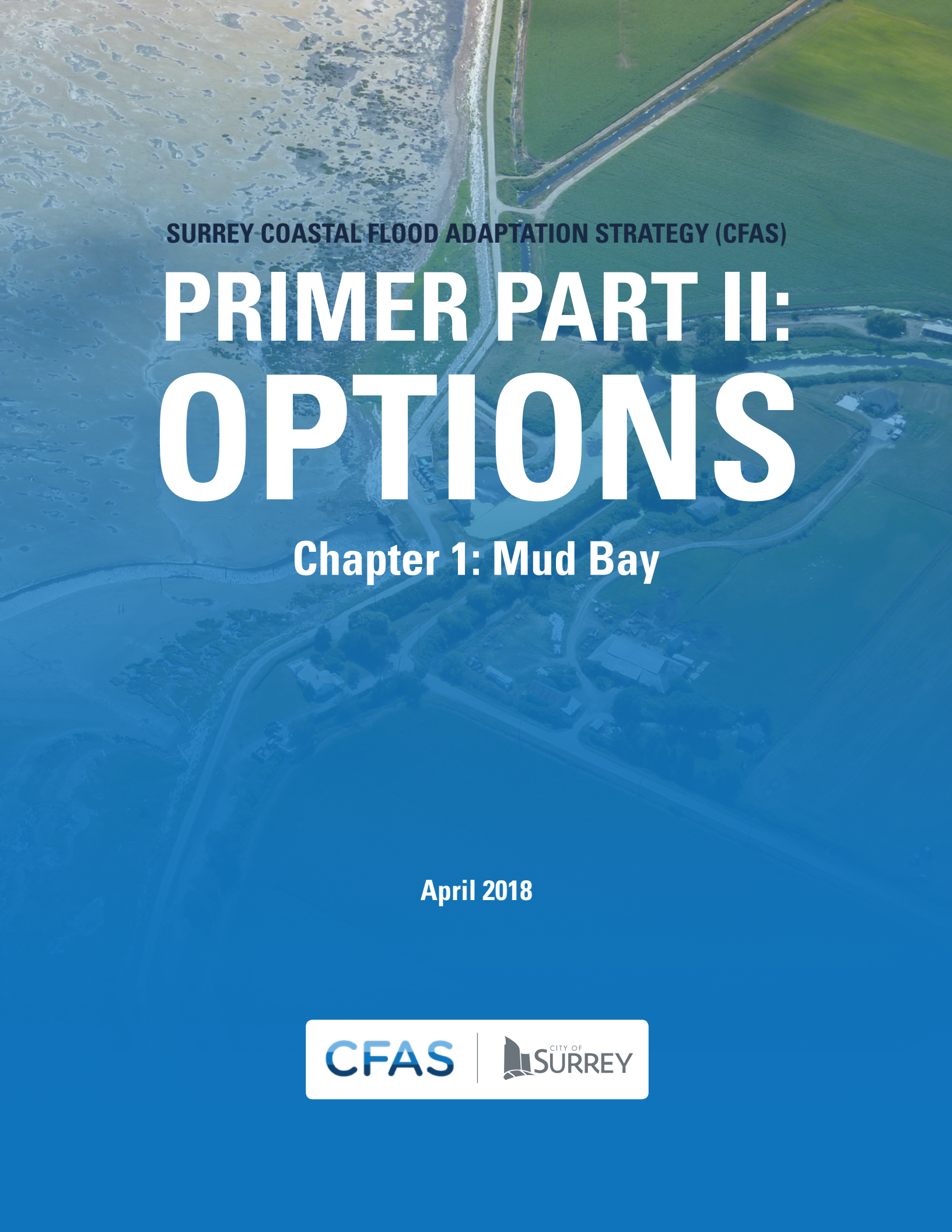


SURREY COASTAL FLOOD ADAPTATION STRATEGY (CFAS)

PRIMER PART II: OPTIONS

Chapter 1: Mud Bay

April 2018

CFAS | CITY OF SURREY

PRELIMINARY OPTIONS PRIMER

SURREY COASTAL FLOOD ADAPTATION STRATEGY (CFAS)

Climate change is driving some big changes on Surrey's coastline. Our changing climate means that the historic controls that have been put in place to limit flood damages will be ineffective in limiting future flood damage as sea levels continue to rise. In the short-term, we can expect more nuisance flooding and more frequent and severe flooding from storm surges, while over the longer-term we can expect even greater challenges.

