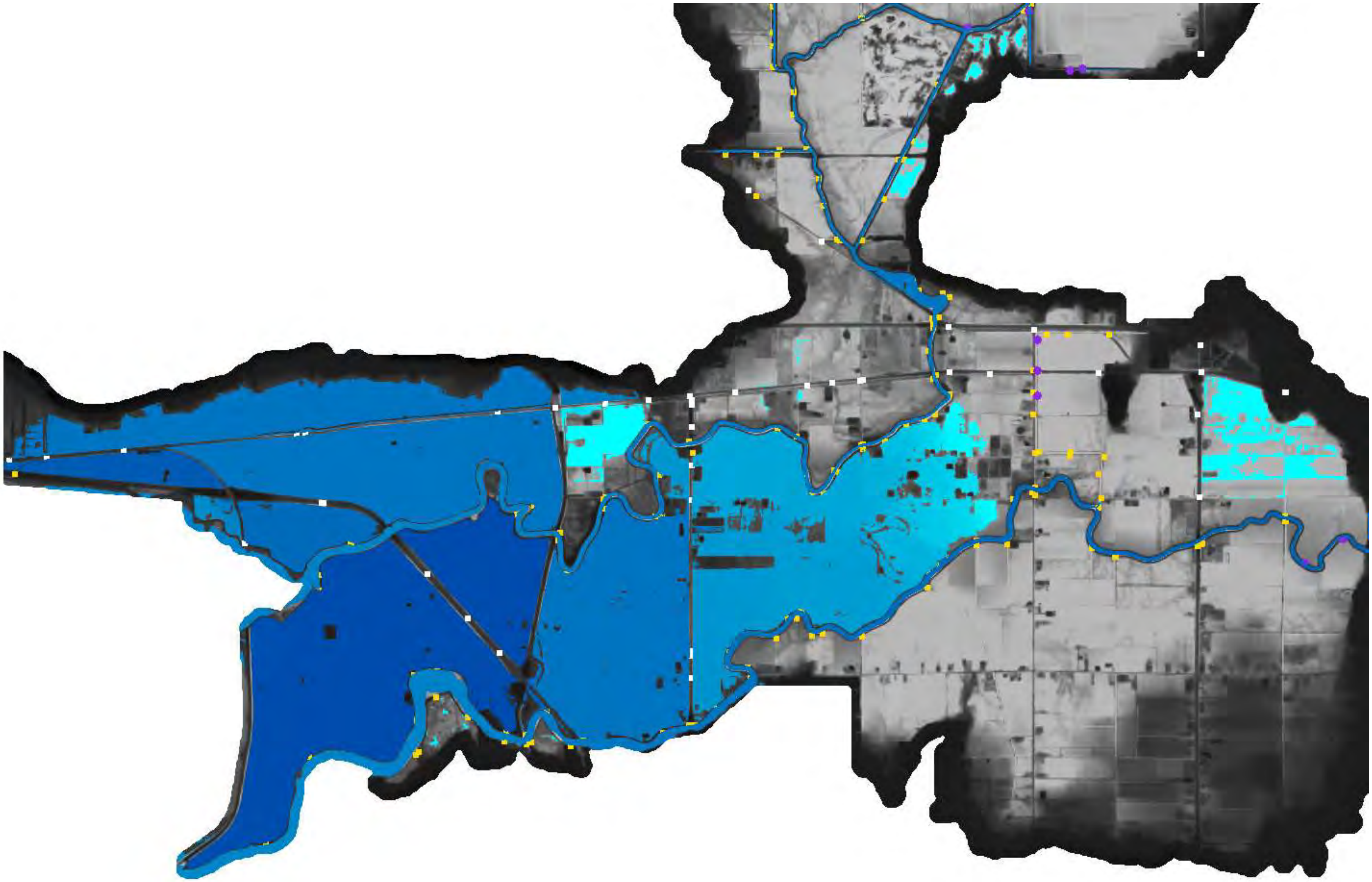

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Water Surface Elevation, T = 14:00:00

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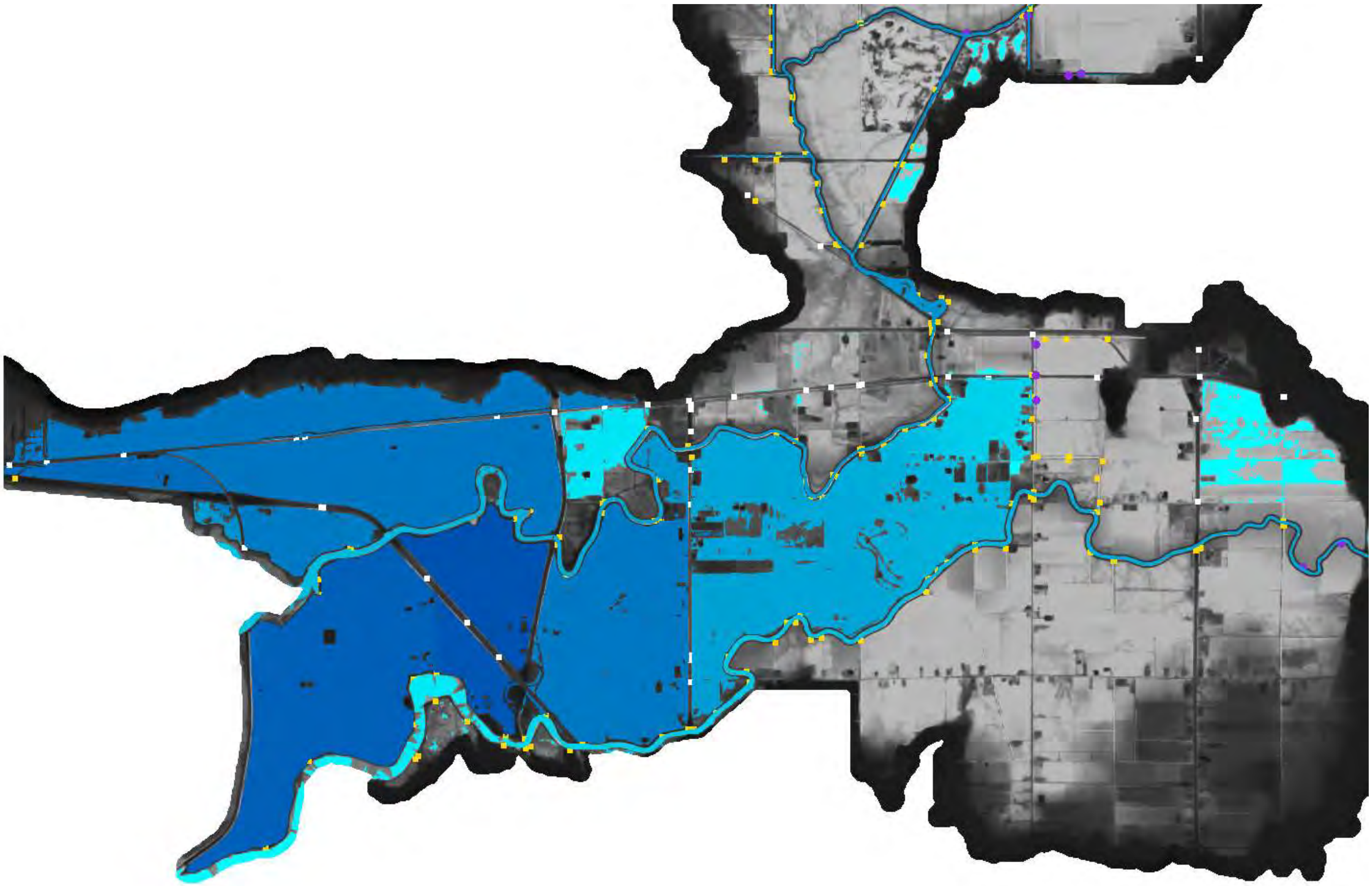
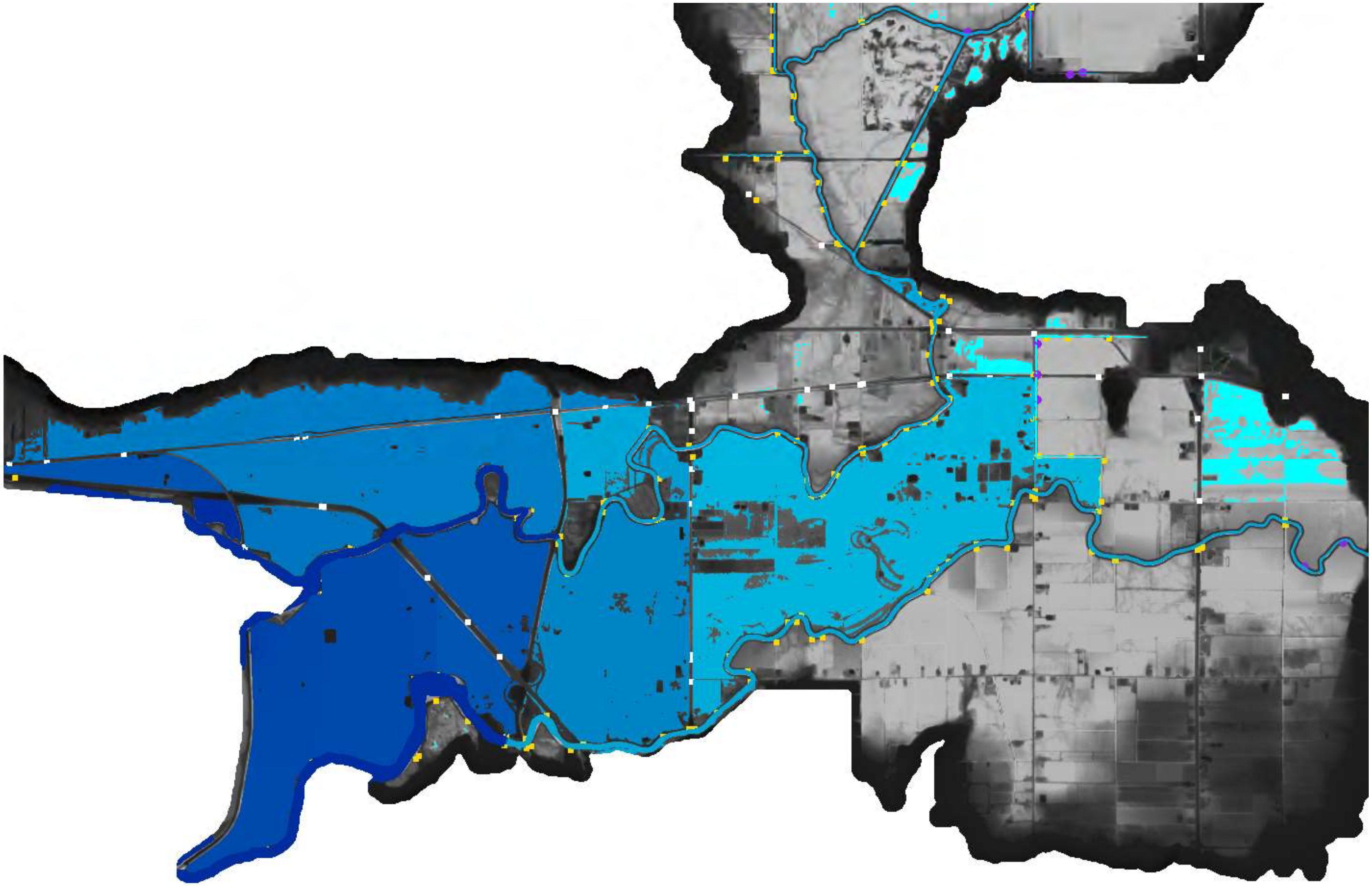


Water Surface Elevation, T = 16:00:00



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Water Surface Elevation, T = 24:00:00

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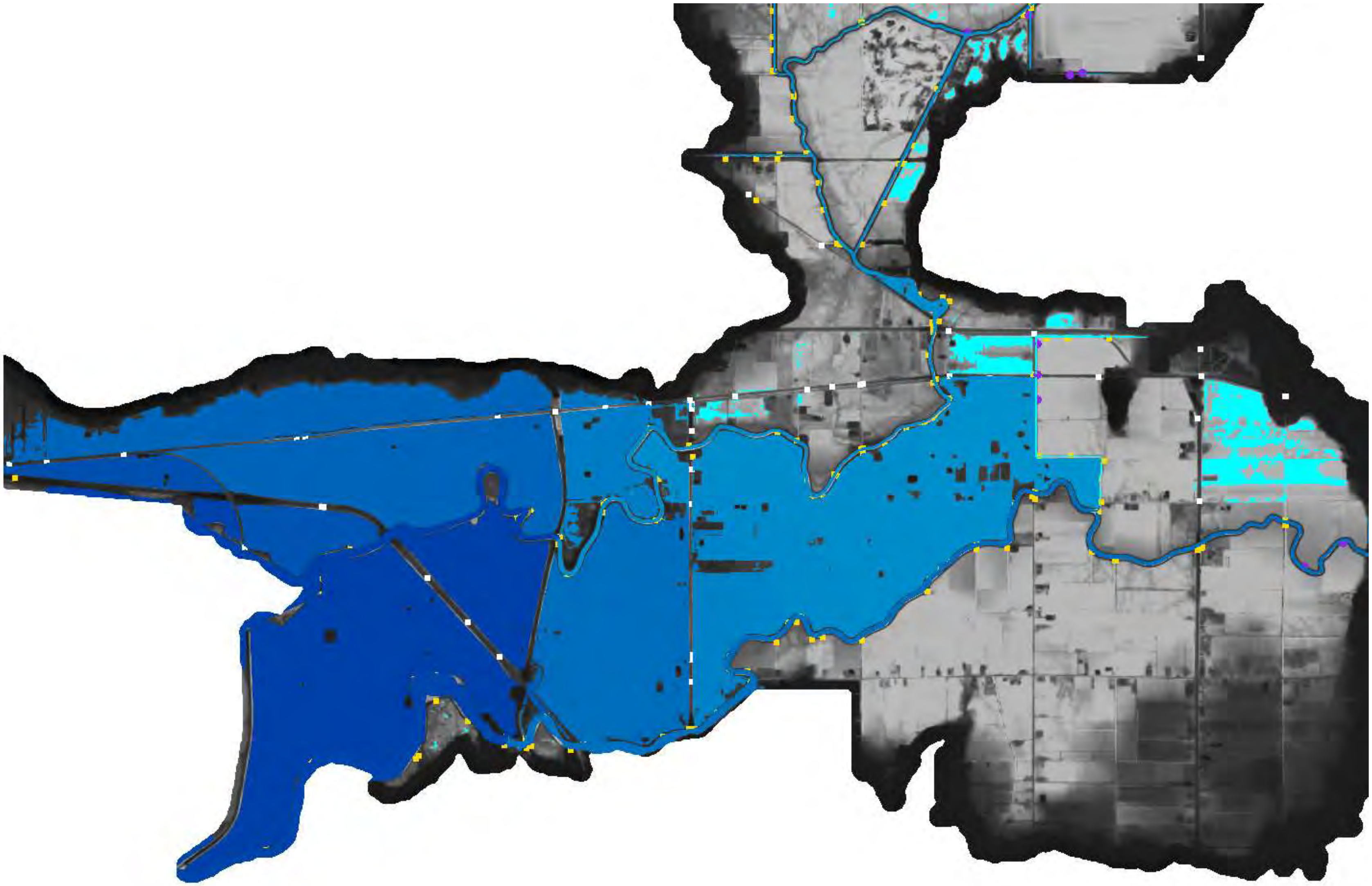

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Water Surface Elevation, T = 30:00:00

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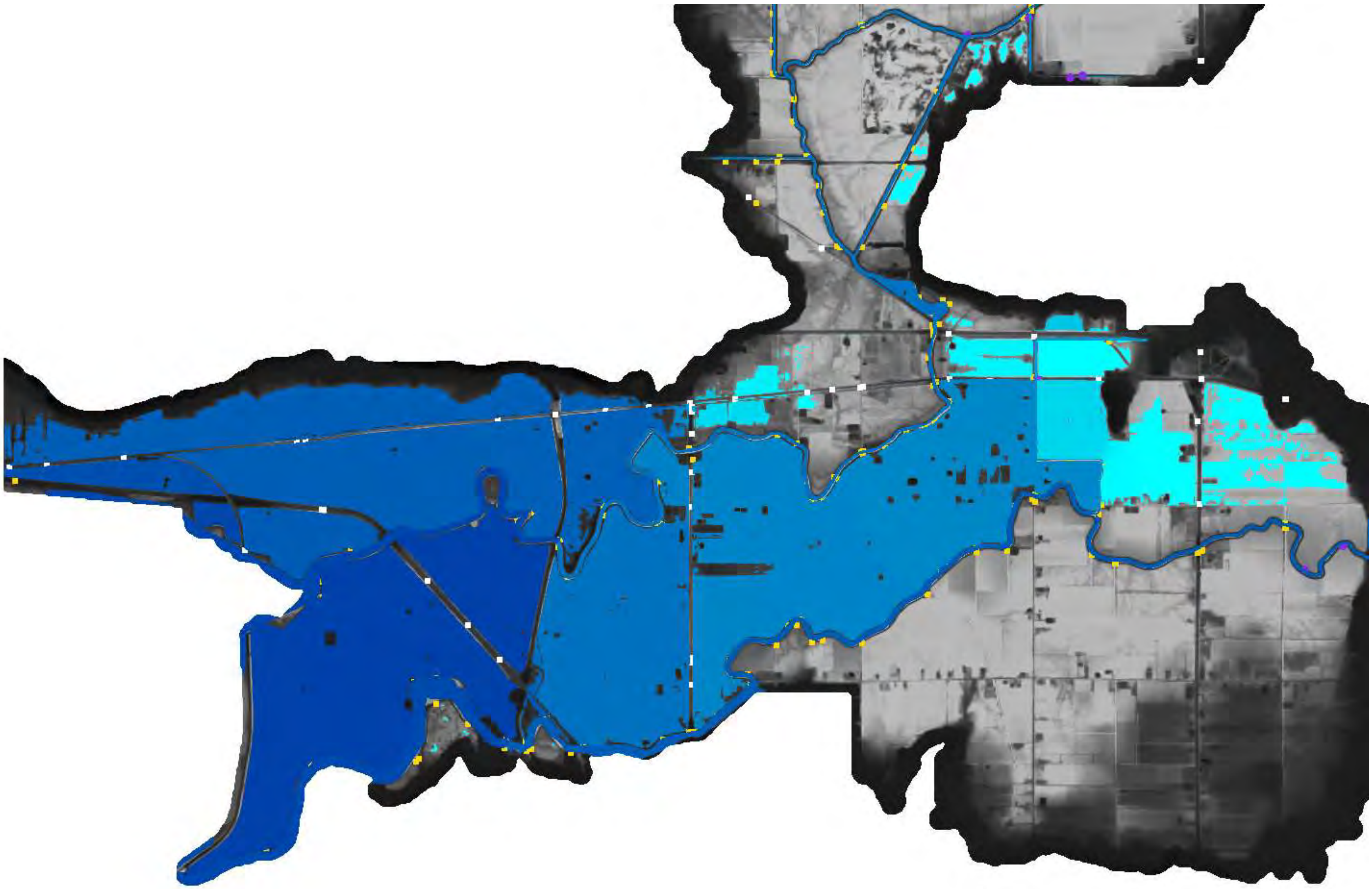

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Water Surface Elevation, T = 36:00:00

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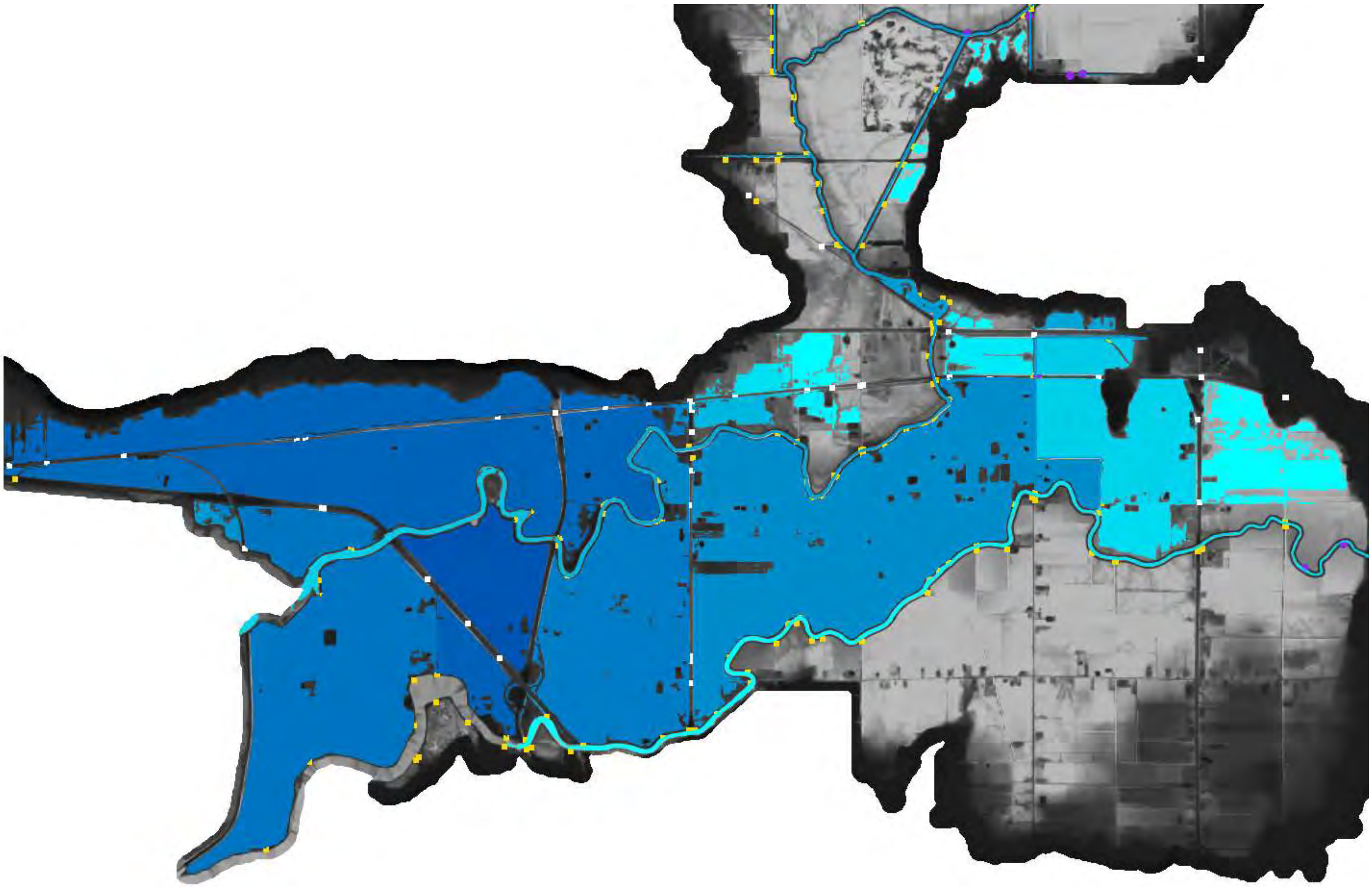

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Water Surface Elevation, T = 42:00:00

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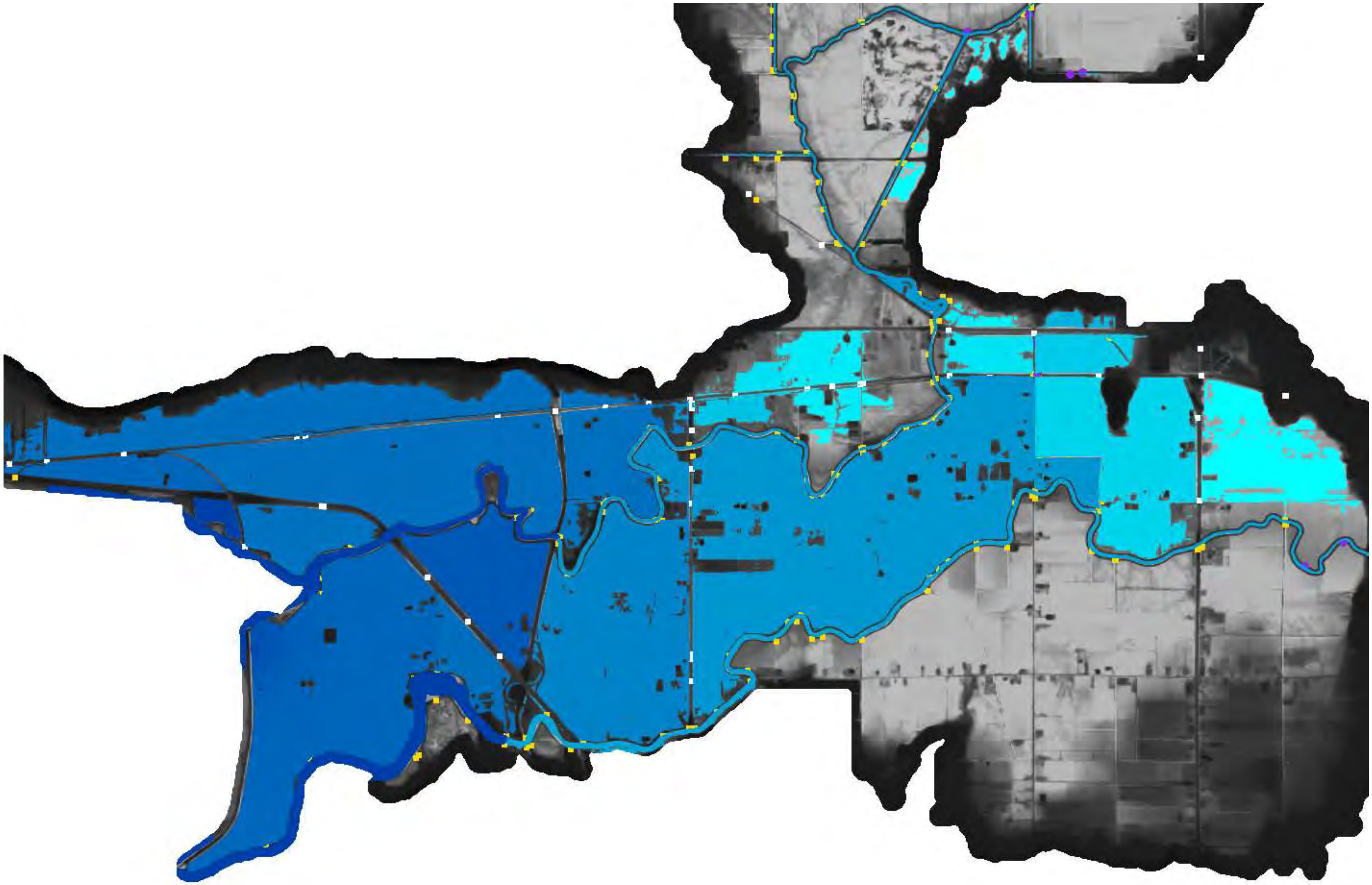

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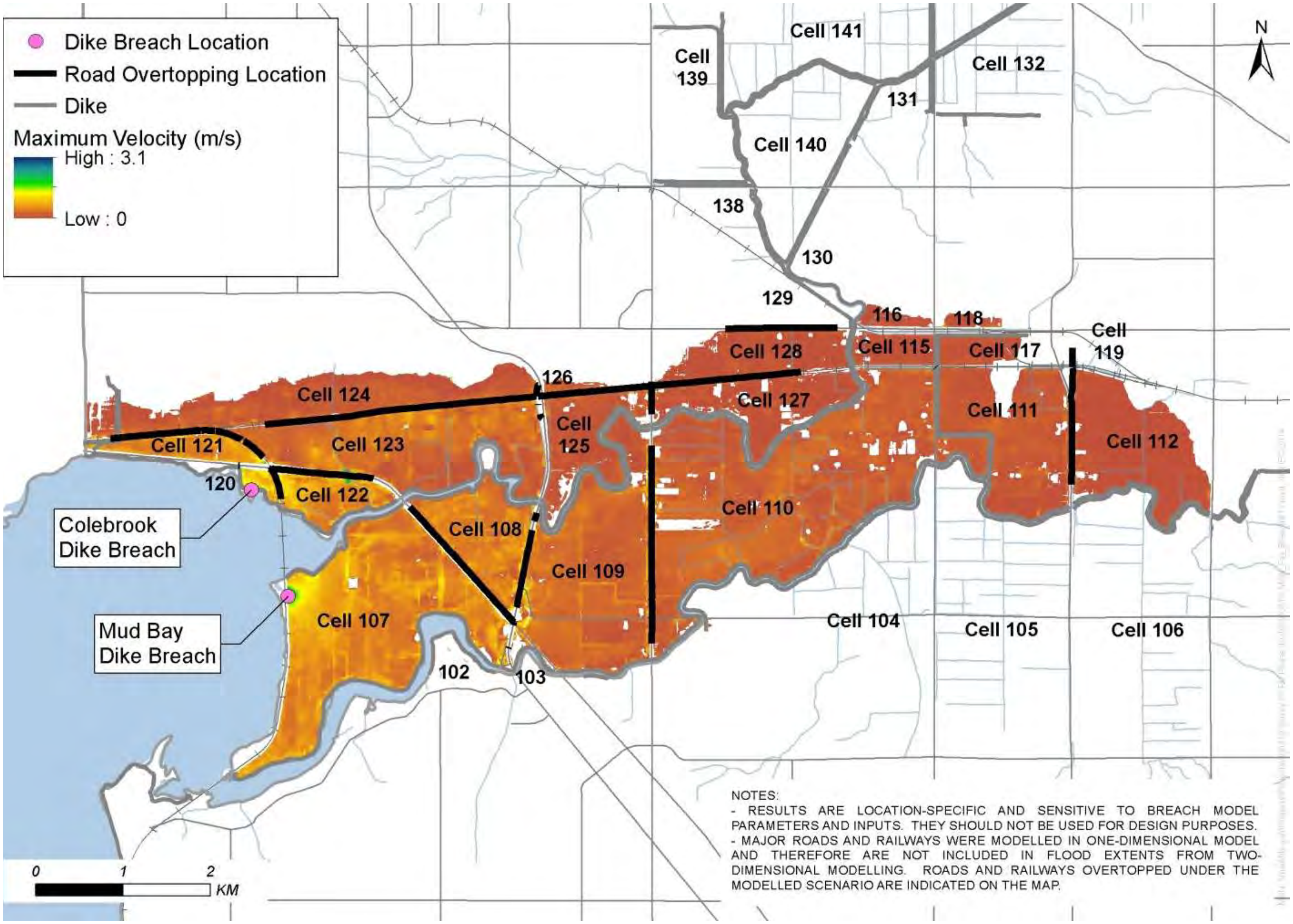
Water Surface Elevation, T = 48:00:00