To help prepare Surrey for a changing climate and help make our coastal communities more resilient, we are developing a Coastal Flood Adaptation Strategy (CFAS). To be completed in late 2018, the final strategy will outline the potential future impacts of climate change on Surrey's coastline and the best adaptation options available to address them over the short-, medium, and longer-terms.

Launched in 2016, the project is taking a community-based, participatory approach and engaging residents, stakeholders, and other partners in the project, including First Nations, community and environmental organizations, business associations and groups, senior governments, farmers and the agricultural community, and neighbouring jurisdictions.

For more information about CFAS and flooding risk in Surrey's coastal areas see Primer Part I: Coastal Flooding in Surrey www.surrey.ca/files/CFAS-primerpart1.pdf.

FLOOD ADAPTATION OPTIONS EVALUATION

This Options Primer presents 11 shortlisted coastal flood adaptation options developed for the three CFAS study areas — Mud Bay (Chapter 1), Crescent Beach (Chapter 2), and Semiahmoo Bay (Chapter 3). The options were developed and shortlisted through extensive community consultation, technical analysis from project engineers and City of Surrey staff, and with input through a partnership with UBC and Dutch landscape architects and engineers.

The Options Primer provides a short summary description of each option. Images of similar adaptation approaches from other areas and jurisdictions are provided along with a sketch plan of the option that illustrates potential conditions in 2100, which is when sea levels are projected to have risen by 1 metre.

For each study area, a summary Technical Overview is provided that highlights the technical merits of the options. For each option, the following information is provided:

INFRASTRUCTURE, EARTHQUAKE & LANDUSE CHANGES & DESIGN: a summary of how each option impacts the following:

- ***Reduction in dyking:*** length of river and coastal dykes that can be decommissioned over time
- ***New dyke:*** length of new river and coastal dykes required
- ***Changes to sea dams:*** replacement, decommissioning or relocation needs for existing sea dams
- ***Earthquake design:*** option performance in an earthquake event
- ***Re-purposed land:*** land area where the current land uses would change from existing uses
- ***Relocated roads and rail lines:*** the primary transportation corridors that would need to be raised, relocated, or otherwise adapt
- ***Runoff management:*** option ability to address river flooding

VALUES ASSESMENT: a summary of how each option performs against seven "values criteria" that capture what people and partners in the study area care about most. The values were developed through an extensive engagement process in the winter and spring of 2017, which included: residential, agricultural and environmental stakeholder focus groups; a special workshop with infrastructure operators and owners; Semiahmoo First Nation; meetings with agriculture and environmental stakeholders (e.g., South Nicomekl Irrigation District, Friends of Semiahmoo Bay, Ducks Unlimited); outreach at community events like Surrey's Earth Day celebration (Party for the Planet); input from high school and elementary school students in the study area; an on-line survey using Surrey's CitySpeaks platform; and other outreach. The seven values criteria are:

- ***Residents:*** Number of people permanently displaced by the option and anticipated health and safety impacts
- ***Agriculture:*** Amount of agricultural land permanently lost due to the option
- ***Environment:*** Anticipated impact (positive and negative) to wetland habitats, freshwater fish habitat and riparian areas that could be expected from the option
- ***Infrastructure:*** Transportation and utilities service disruptions that could be expected from the option
- ***Economy:*** Permanent loss of businesses that could be expected from the option
- ***Recreation:*** The diversity of recreation opportunities (positive and negative) that could be expected from the option
- ***Culture:*** Semiahmoo First Nation cultural impacts that could be expected from the option

COST ASSESMENT: a high-level overview of the cost of implementing the option, including:

- ***Capital Cost:*** Capital infrastructure cost, estimated land purchasing costs, decommissioning existing infrastructure and land remediation costs
- ***Operation & Maintenance Cost:*** The yearly operations and maintenance costs
- ***Other Infrastructure Cost:*** The additional cost of adapting non-flood related infrastructure (e.g., roads & highways, hydro lines, water & sewage mains, etc.)
- ***Future Adaptation Cost:*** Estimated costs of continued adaptation requirements from both upgrading flood protection infrastructure beyond 1 metre of sea level rise and future replacement costs of aging flood protection infrastructure

IMPACT & RISK OF FAILURE: recognizing that all flood protection infrastructure carries some risk of failure, a description of the anticipated impacts to community values from a failure of an option's flood protection infrastructure is provided. To quantify this risk, the likelihood of a failure of an option to provide flood protection was assessed (see appendix) with the consequence that failure would have on identified community values. For each option, a detailed description of the anticipated impacts to community values is provided using a scale from Very Low to Very High.

- ***Impact of a Failure:*** A description of the consequences to a given value from a catastrophic flooding event due to the failure of the option to provide protection
- ***Likelihood of Failure of Option:*** Provides a summary evaluation of how likely the option is to fail in the future
- ***Risk:*** The combination of the likelihood that an option will fail with the impact its failure would have on the value
- ***Overall Risk:*** The overall risk across all identified community values

A summary table comparing the options for each study area (Mud Bay, Crescent Beach, Semiahmoo Bay) is provided at the end of each chapter.

STUDY AREAS

CURRENT CONDITIONS

The Mud Bay Study area extends from the Serpentine & Nicomekl Lowlands in the East, including the Colebrook and Mud Bay Dyking Districts, and Mud Bay in the West.

TECHNICAL OVERVIEW

Flood hazards along Mud Bay and the Serpentine/Nicomekl Rivers downstream of the sea dams are a function of high tides, in combination with storm surge, waves, and wind effects. Previous work estimated that the existing shoreline dykes can withstand an ocean flood with a return period of 20-30 years, whereas the sheltered shoreline dyke segments offer protection up to the 200 year flood. As a result of sea level rise, the degree of protection will be reduced over time with some dyke overtopping becoming more common in the future, and occurring annually by 2070. When the crests are overtopped, the dykes are likely to breach, causing sudden, widespread inundation. Soil stability in the Mud Bay area is poor, which poses constraints for structural flood protection. Setback dyking increases structural stability.

VALUES IMPACTED

RESIDENTS

Several residential strata developments and subdivisions in addition to many farm houses in the Panorama/Gray Creek, Cloverdale, Inter-River Area, Colebrook, Mud Bay, Nico-Wynd/ Crescent Road areas. Public safety and emergency response are current concerns with over 200,000 vehicle trips passing through the area.

AGRICULTURE

Approximately 60 km^2 agricultural land with a variety of field crops, livestock, and other agricultural production. This represents two thirds of the City's Agricultural Land Reserve. Soil salination and prolonged flooding are a concern in coastal areas.

ENVIRONMENT

Significant natural areas, including mud flats, wetland areas, and riparian/estuarine habitat. Coastal Squeeze of marsh land is an issue.

INFRASTRUCTURE

Over 10 km of Provincial Highways, 30 km of railways and local roads. Other infrastructure and utilities include major sewer and waterlines, natural gas pipelines, and high-voltage electrical transmission lines. Both local and surrounding jurisdictions rely on this infrastructure.

ECONOMY

There are 3,000+ jobs in the area and many businesses. Over $100 million in annual farm gate revenue is produced in the area.

RECREATION

Popular walking, riding and bird watching area. Several parks and protected areas.

CULTURE

Though the area has no known spiritual sites it has been used time immemorial as an important food, resources and medicine harvesting area, as well as a transportation corridor. Therefore, the area likely has many unknown archeological sites. Any disturbance to the soils could potentially disturb human remains which would negatively impact First Nations who traditionally used the area.