SURREY

Flow Velocities



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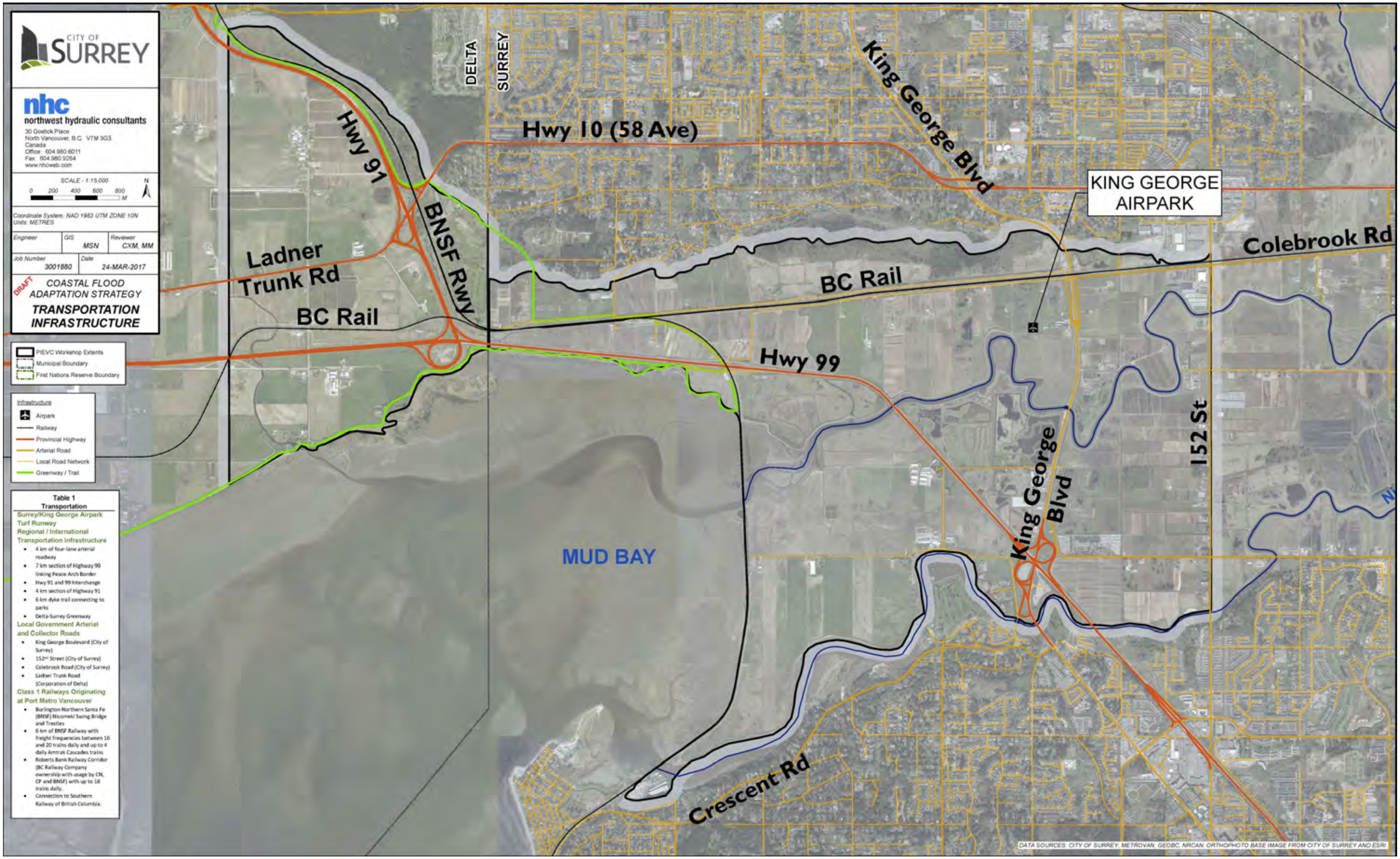
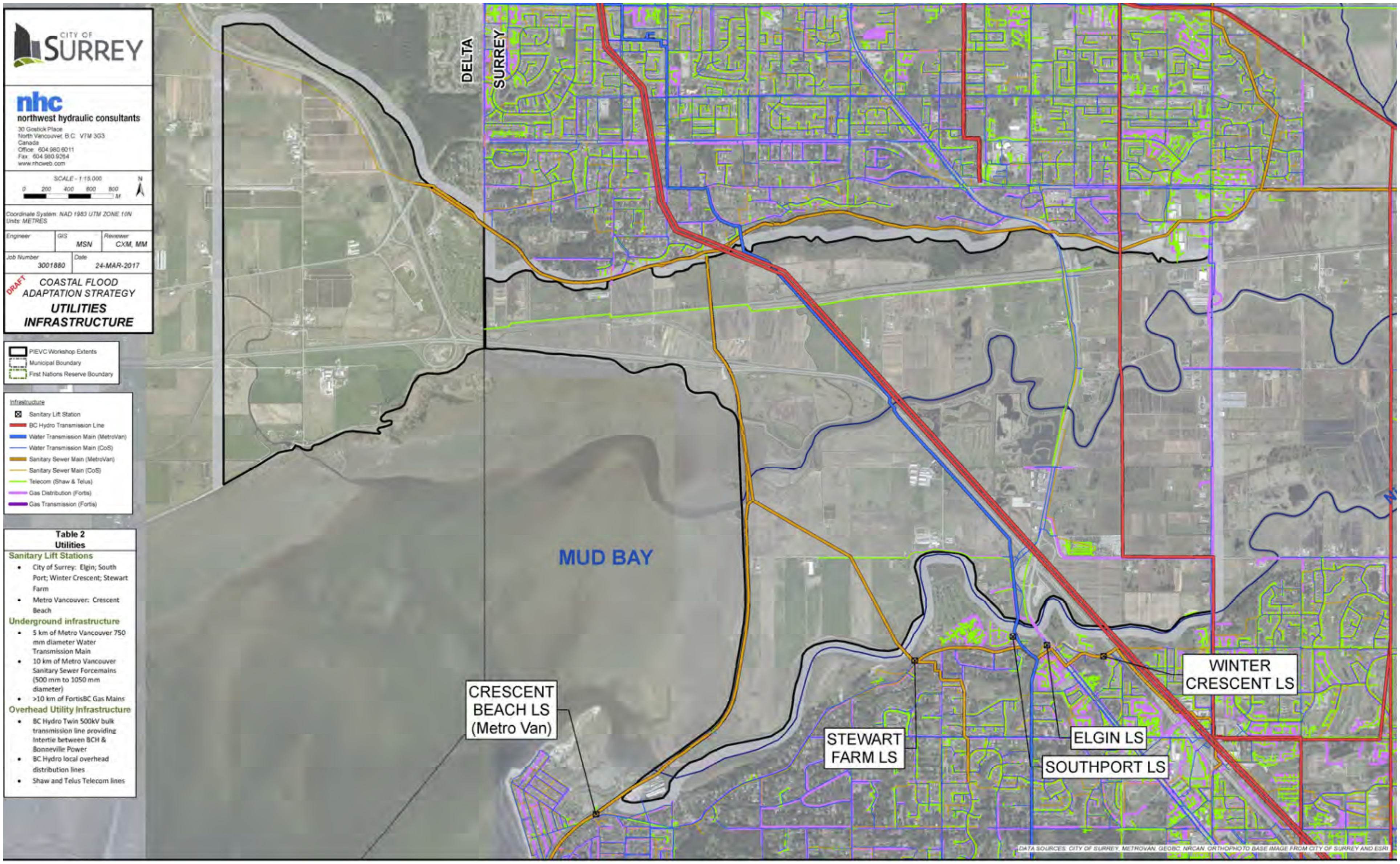
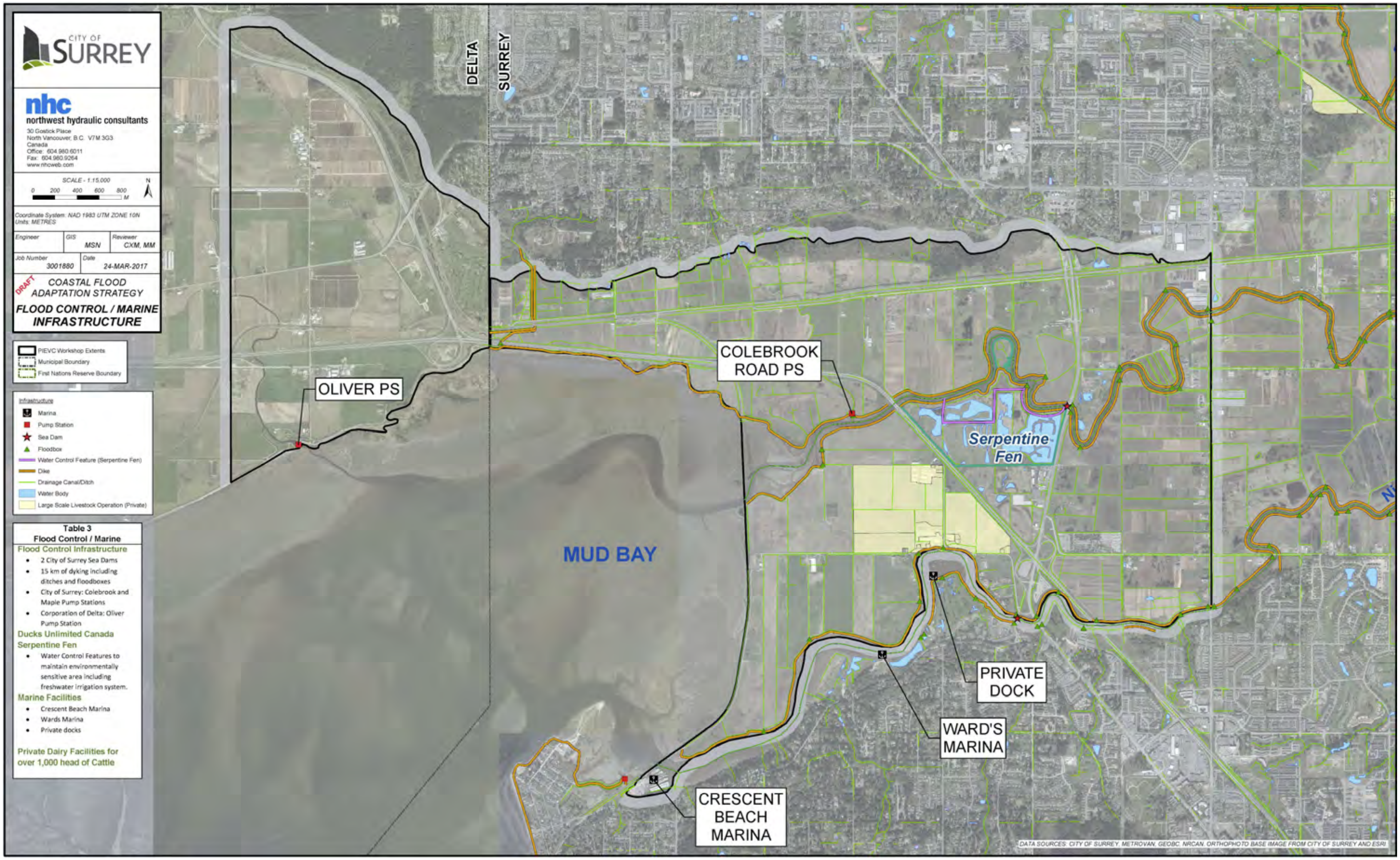
Transportation Infrastructure



Utilities Infrastructure



Other Infrastructure



Hazards and Impacts

- **Transportation & Other Infrastructure**
  - Infrastructure will be exposed to impacts not designed for
  - Useable lifespans reduced
  - Serpentine sea dam not seismically sound
  - Few dykes will meet Provincial 200-year standard by 2020
  - By 2070, 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
  - Interruption of railway operations and goods movement

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SURREY COASTAL FLOOD ADAPTATION STRATEGY (CFAS)

Presented by: Monica Mannerstrom
mmannerstrom@nhcweb.com

nhc northwest hydraulic consultants

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GROUP EXERCISE 1 - DISCUSS IMPACTS FROM FLOOD SCENARIO A

Associated Engineering | GLOBAL PERSPECTIVE. LOCAL FOCUS.

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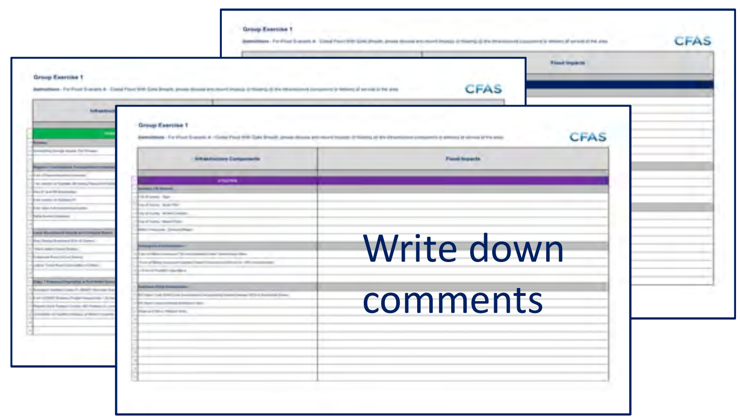
Group Exercise 1 - Impacts From Flood Scenario A

- For Flood **Scenario A, Coastal Flood with Dyke Breach**, please discuss and record impacts of flooding on the infrastructure components or delivery of services in the area.

- Table Facilitator will record on comments flip chart.

- Please write down your comments into the workbook
  - Table Discussion (20 min)
  - Group Discussion (10 min)



Group Exercise 1 - Impacts From Flood Scenario A

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

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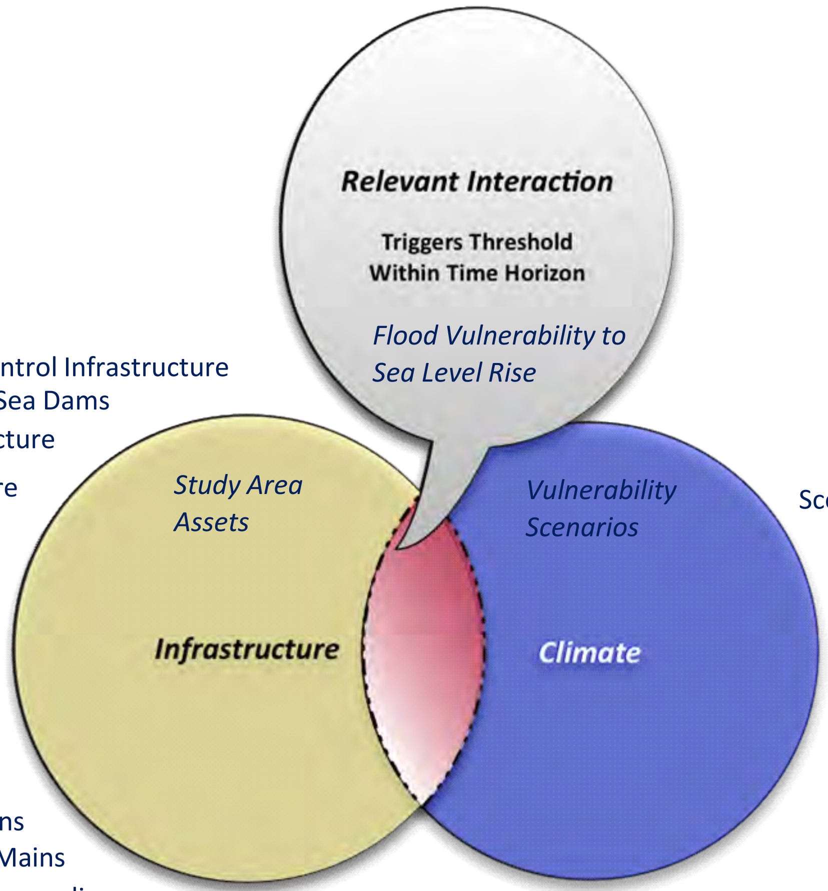
PIEVC RISK ASSESSMENT ORIENTATION

PIEVC Risk Assessment



Flood Control Infrastructure
Sea Dams
Dyking infrastructure
Water Control Infrastructure
Arterial roadway
Railways
International Highways:
Marinas
Water Transmission Mains
Sanitary Sewer Forcemains
Lift Stations
Natural Gas Mains
Telecom lines
Hydro Distribution / Transmission

Scenario A & B:
Sea Level Rise
Storm Surge
High Tide
Long Duration Rainfall
High Intensity Rainfall

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PIEVC Risk Assessment

- Risk (R) is defined as the product of the probability (P) of an event and the consequence (C) of that event – should it occur.

R = P X C

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PIEVC Risk Assessment

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

FLOOD

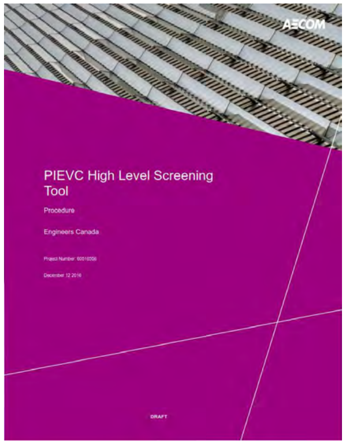
Climate Change

FLOOD

Adaptation

FLOOD

PIEVC Risk Assessment



High Level Screening Assessment

Step 1
Define Infrastructure

Step 2
Evaluate Climate Changes

Step 3
Conduct Risk Assessment

Step 5
Conclusions and Recommendations

Comprehensive Level Assessment

Step 1
Project Definition

Step 2
Data Gathering

Step 3
Risk Assessment

Step 4
Engineering Analysis

Step 5
Conclusions and Recommendations

TBL Module

Step 6
Adaptation Scenarios

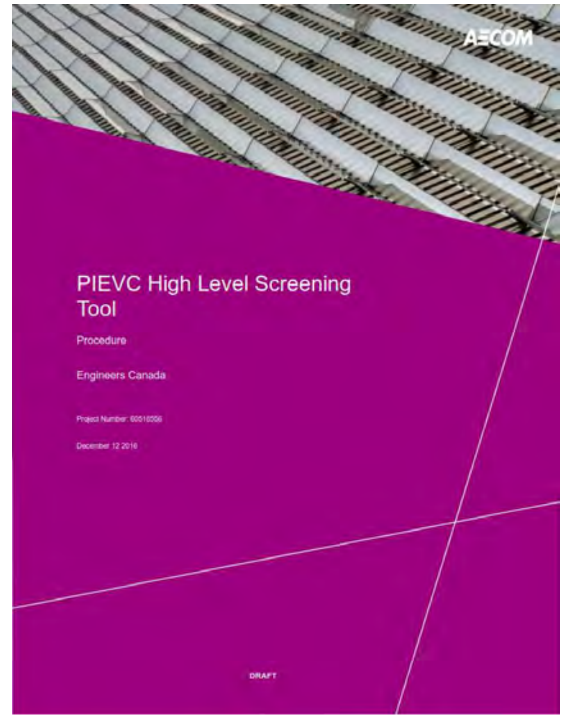
Step 7
Multi-criteria Analysis

Step 8
Recommendations and Follow-up

- High Level Screening Assessment
  - Process is designed to help infrastructure owners gain a high level and quick overview of the potential risk posed by climate change to their infrastructure.

PIEVC Risk Assessment

- **Step 1 Infrastructure Definition**
  - Define infrastructure
  - Conduct a site visit
  - Confirm infrastructure components and discuss climate hazards and impacts
- **Step 2 Climate Parameters**
  - Define climate parameters, obtain information about future probabilities
- **Step 3 Risk Assessment**
  - Evaluate consequences of climate-infrastructure interaction
- **Step 4 Recommendations**
  - Develop a list of recommendations to address climate change risks, and identify areas of further study
  - Produce Summary Report



PIEVC Risk Assessment

➡ Step 1
Define Infrastructure

Step 2
Evaluate Climate Changes

Step 3
Conduct Risk Assessment

Step 5
Conclusions and Recommendations

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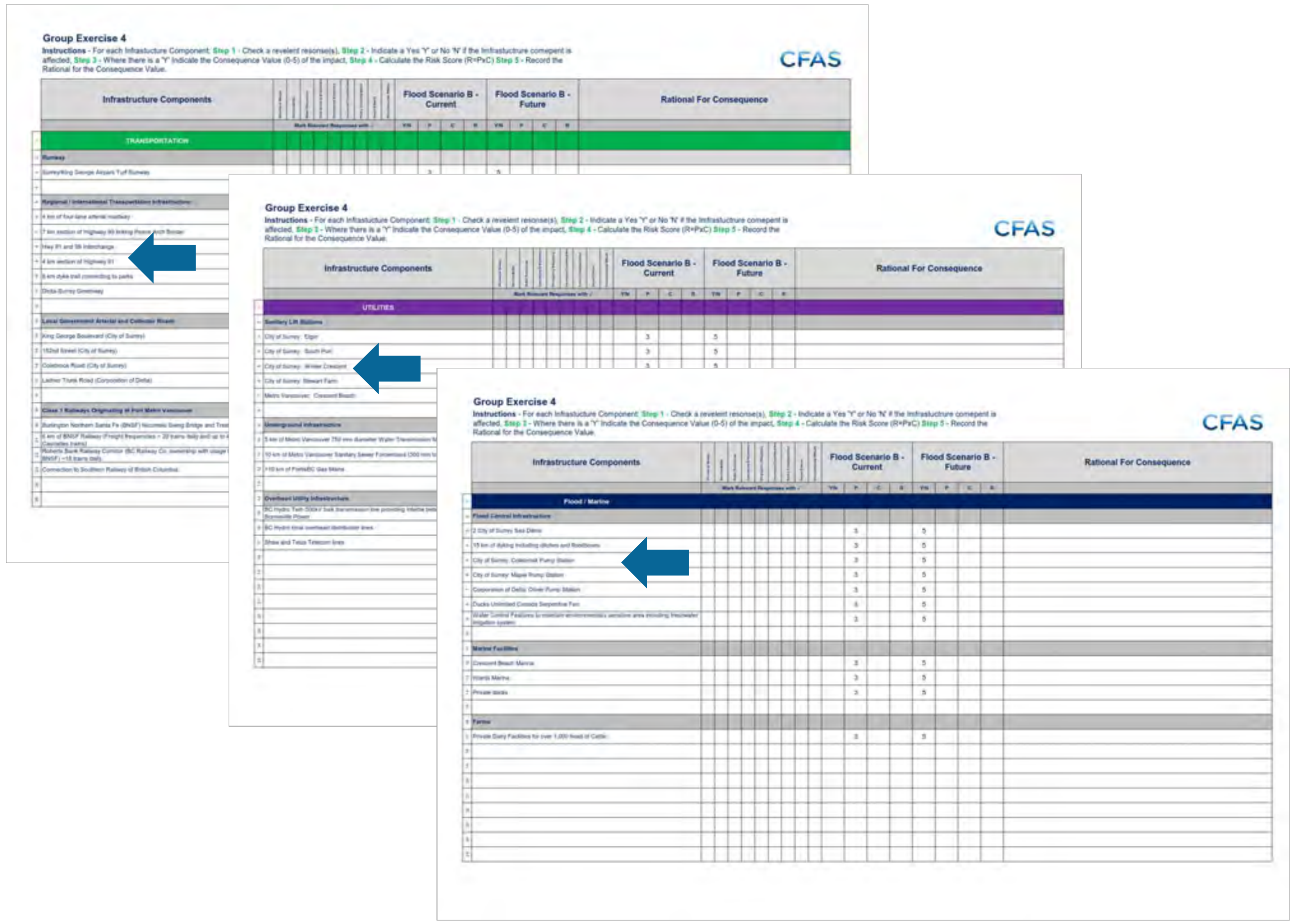
PIEVC Risk Assessment

Step 1
Define Infrastructure

Step 2
Evaluate Climate Changes

Step 3
Conduct Risk Assessment

Step 5
Conclusions and Recommendations



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PIEVC Risk Assessment

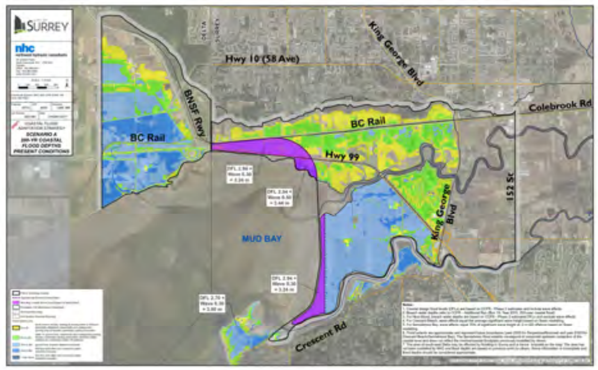
Step 1
Define Infrastructure

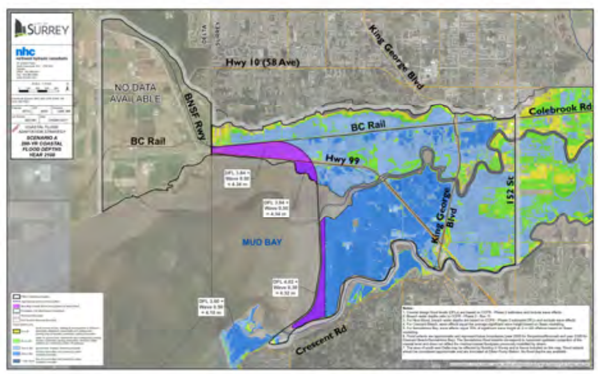
Step 2
Evaluate Climate Changes

Step 3
Conduct Risk Assessment

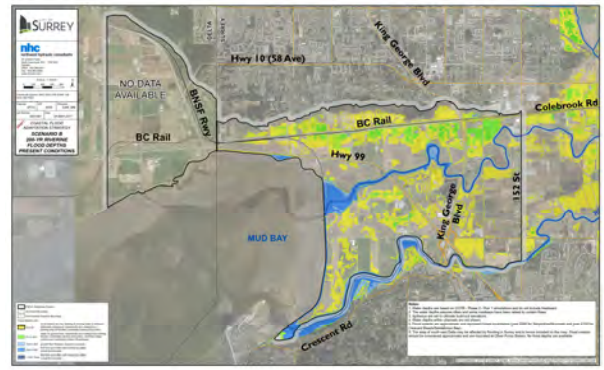
Step 5
Conclusions and Recommendations

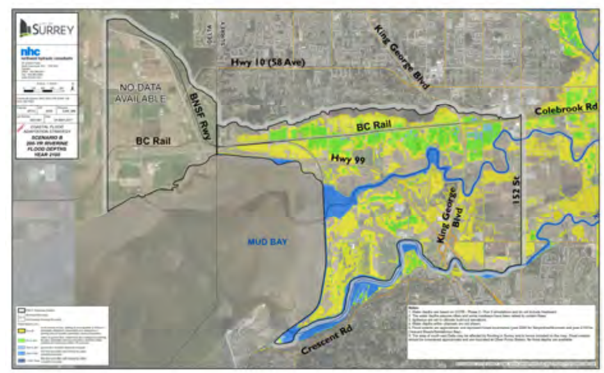
Flood Scenario A





Flood Scenario B





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PIEVC Risk Assessment

Step 1
Define Infrastructure

Step 2
Evaluate Climate Changes

Step 3
Conduct Risk Assessment

Step 5
Conclusions and Recommendations

- Probability Scores for the Flood Scenarios have been Established:

Score	Probability
	Method A
0	Negligible Not Applicable
1	Highly Unlikely Improbable
2	Remotely Possible
3	Possible Occasional
4	Somewhat Likely Normal
5	Likely Frequent

Scenario $A_{current}$: P = 4

Scenario A_{future}: P = 5

Scenario $B_{current}$: P = 3

Scenario B_{future}: P = 5

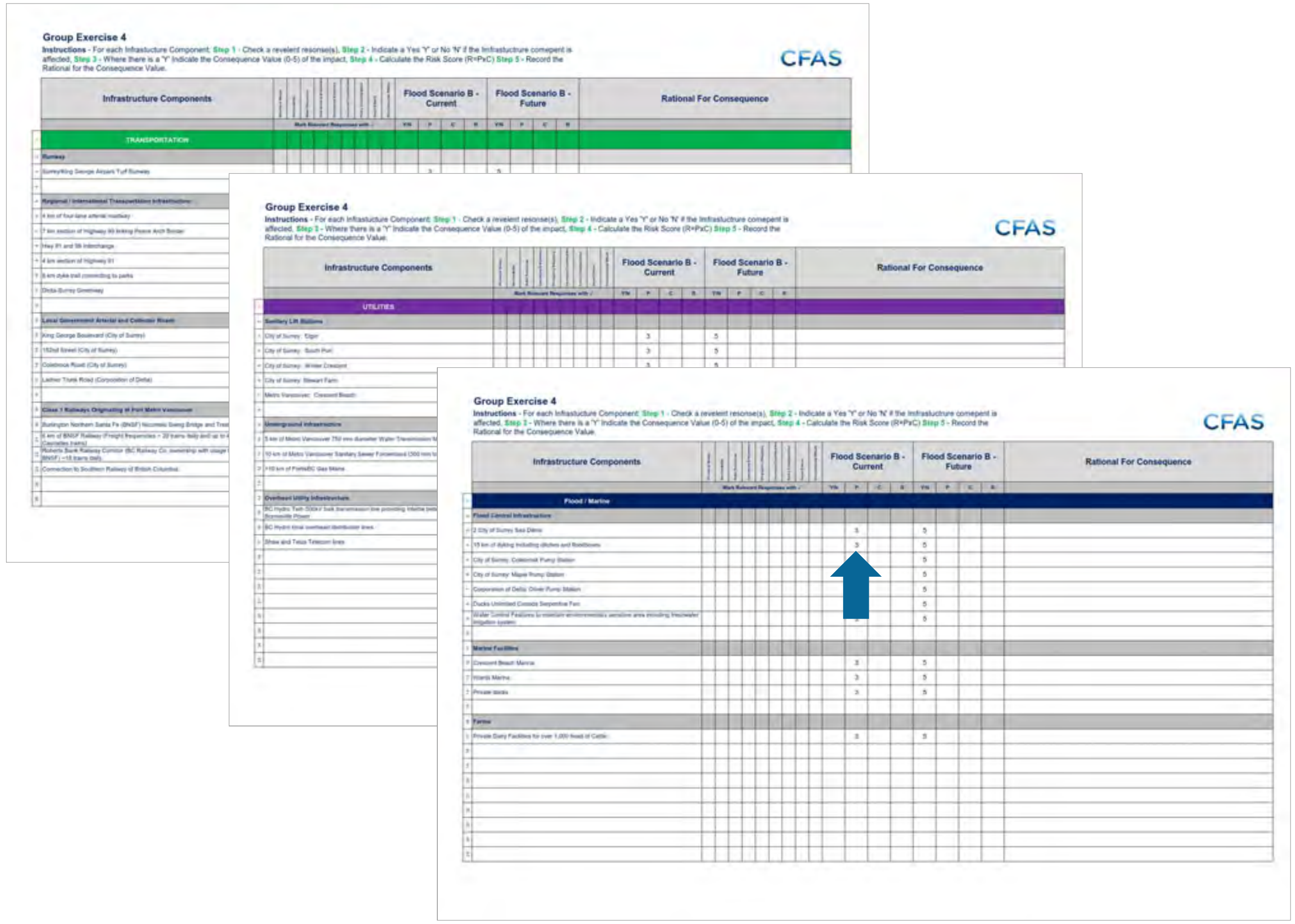
PIEVC Risk Assessment

Step 1
Define Infrastructure

Step 2
Evaluate Climate Changes

Step 3
Conduct Risk Assessment

Step 5
Conclusions and Recommendations



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PIEVC Risk Assessment

Step 1
Define Infrastructure

Step 2
Evaluate Climate Changes

Step 3
Conduct Risk Assessment

Step 5
Conclusions and Recommendations

- Consequence Scores

Score	Consequence
	Method D
0	No Effect
1	Insignificant
2	Minor
3	Moderate
4	Major
5	Catstrophic

PIEVC Risk Assessment

Step 1
Define Infrastructure

Step 2
Evaluate Climate Changes

➔ Step 3
Conduct Risk Assessment

Step 5
Conclusions and Recommendations

- A resulting Risk score is established.
  - R = >10 — Low Risk (grey)
  - R = 10 – 19 — Medium Risk (yellow)
  - R = 20 – 25 — High Risk (red)

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

Risk Thresholds can be adjusted based on risk tolerance

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GROUP EXERCISE 2 - RISK ASSESSMENT FOR SCENARIO A

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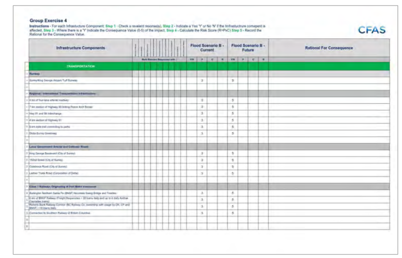
Group Exercise 2 - Risk Assessment For Scenario A

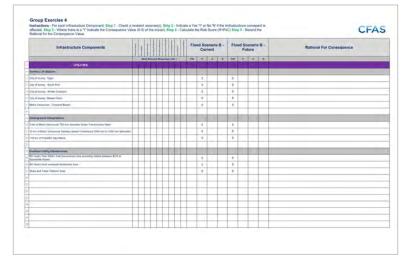
- For **Flood Scenario A, Coastal Flood with Dyke Breach,** complete the risk assessment. Discuss and record the Rational for the Consequence Score Selected.

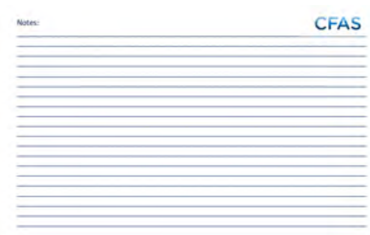
- Table Facilitator will record on comments on their worksheet

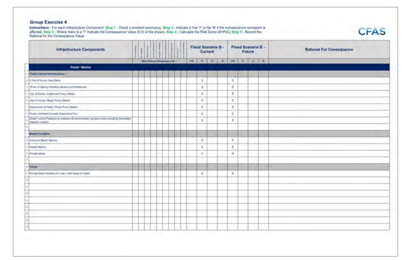
- Please write down your Scores and comments into the workbook

  - Table Discussion (80 min)
  - Group Discussion (15 min)









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Group Exercise 2 - Risk Assessment For Scenario A

- Step 1
  - Check a relevant response(s)

Structural Design	Serviceability	Water Resources	Operations & Maintenance	Emergency Response	Insurance Considerations	Policy Considerations	Social Effects	Environmental Effects
Mark Relevant Responses with ✓								

Infrastructure Components	Structural Design	Serviceability	Water Resources	Operations & Maintenance	Emergency Response	Insurance Considerations	Policy Considerations	Social Effects	Environmental Effects	Flood Scenario A - Current				Flood Scenario A - Future				Rational For Consequence
	Mark Relevant Responses with ✓									Y/N	P	C	R	Y/N	P	C	R	
UTILITIES																		
Sanitary Lift Stations																		
City of Surrey: Elgin											4				5			
City of Surrey: South Port	✓		✓	✓		✓		✓		Y	4	4	16	Y	5	4	20	
City of Surrey: Winter Crescent											4				5			
City of Surrey: Stewart Farm											4				5			
Metro Vancouver: Crescent Beach											4				5			

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Group Exercise 2 - Risk Assessment For Scenario A

- Step 2
  - Indicate a Yes 'Y' or No 'N' if the Infrastructure component is affected

Flood Scenario A - Current			
Y/N	P	C	R

Infrastructure Components	Structural Design	Serviceability	Water Resources	Operations & Maintenance	Emergency Response	Insurance Considerations	Policy Considerations	Social Effects	Environmental Effects	Flood Scenario A - Current				Flood Scenario A - Future				Rational For Consequence
	Mark Relevant Responses with ✓									Y/N	P	C	R	Y/N	P	C	R	
UTILITIES																		
Sanitary Lift Stations																		
City of Surrey: Elgin											4				5			
City of Surrey: South Port	✓		✓	✓		✓		✓		Y	4	4	16	Y	5	4	20	
City of Surrey: Winter Crescent											4				5			
City of Surrey: Stewart Farm											4				5			
Metro Vancouver: Crescent Beach											4				5			

Group Exercise 2 - Risk Assessment For Scenario A

- Step 3
  - Where there is a 'Y' Indicate the Consequence Value (0-5) of the impact

Score	Consequence
	Method D
0	No Effect
1	Insignificant
2	Minor
3	Moderate
4	Major
5	Catstrophic

Infrastructure Components	Structural Design	Serviceability	Water Resources	Operations & Maintenance	Emergency Response	Insurance Considerations	Policy Considerations	Social Effects	Environmental Effects	Flood Scenario A - Current				Flood Scenario A - Future				Rational For Consequence
	Mark Relevant Responses with ✓									Y/N	P	C	R	Y/N	P	C	R	
UTILITIES																		
Sanitary Lift Stations																		
City of Surrey: Elgin											4				5			
City of Surrey: South Port	✓		✓	✓		✓		✓		Y	4	4	16	Y	5	4	20	
City of Surrey: Winter Crescent											4				5			
City of Surrey: Stewart Farm											4				5			
Metro Vancouver: Crescent Beach											4				5			

Group Exercise 2 - Risk Assessment For Scenario A

- Step 4
  - Calculate the Risk Score R=PxC
- Step 5
  - Record the Rational for the Consequence Value

Infrastructure Components	Structural Design	Serviceability	Water Resources	Operations & Maintenance	Emergency Response	Insurance Considerations	Policy Considerations	Social Effects	Environmental Effects	Flood Scenario A - Current				Flood Scenario A - Future				Rational For Consequence
	Mark Relevant Responses with ✓									Y/N	P	C	R	Y/N	P	C	R	
UTILITIES																		
Sanitary Lift Stations																		
City of Surrey: Elgin											4				5			
City of Surrey: South Port	✓		✓	✓		✓		✓		Y	4	4	16	Y	5	4	20	
City of Surrey: Winter Crescent											4				5			
City of Surrey: Stewart Farm											4				5			
Metro Vancouver: Crescent Beach											4				5			

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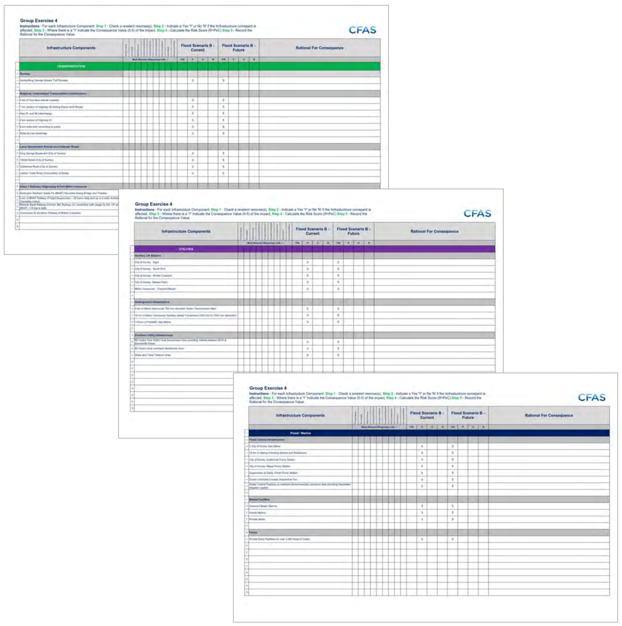
Group Exercise 2 - Risk Assessment For Scenario A

- Group Discussion



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FLOOD SCENARIO B - RIVERINE FLOOD - CURRENT AND FUTURE

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SURREY COASTAL FLOOD ADAPTATION STRATEGY (CFAS)

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Riverine Flooding - Scenario B