TECHNICAL OVERVIEW

CURRENT CONVENTIONS

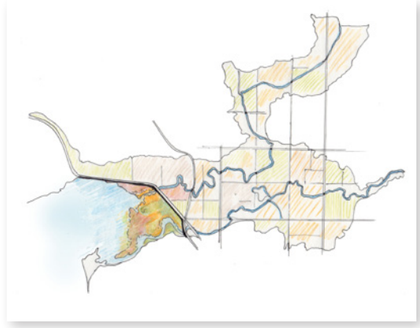
By the year 2100, this option is associated with a very high risk of catastrophic flooding from even a moderate flood or earthquake. There will likely be practical constraints with achieving desired flood protection standards with upgrades only. A future catastrophic failure would likely lead to full retreat and the loss of investments made in any upgrades completed. Whereas the option is viable in the near term "to buy time" and prolong living and farming in the floodplain, it is not a realistic long-term solution from an engineering, operations and maintenance, and future generations cost perspective.

OVERALL ASSESSMENT: ***Not viable for end of century time span.***
TECHNICAL RANKING: ***3rd***

MUD BAY BARRIER

The option is associated with very high risk to the entire floodplain population. Even a moderate earthquake would likely cause the barrier to fail because of the relatively poor underlying soils in the bay. The failure would lead to other cascading and catastrophic dyke failures and sudden widespread inundation. Rebuilding would take a long time, leaving the floodplain exposed to regular tidal flooding. The capital, operations and maintenance, and future costs would be very high. There would be no gain in net land area to offset these costs, as land behind the barrier would be used for freshwater storage. Other associated issues with this option include sediment deposition in the bay and the potential need to dredge outlet channels, reduction in water quality, loss of habitat, and impacts to views for Crescent Beach residents.

OVERALL ASSESSMENT: ***Not advisable from risk and cost perspectives.***
TECHNICAL RANKING: ***4th***



HIGHWAY 99 REALIGNMENT

The option is a combination of partial managed retreat and "holding the line." With properly designed components and by limiting future development in the area, flood risks can be managed and some agricultural operations could remain and be continued. Primary public transportation corridors and key infrastructure are maintained. The new dyke would have a more gradual side slope, some natural protection behind the BNSF line, and require much less riprap than an offshore barrier. There would likely be some environmental benefits from enhanced areas of salt marsh to the west.

OVERALL ASSESSMENT: ***Viable option for current century. It can potentially be a long term solution with changes to the land use behind the dykes to allow for water storage as a way of accommodating higher riverine flooding by 2100.***
TECHNICAL RANKING: ***2nd***

MANAGED RETREAT

The option essentially returns the floodplain to its original state. Major roads and other infrastructure can be maintained by raising, upgrading and adapting. Current residents in the floodplain (approx. 1,500) will need to relocate. All farmland is lost, impacting local food security and livelihoods. Considering that the area contains less than 0.5% of the City's population and approximately 10% of Metro Vancouver's farmland, the option likely offers the least-costly, most viable long-term solution, completely eliminating coastal flood risk in Mud Bay.