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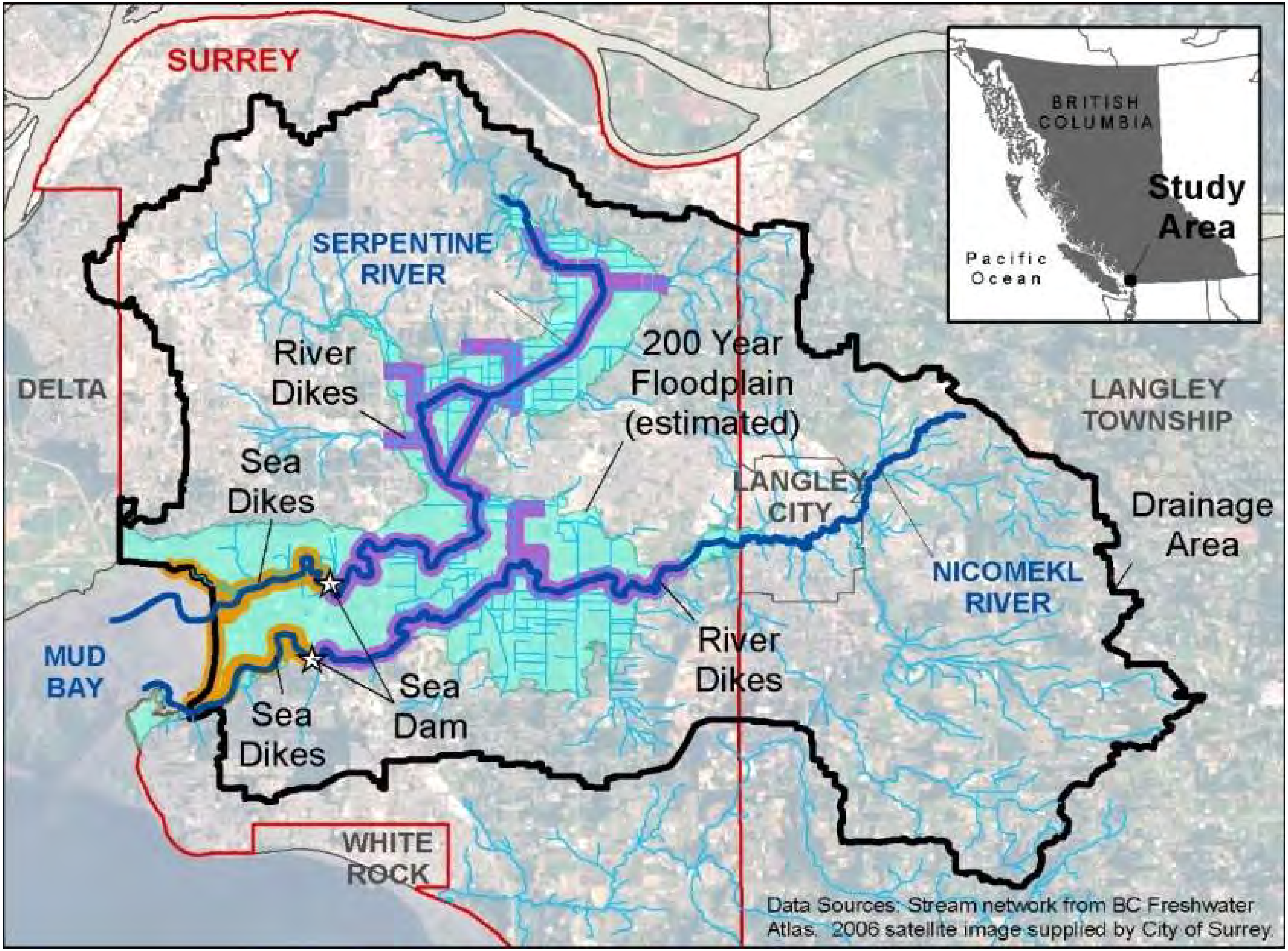
Presentation Outline

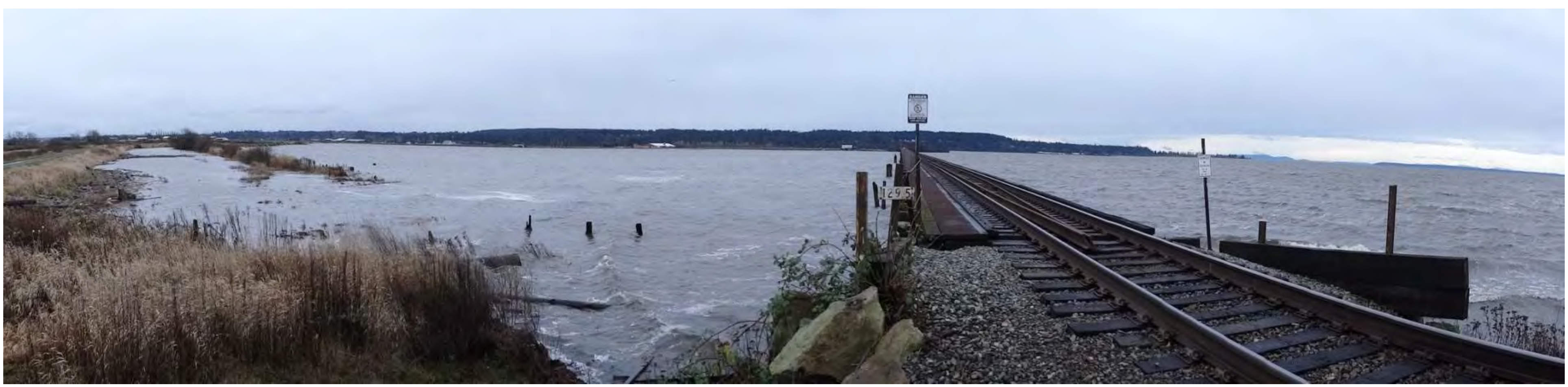
- Additional background information
- Present and future floods
- Study limitations


SURREY
BRITISH COLUMBIA
Study Area
Pacific Ocean
SERPENTINE RIVER
200 Year Floodplain (estimated)
River Dikes
DELTA
LANGLEY TOWNSHIP
Sea Dikes
LANGLEY CITY
Drainage Area
NICOMEKL RIVER
MUD BAY
River Dikes
Sea Dam
Sea Dikes
WHITE ROCK
Data Sources: Stream network from BC Freshwater Atlas. 2006 satellite image supplied by City of Surrey.

Flood Hazards

- Coastal:
  - High tides
  - Storm surge
  - Wind + wave setup

- Riverine:
  - Heavy precipitation
  - Rain on snow, snow melt
  - Long-duration relatively high tides



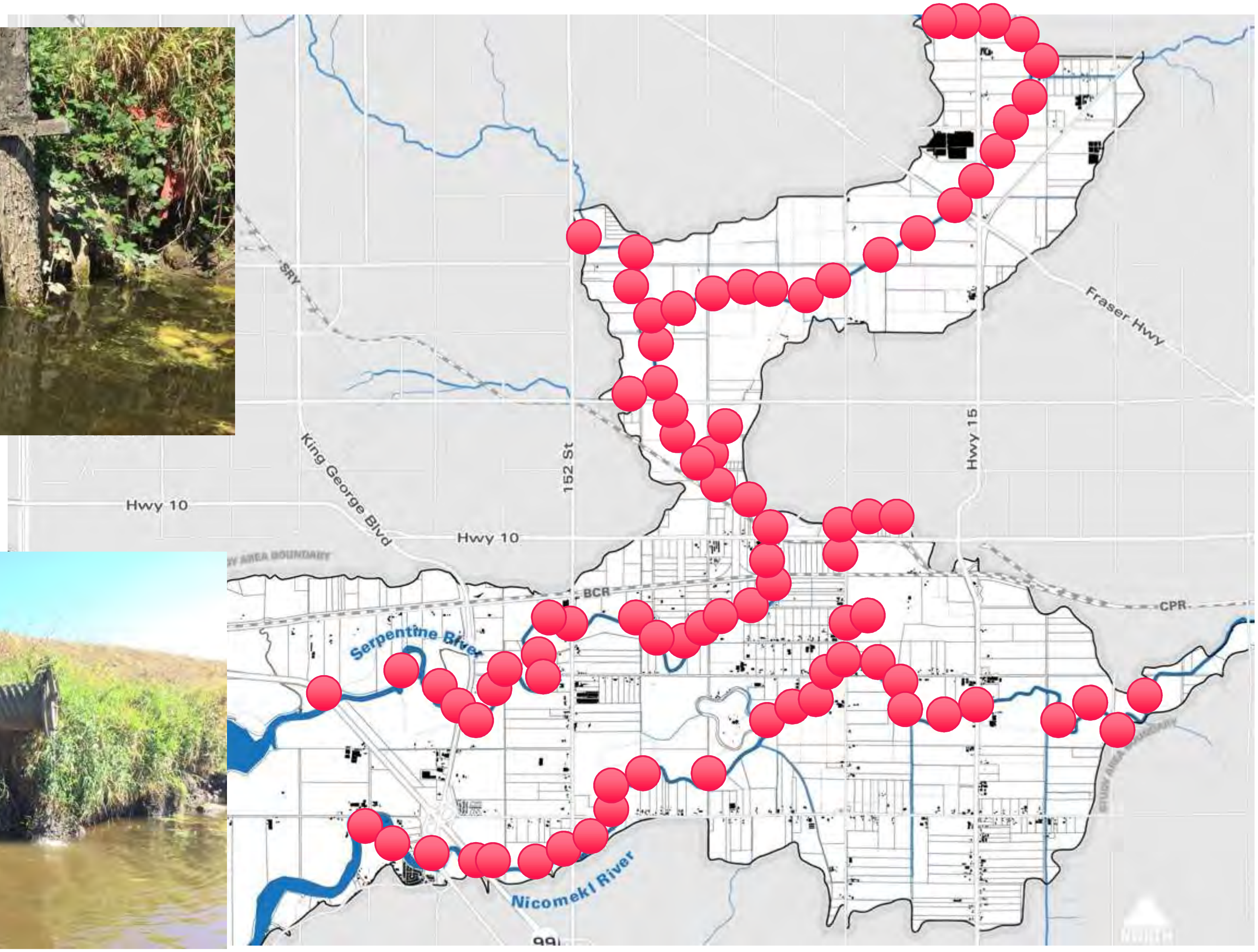
Flood Infrastructure

- Coastal:
  - ➢ Sea dikes & sea dams

Note: Dikes are assumed raised to contain the 200-year flood!

- Riverine:
  - ➢ River dikes with spillways, 200 flood-boxes, 30 pump-stations, complex network of flow storage areas, canals, ditches and culverts

Floodboxes



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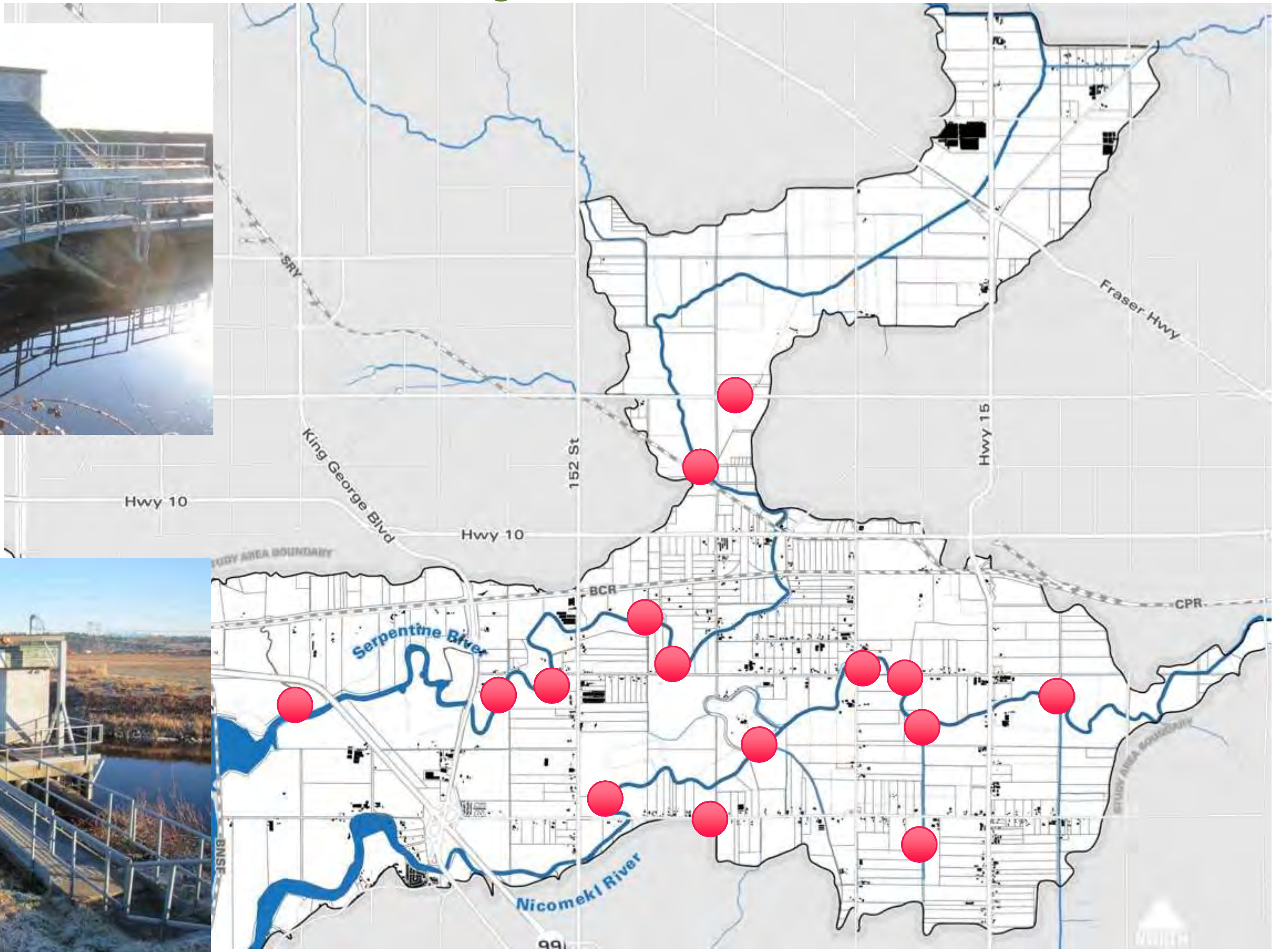
Pumps



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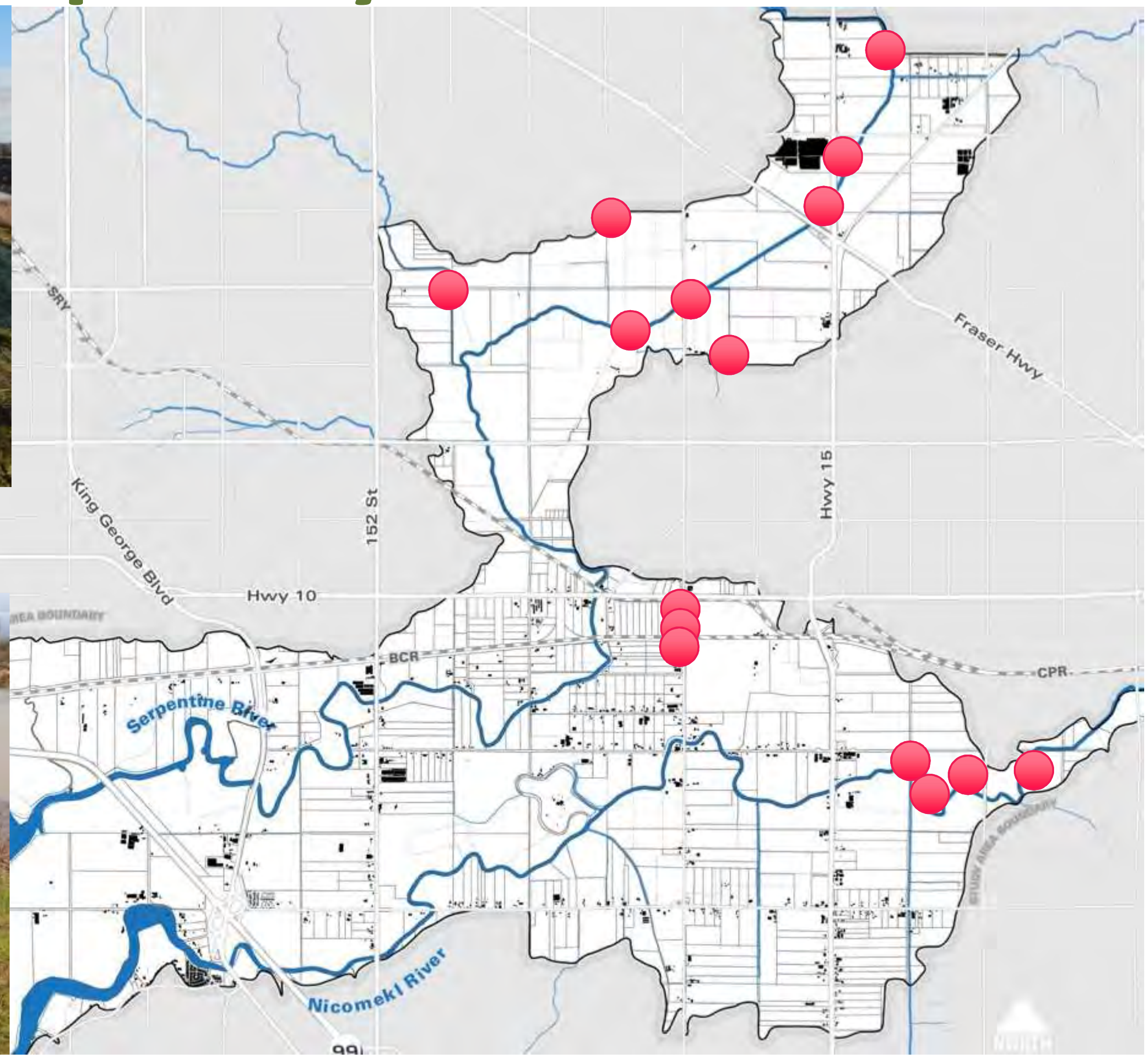
Spillways



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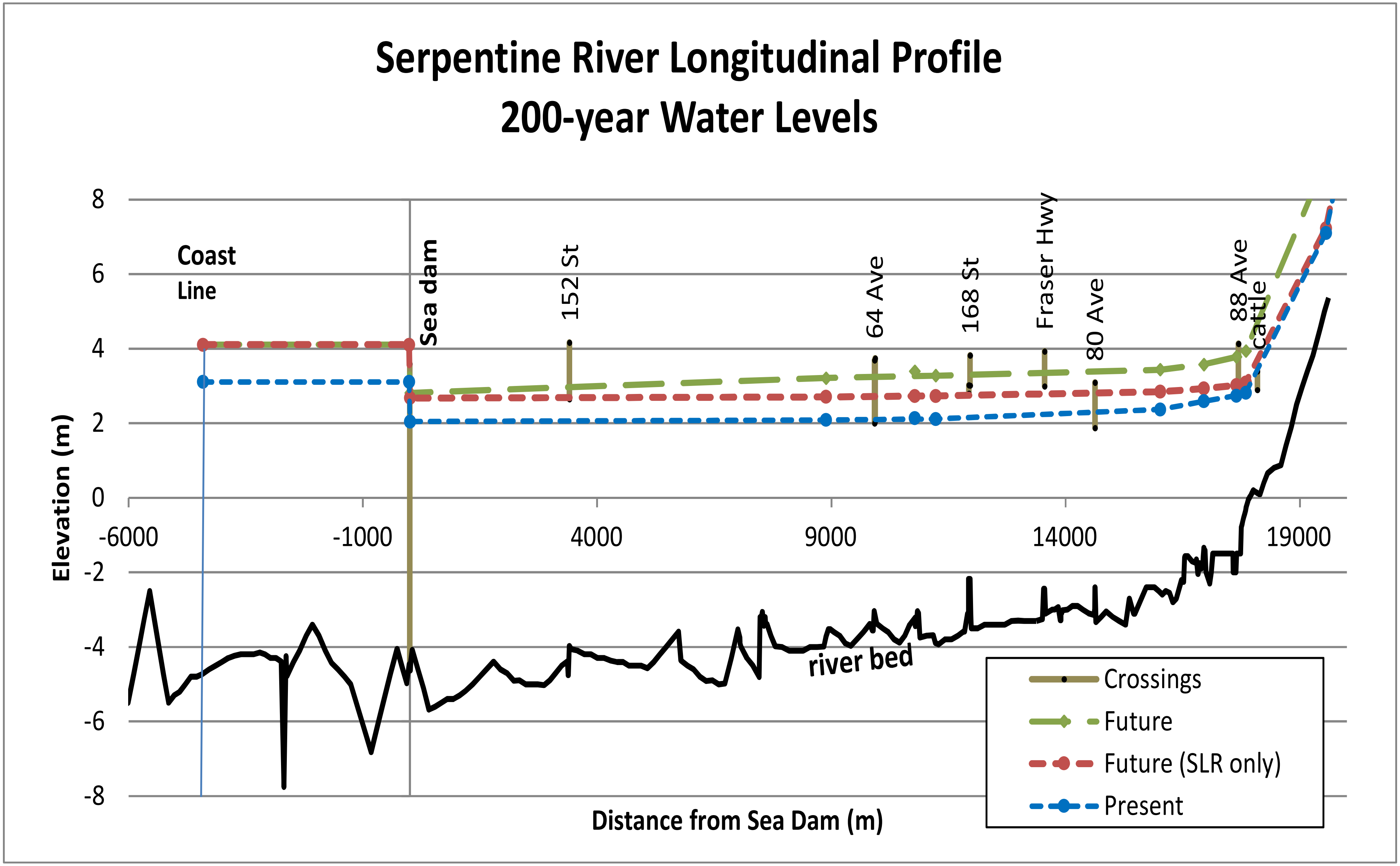
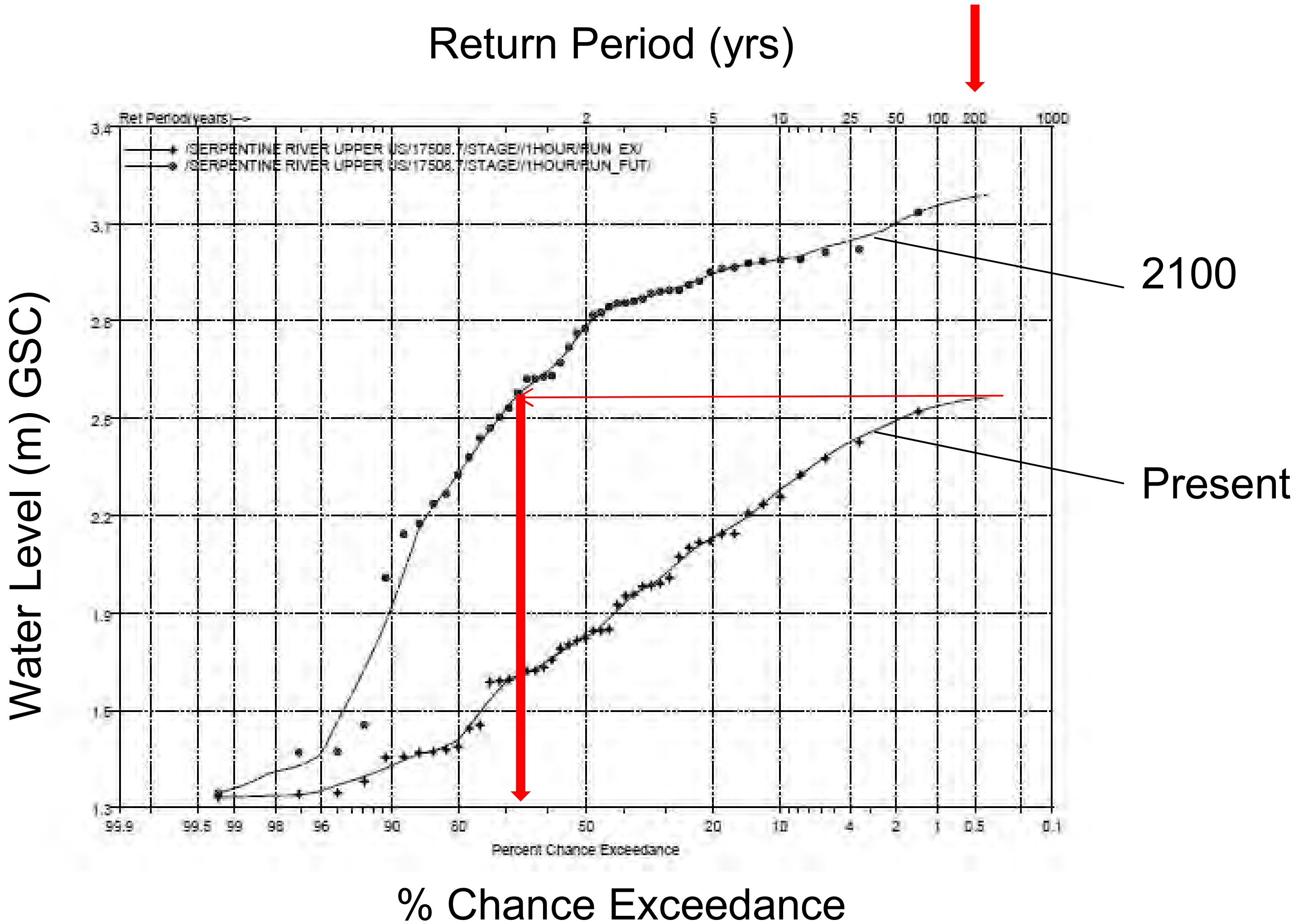
Water surface profiles



Change in return periods



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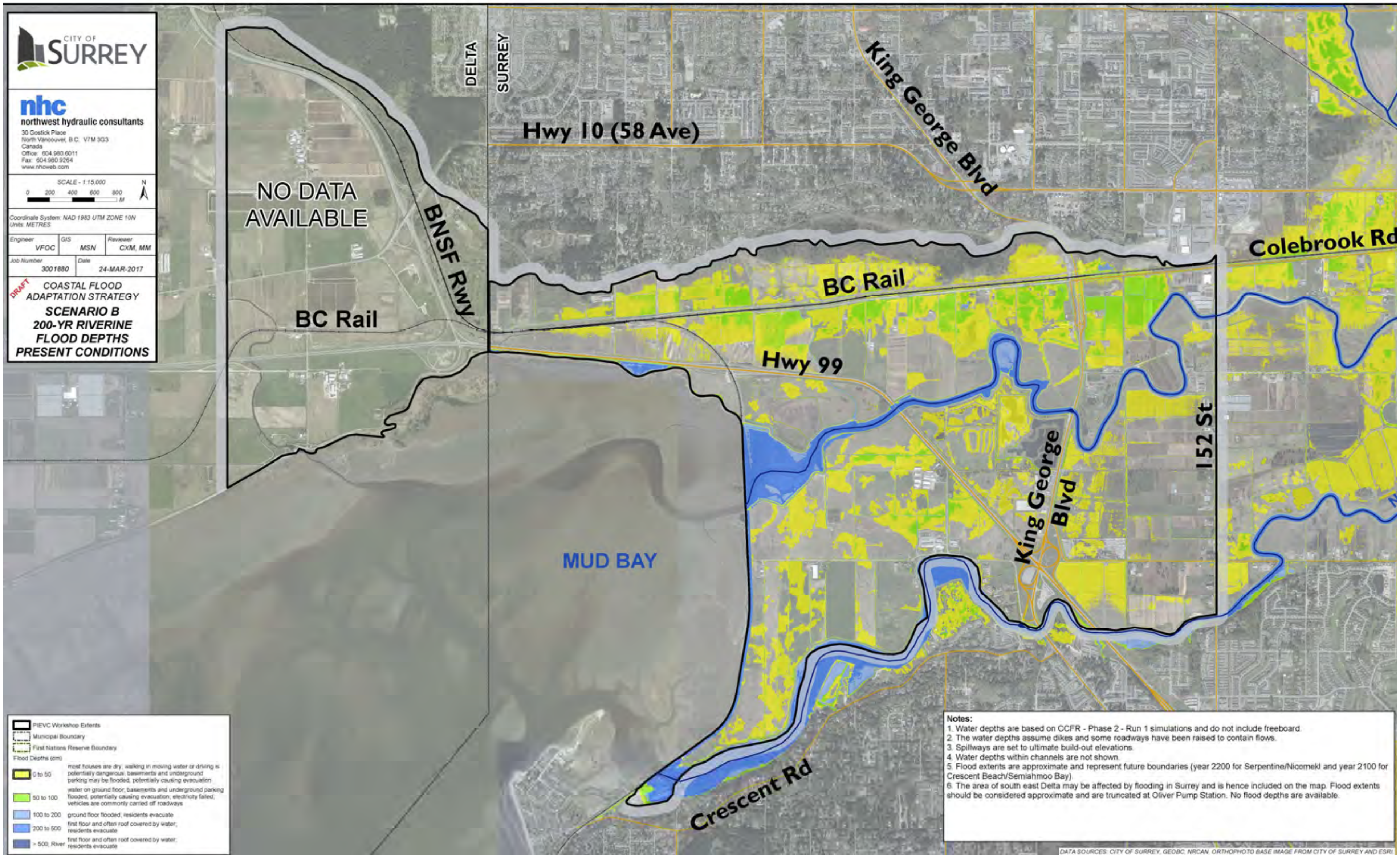
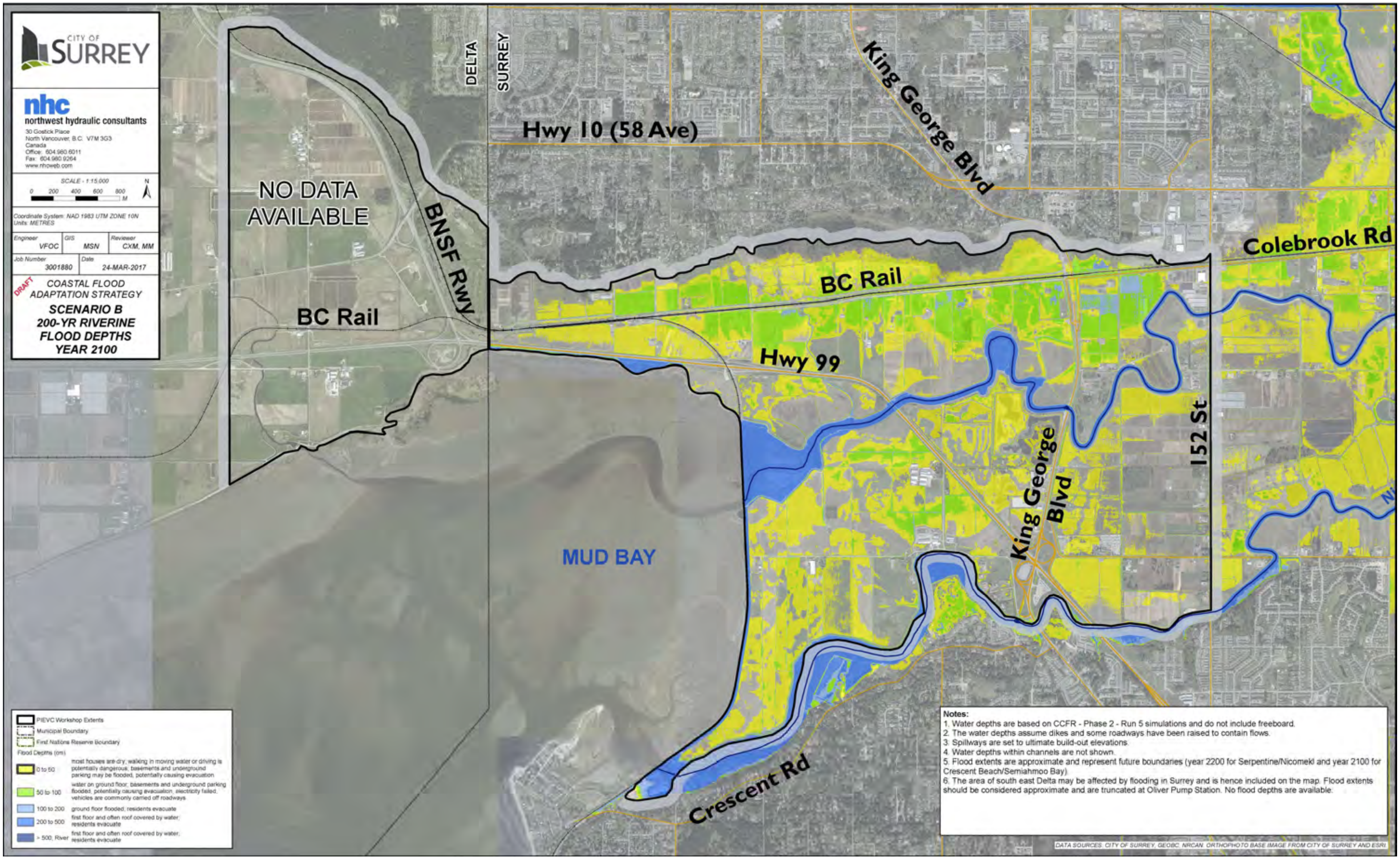
Scenario B - Present



Scenario B – Year 2100



Limitations

- Uncertainty in SLR projections
- Precipitation increases not accounted for in Scenario B
- Dykes assumed to be raised
- Sea dams assumed to be functional in 2100
- “Do nothing” approach = back to salt marshes of 1800’s

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SURREY COASTAL FLOOD ADAPTATION STRATEGY (CFAS)

Presented by: Monica Mannerstrom
mmannerstrom@nhcweb.com

nhc northwest hydraulic consultants

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GROUP EXERCISE 3 - DISCUSS IMPACTS FROM FLOOD SCENARIO B

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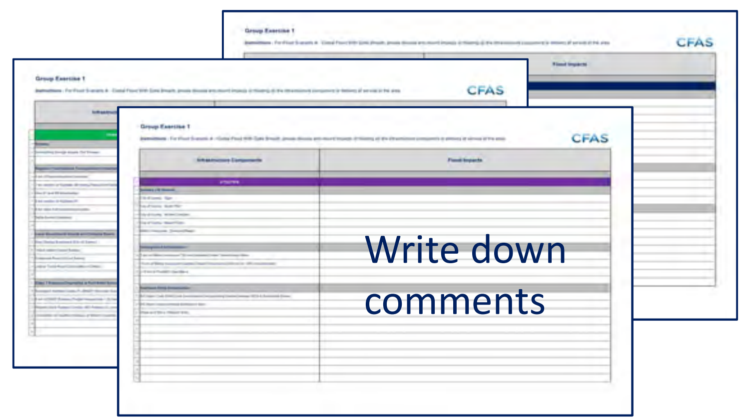
Group Exercise 3 - Impacts From Flood Scenario B

- For **Flood Scenario B, Riverine Flood,** please discuss and record impacts of flooding on the infrastructure components or delivery of services in the area.

- Table Facilitator will record on comments flip chart.

- Please write down your comments into the workbook
  - Table Discussion (15 min)
  - Group Discussion (10 min)



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Group Exercise 3 - Impacts From Flood Scenario B

	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*

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GROUP EXERCISE 4 - RISK ASSESSMENT FOR SCENARIO B

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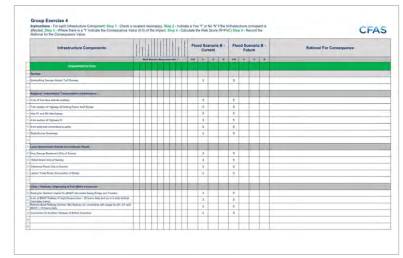
Group Exercise 4 - Risk Assessment For Scenario B

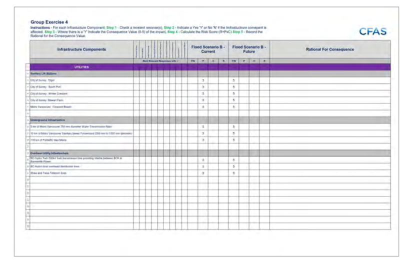
- For **Flood Scenario B, Riverine Flood,** complete the risk assessment. Discuss and record the Rational for the Consequence Score Selected.