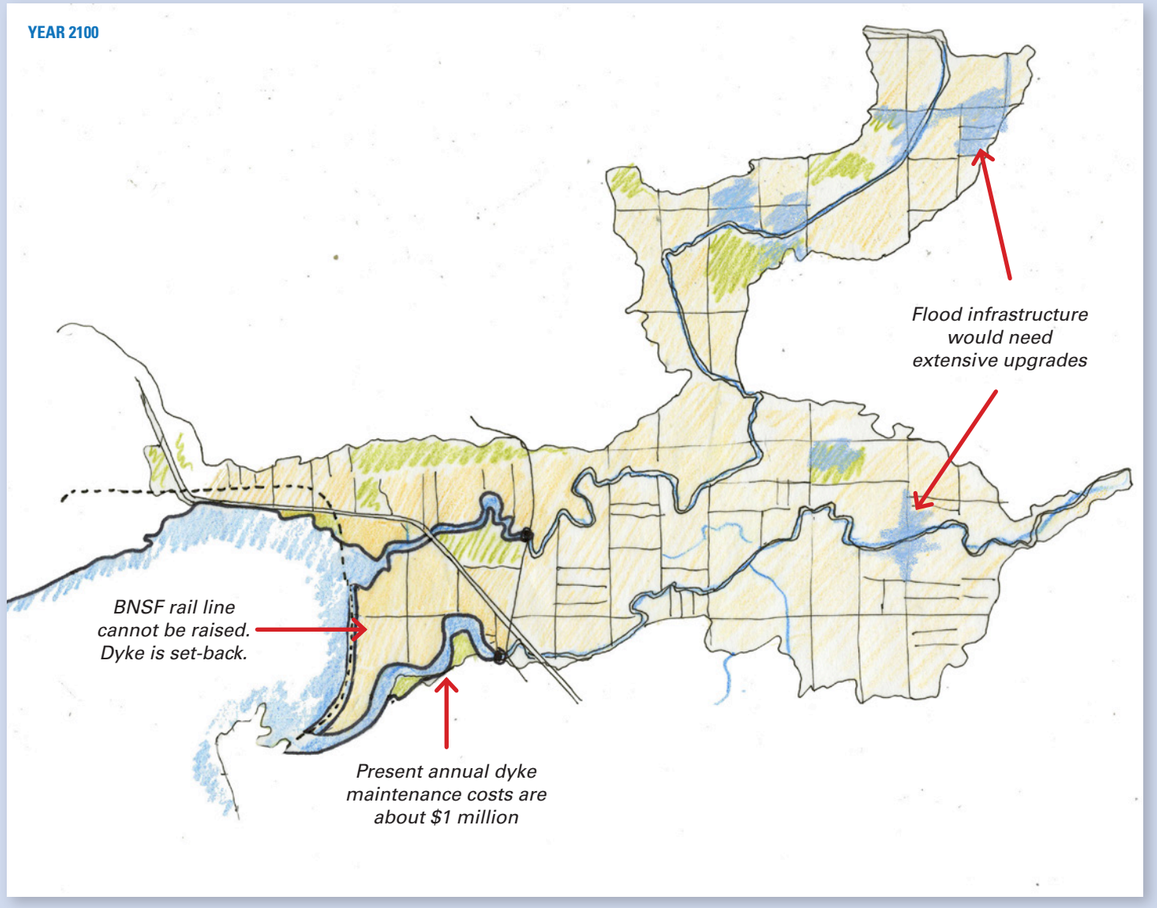
OVERALL ASSESSMENT: ***Most viable option in the long term.***
TECHNICAL RANKING: ***1st***

RISK ASSESSMENT HEAT MAP

The table below provides a high-level overview of risk for each option. Risk is defined as the combination of the likelihood that an option will fail with the impact its failure would have on identified community values. A detailed description of how the likelihood of a failure was calculated is included in the appendix. A detailed description of the impact of the failure of an option on community values is provided for each option description.

LIKELIHOOD	IMPACT: Very Low	Low	Medium	High	Very High
Very High				CURRENT CONVENTIONS	
High					MUD BAY BARRIER
Medium			HIGHWAY 99 REALIGNMENT		
Low					
Very Low		MANAGED RETREAT			

OPTION 1: CURRENT CONVENTIONS



OPTION DESCRIPTION

As sea levels rise, Surrey continues to maintain existing flood control works to meet protection requirements. Present day annual dyke maintenance costs of about $1 million increase substantially over time. Significant investments in upgrading existing flood control measures are required. The BNSF railway embankment along Mud Bay is not a dyke and cannot be raised, so a separate parallel dyke is built. Coastal dykes are raised over time by up to 3 metres and river dykes are raised by up to 1 metre. For every metre dykes are raised, an additional 8 metres of land is required for the base of the dykes, which requires easements from land owners on the landward side or building out into the foreshore on the ocean side. Going forward, the time the two sea dams remain open continues to decrease as a result of sea level rise, resulting in higher river levels and increased flooding of agricultural lands. Additional pumping capacity is unlikely to offset the increased flooding. The raising of dykes and other upgrades are implemented in phases over time. Ongoing costs are significant. This option is most familiar to stakeholders and no new land owners are impacted.