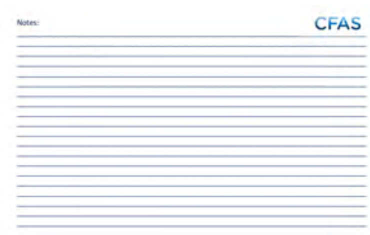
- Table Facilitator will record on comments on their worksheet

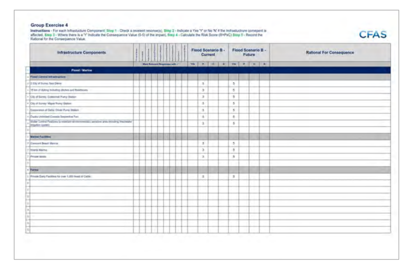
- Please write down your Scores and comments into the workbook

  – Table Discussion (45 min)
  – Group Discussion (10 min)









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Group Exercise 4 - Risk Assessment For Scenario B

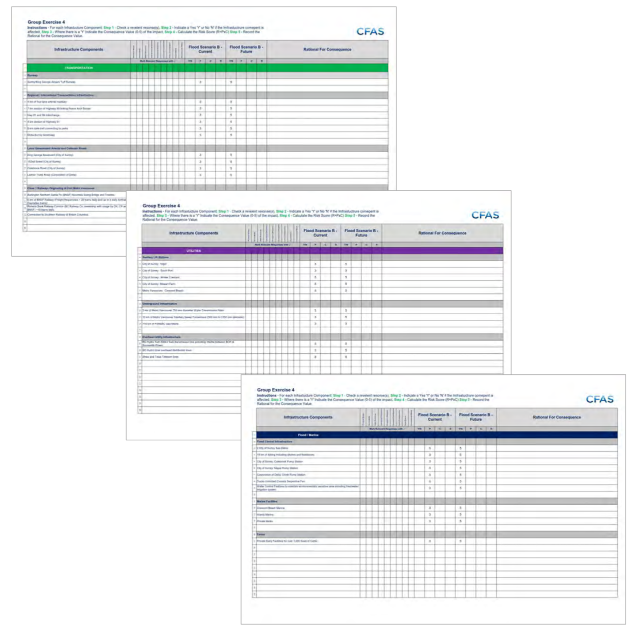
- Group Discussion

Reference and Resources for Exercises

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

Score	Probability
	Method A
0	Negligible Not Applicable
1	Highly Unlikely Improbable
2	Remotely Possible
3	Possible Occasional
4	Somewhat Likely Normal
5	Likely Frequent

Score	Consequence
	Method D
0	No Effect
1	Insignificant
2	Minor
3	Moderate
4	Major
5	Catstrophic



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ADAPTATION BACKGROUND

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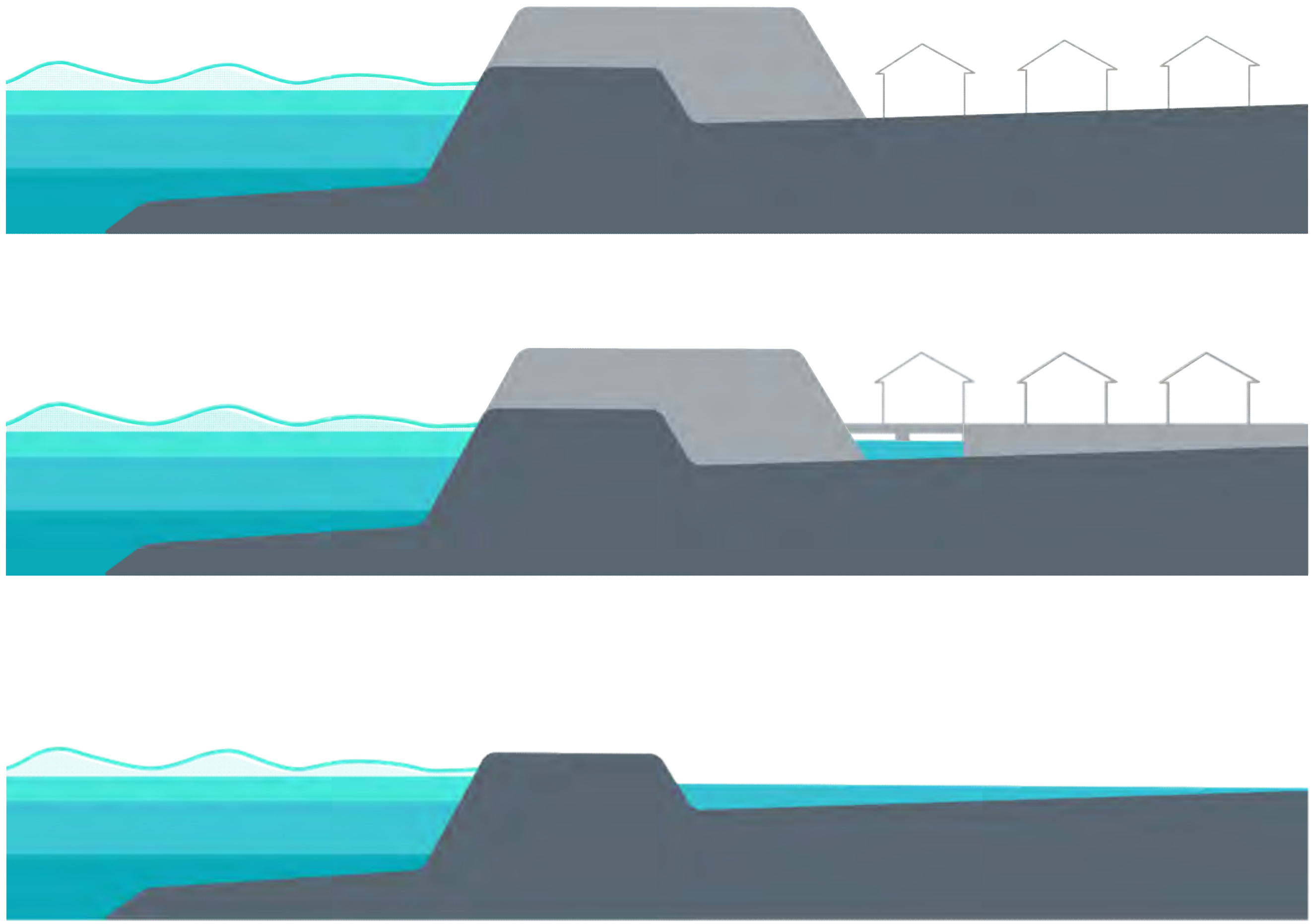
Adaptation Approaches



Protect

Accommodate

Combination

Retreat

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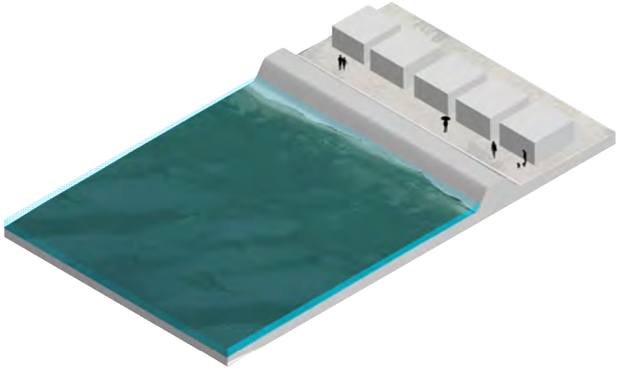
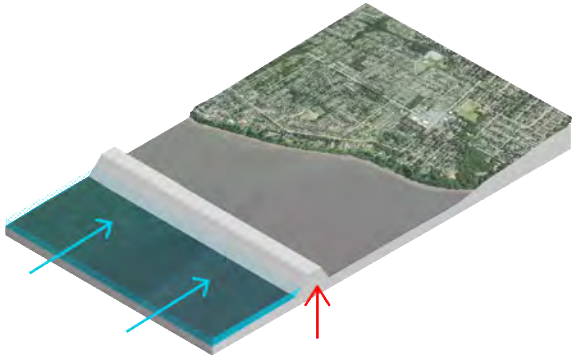
Protect



Raise Coastal and River Dykes

Offshore Barrier Islands



Offshore Sea Barrier

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Protect Considerations

Protect Scale

Colebrook West Dyke

2015 vs 2100 Coastal Impacts

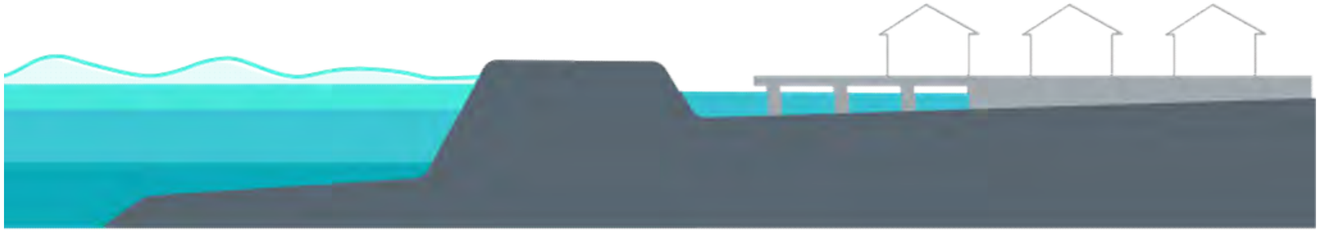
Exposed area of the Serpentine River

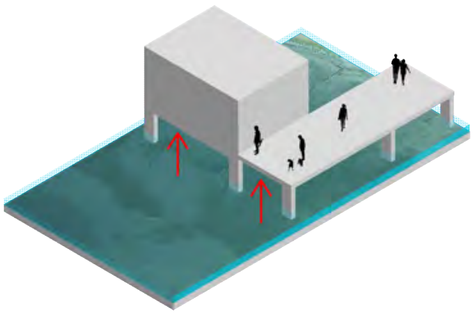
- Existing DCE = 3.15m (nominal)
- Target 2015 DCE = 3.87m
- Target 2100 DCE = 6.76m


Breakwater or Jetty
Offshore Islands

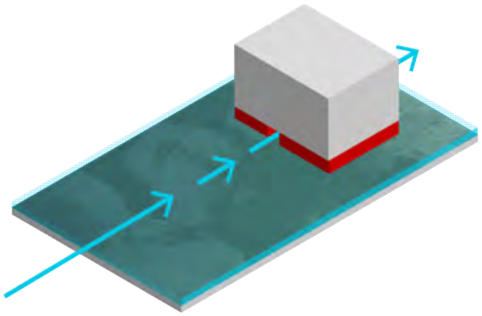
Source: http://www.industrytap.com/the-great-wall-of-louisiana/677

Accommodate

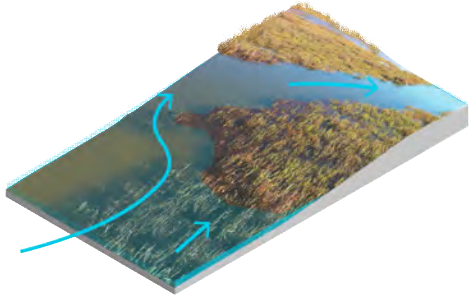




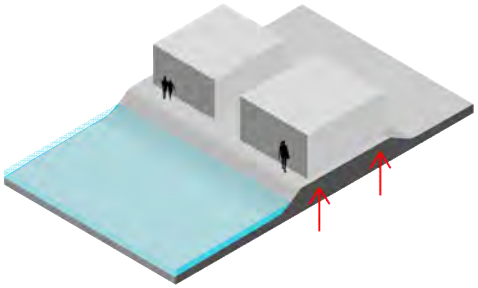
Raised Structures



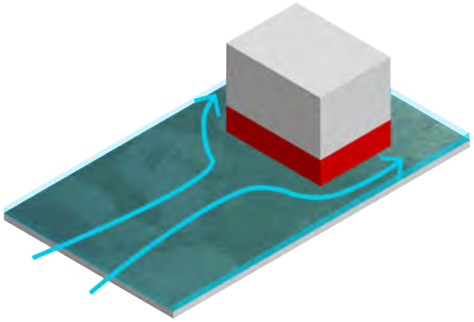
Wet Proofing



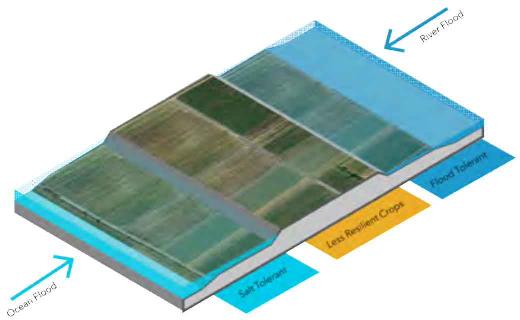
Wetland Restoration



Build on Fill



Dry Proofing



Crop Reorganization

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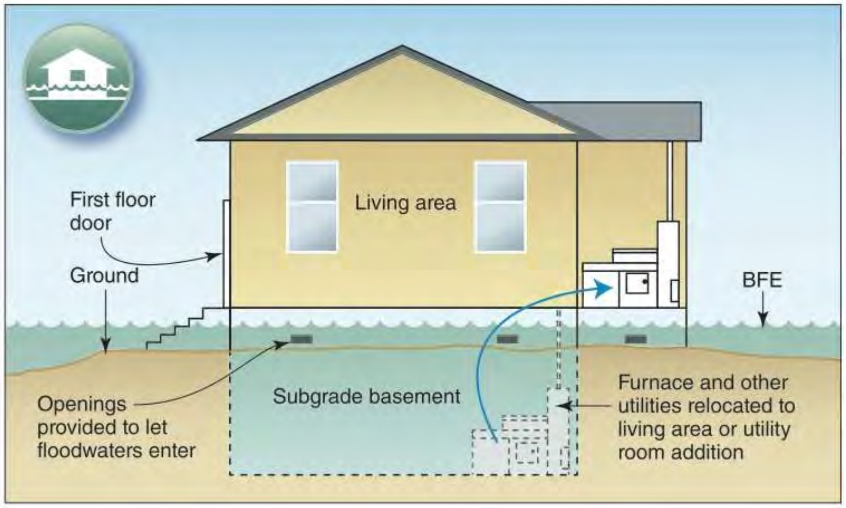
Housing on pile foundations in Rotterdam

http://frameworks.ced.berkeley.edu/2015/a-modest-proposal-adapting-to-sea-level-rise/

Coastal marsh restoration

https://blog.savesfbay.org/2014/04/climate-report-supports-wetland-restoration-as-sea-level-rise-adaptation-strategy/



Wet Proofing Strategies

http://cnycn.org/2014/10/coping-with-big-flood-insurance-changes-in-nyc-part-iv-mitigation/

Accommodate Considerations

1968 Halls Prairie Original Pump Station Constructed
1980 Station replaced to meet ARDSA
2017 Station upgraded to achieve base flow requirements

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Panorama Pump Station Upgrades

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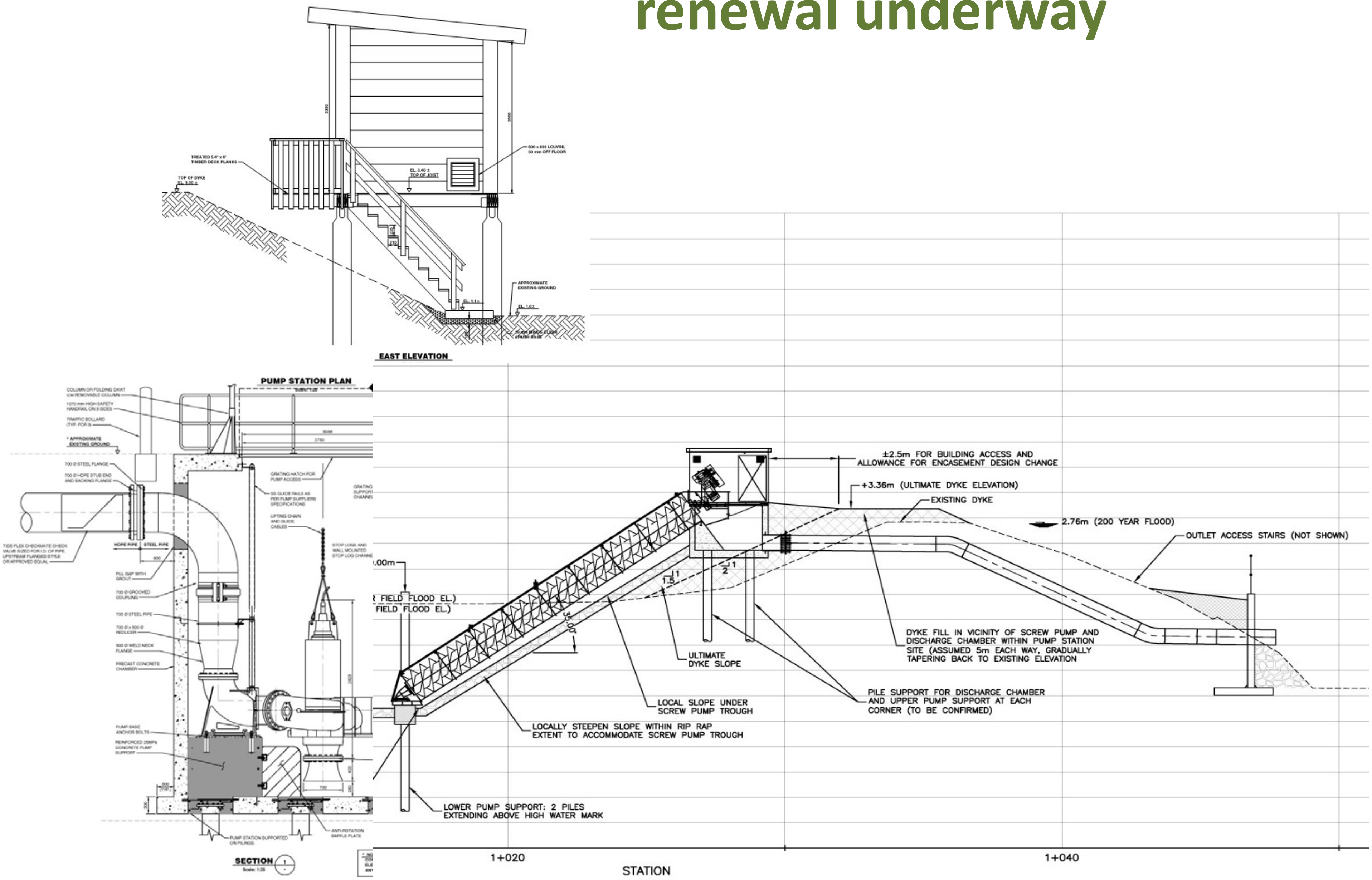
New approaches to infrastructure renewal underway



4 - Forebay General

- Design with flexibility:
  - Higher discharge levels
  - Lower intake levels
  - Situate electrical components above Flood Level
  - Seismic Resistance
  - Provision for Backup Power