WHAT THIS COULD LOOK LIKE

Maintain flood infrastructure: raised dykes

Maintain flood infrastructure: sea dams

Maintain flood infrastructure: pump stations

INFRASTRUCTURE, EARTHQUAKE & LANDUSE CHANGES & DESIGN

Reduction in dyking: *None.*

New dykes: *2.5 km long, 5 metre high, 35 metre wide dyke parallel to and set back from BNSF railway embankment. Raise all other existing dykes to design level and protect against erosion as required. This includes the south Nicomekl River dyke downstream of the sea dam which will need to be moved inland some distance and extended along Crescent Road.*

Changes to sea dams: *Over time, replace in same locations. Raise and design to meet current earthquake standards. Add pumping capacity.*

Earthquake design: *Present dykes would fail in an earthquake. New dyke parallel to BNSF would be more earthquake resistant, but not earthquake proof.*

Re-purposed land: *None. Some reduction in farmland due to footprint of dyke parallel to BNSF and other dyke improvements.*

Relocated roads/rail lines: *None. Extensive improvements required to accommodate future flood levels.*

Runoff management: *Improved with additional pumping capacity added at sea dams.*

OPTION 1: CURRENT CONVENTIONS

VALUES CRITERIA

NO CHANGE
FAR WORSE ← → FAR BETTER

RESIDENTS

Some residents (approximately 25 homes) are displaced because over time dykes will need to be pushed back, widened, and raised, displacing homes near the current dykes. Also, quality of life will be negatively impacted as there will be a loss of views with higher dykes. Potentially, insurance rates could go up significantly and property values could decrease.

Indicator: *People permanently displaced*

SLIGHTLY WORSE

AGRICULTURE

Some agricultural land is lost due to raising and widening of dykes. Land productivity is negatively impacted given that salinization, subsidence, and localized flooding become more of an issue. Waterfowl begin to impact crops, as they start utilizing crops for feed as they lose natural habitat.

Indicator: *Permanent loss of agriculture land*

SLIGHTLY WORSE

ENVIRONMENT

Over time all the tidal flats in Mud Bay would be negatively impacted by coastal squeeze. Even though sea dams would be replaced with ones that have fish ladders allowing salmon migration, the loss of eelgrass beds would likely be detrimental to salmon. Migration from land to water could be difficult for some species due to larger dykes.

Indicator: *Impacts to wetland habitats, freshwater fish habitat & riparian areas*

FAR WORSE

INFRASTRUCTURE

All transportation corridors and utilities adapt alongside the option and citizens do not experience any change in infrastructure services.

Indicator: *Percent of service/transportation infrastructure made vulnerable*

NO CHANGE

ECONOMY

River dyke setback may displace some businesses. As well, farms will be affected by increased soil salination and increased spillway or riverine flooding. Farms will likely need to change crop types and practices, and likely experience higher maintenance costs due to regular flooding and salination.

Indicator: *Revenue*

SLIGHTLY WORSE

RECREATION

Walking trails and wildlife areas could potentially be more difficult to access. At the same time, with wider and better dyke design, trails could be better integrated into future options. However, there is no significant change from today. The present natural shoreline will disappear. Waves will wash over the now abandoned BNSF railway embankment.

Indicator: *Diversity of recreational opportunities*

NO CHANGE

CULTURE

New dykes would not disturb subsurface soils and therefore have limited archeological impacts.

Indicator: *Opportunities for traditional practices*

NO CHANGE

COST CRITERIA

CAPITAL COST	OPERATION & MAINTENANCE COST	OTHER INFRASTRUCTURE COST	FUTURE ADAPTATION COST
$100M - $1B	*more than $10M*	*$10M - $100M*	*$1B - $4B*