Provisions to allow future maintenance under higher water levels

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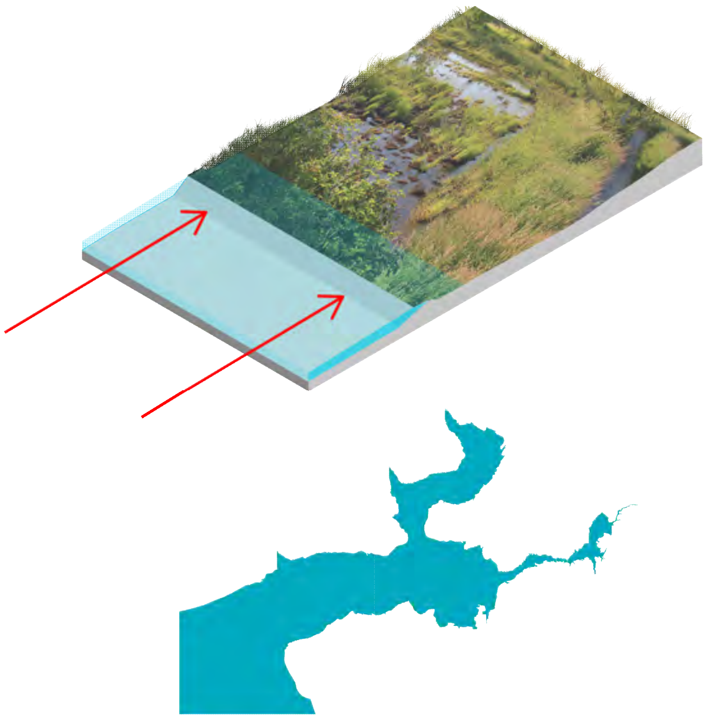
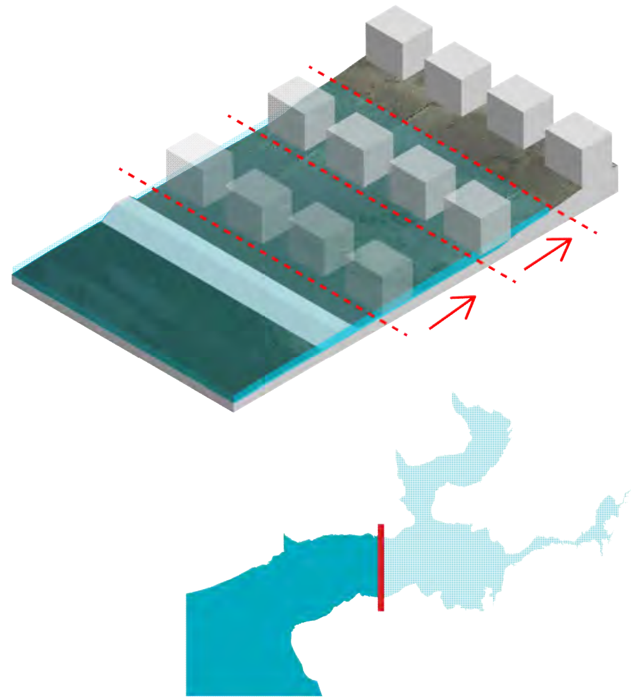
Retreat



Complete Retreat



Managed Retreat

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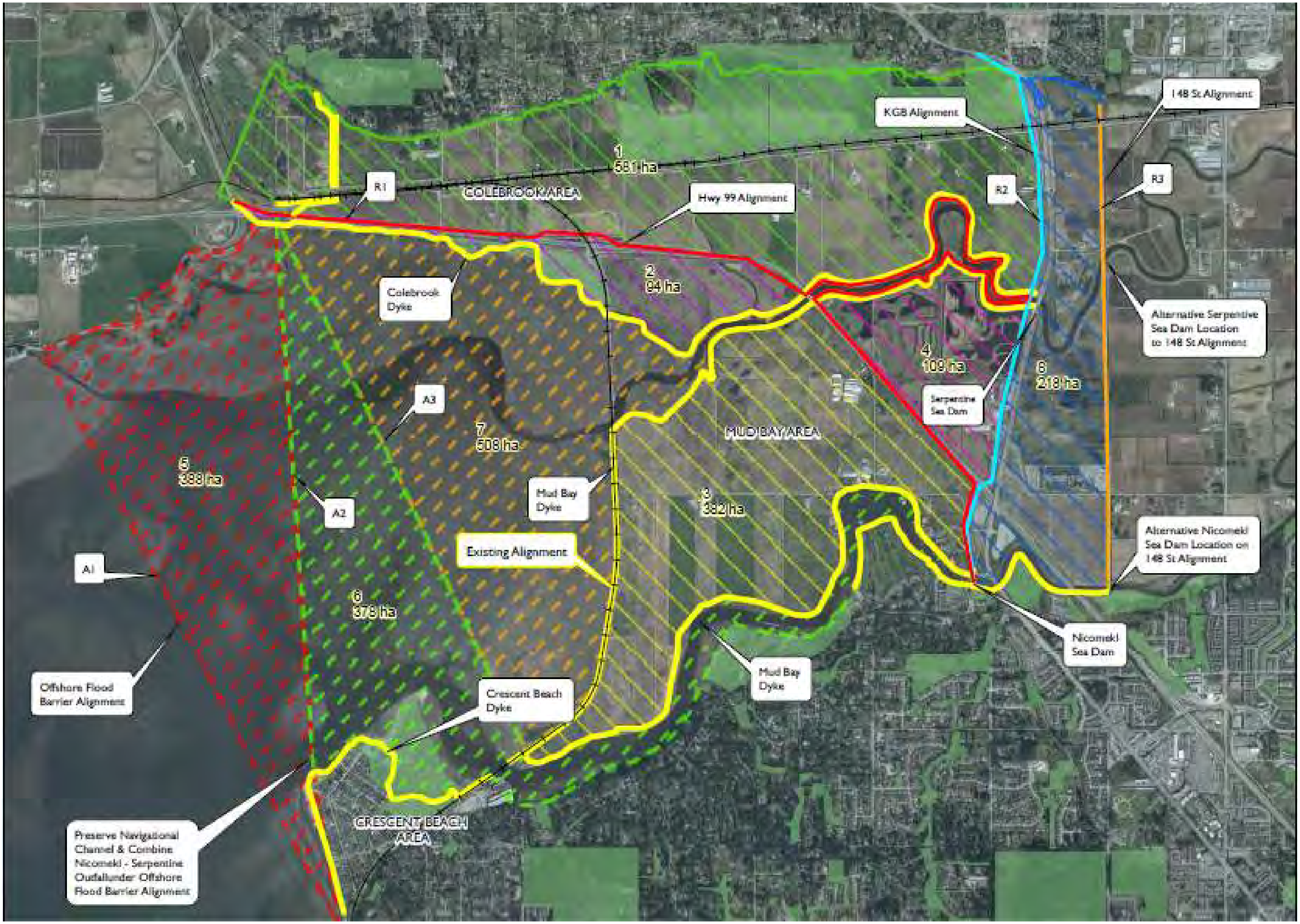

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Retreat at Abbotts Hall Farm, Essex UK

http://factfile.org/8-facts-about-abbotts-hall-farm

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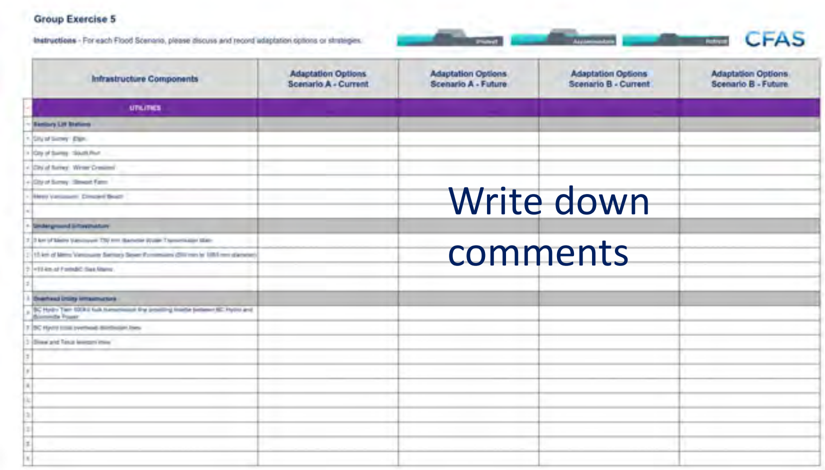
GROUP EXERCISE 5 - ADAPTATION OPTIONS

Group Exercise 5 - Adaptation Options

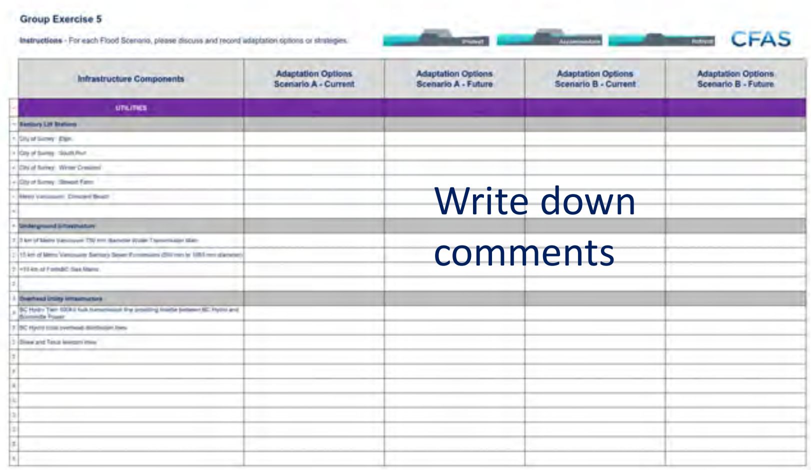
- For **Flood Scenarios A and B,** please discuss and record adaptation options and strategies for each Infrastructure Component
- Table Facilitator will record on comments flip chart.
- Please write down your comments into the workbook
  - Table Discussion (45 min)
  - Group Discussion (15 min)



Group Exercise 5 - Adaptation Options

- For **Flood Scenarios A and B,** please discuss and record adaptation options and strategies for each Infrastructure Component

- **Group questions**
  - What adaptation actions could be pursued to address identified concerns?
  - Which option would you pursue first? Why? In 20 years? in 50 years? In 80 years?
  - How well does the action respond to the top concerns identified by group?



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CLOSING REMARKS AND NEXT STEPS

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CFAS Next Steps

- Collect the workbooks and notes
- Compile the comments of the PIEVC workshop and complete the workshop report
  - Receive comments from City and Assessment Team
- Use the results to inform next steps of the CFAS project.
  - Adaptation Options

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CFAS Engagement

Three primary avenues for participation:

1. **Project Committees and Working Groups**
    - Steering Committee
    - Advisory Group
2. **Existing City Committees and Stakeholder Groups**
    - Involving existing City committees and stakeholder working groups
3. **General Engagement and Outreach**
    - General outreach activities & events

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Advisory Group

- **Membership**
  - Representatives from key partner and stakeholder organizations and agencies
  - Depending on interest and need, themed sub-group meetings and workshops may be organized
  - Some groups may be more involved in later phases of project
- **Role**
  - Project input and participation in decision process

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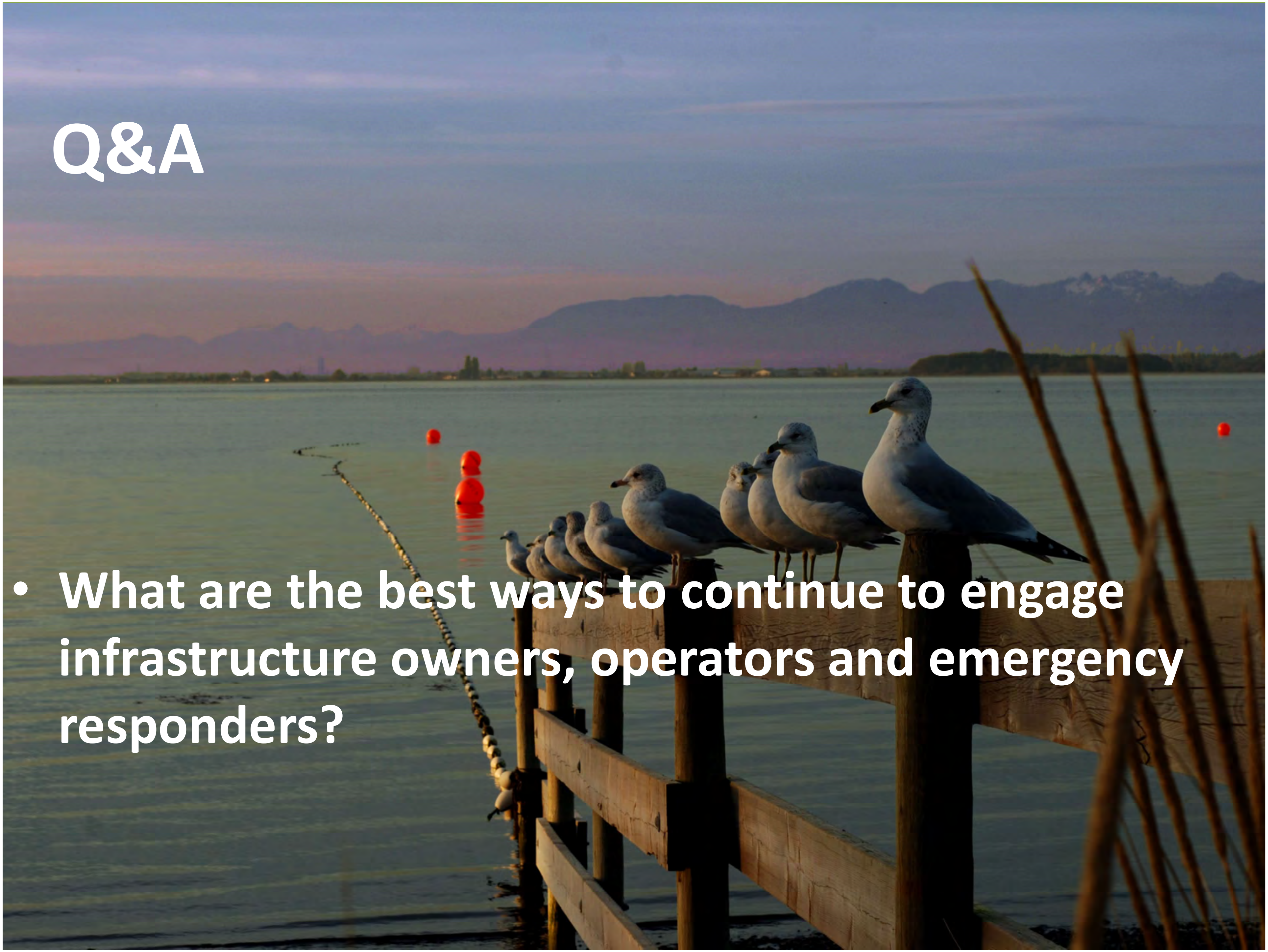
Q&A



- **What are the best ways to continue to engage infrastructure owners, operators and emergency responders?**

More information?

www.surrey.ca/coastal

coastal@surrey.ca

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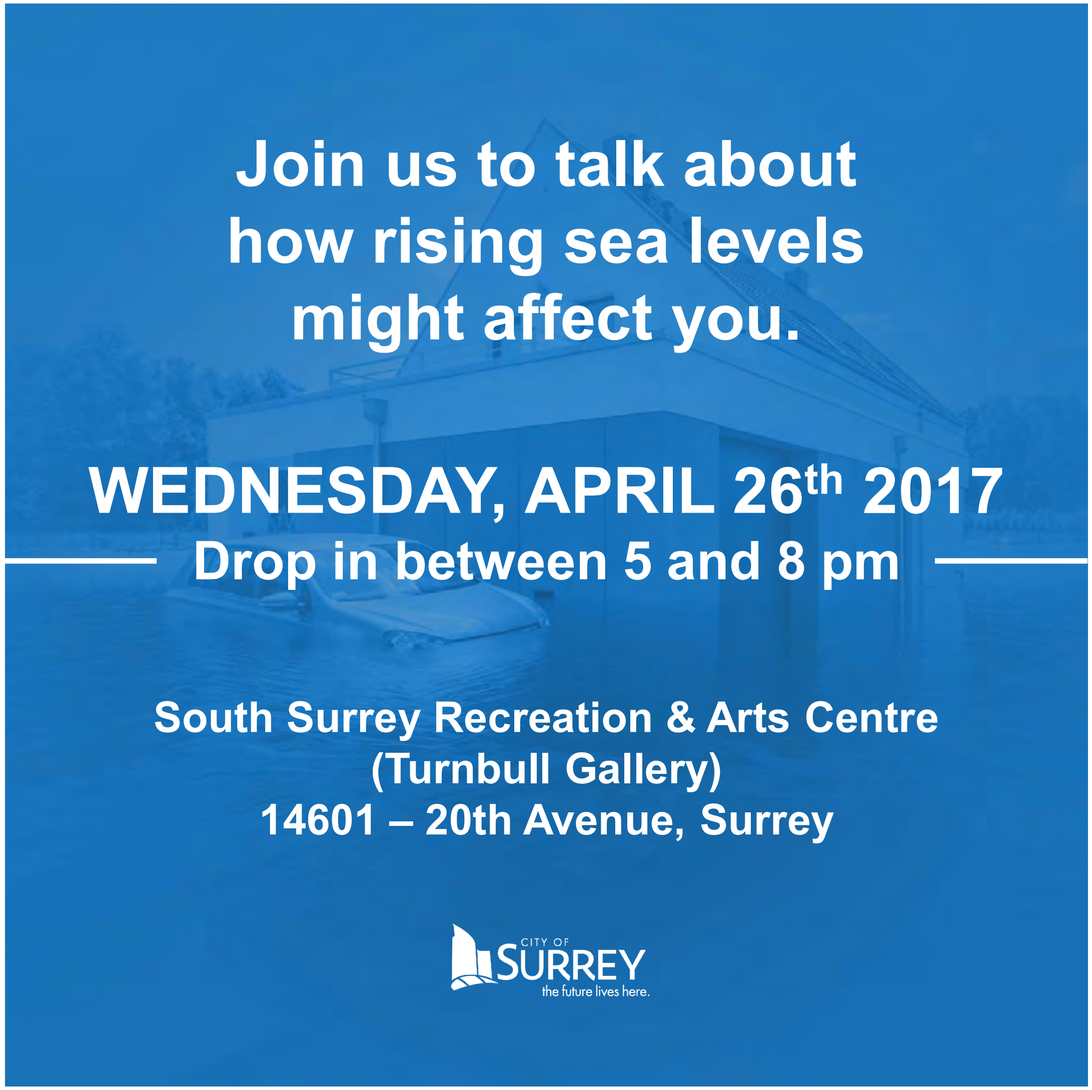

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SURREY COASTAL FLOOD ADAPTATION STRATEGY (CFAS)

Infrastructure Asset Managers, Operators and Emergency Services Stakeholders

PIEVC Workshop

Thank you!

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