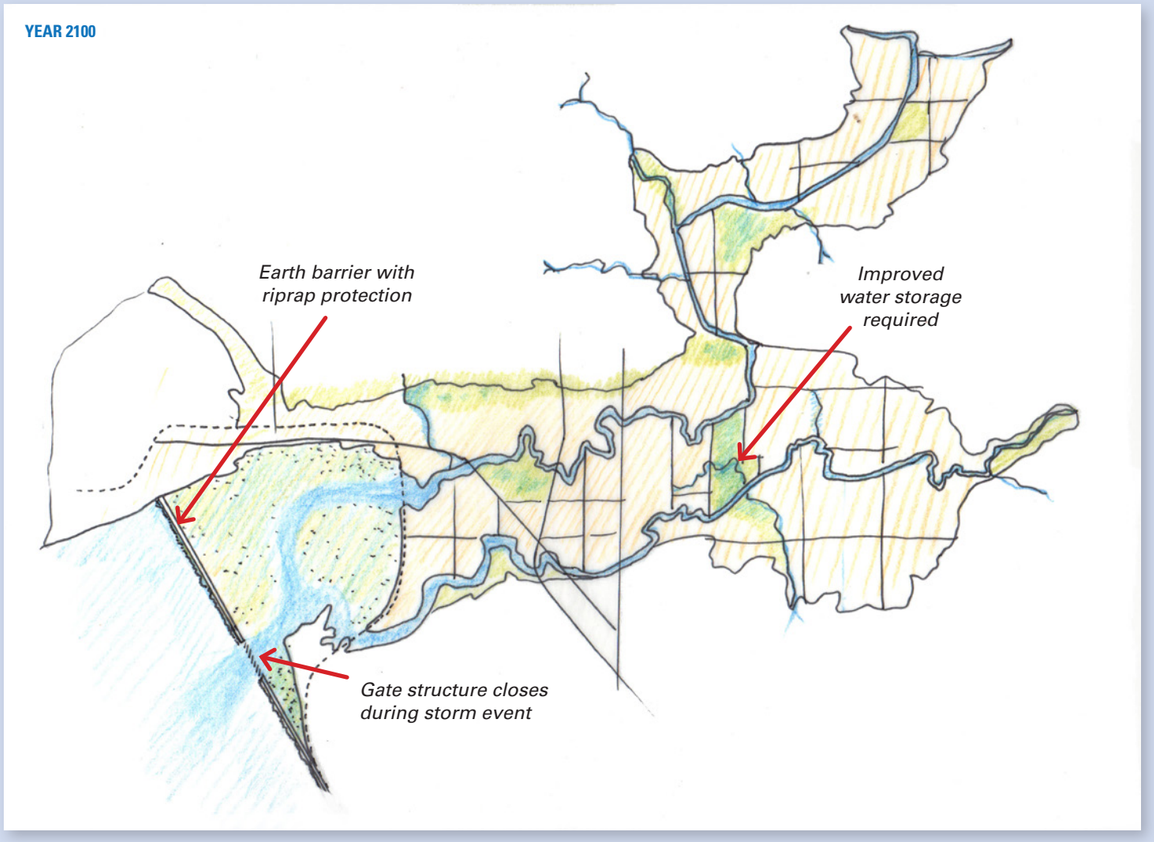
VERY LOW · LOW · MEDIUM · HIGH · VERY HIGH

IMPACT & RISK OF FAILURE

		Impact of Failure on Value	x	Likelihood of Failure of Option	=	Risk
RESIDENTS	All housing within floodplain could be affected. Some loss of life possible from sudden dyke breaching irrespective of failure mode. Restrict future development and limit the population of the area.					
AGRICULTURE	Some agricultural land within floodplain potentially affected but land partly recoverable over time.					
ENVIRONMENT	Contamination from septic fields, sewage backflow, manure, and chemical storage.					
INFRASTRUCTURE	A failure of a dyke would likely disrupt multiple transportation corridors and utilities.					
ECONOMY	Extensive direct and indirect losses.					
RECREATION	Temporary disruptions but trails/ parks likely recoverable.					
CULTURE	A dyke breach and flood event would have limited archeological impacts.					

Overall Risk:

OPTION 2: MUD BAY BARRIER



The barrier has minimal impact on reducing waves and relies on a gate structure to minimize the impacts of storm surges. An alternative barrier near shore for Crescent Beach only is shown in Chapter 2.

OPTION DESCRIPTION

All of the existing flood control works continue to be maintained, but coastal dykes do not need to be raised if a 4.5 km long offshore barrier across Mud Bay is constructed to reduce the impacts of high tides and storm surges from entering the bay. The earth-filled barrier has riprap on both side slopes and is built at an average height of 10 metres above present sea level to allow for 50% settlement and 1 metre sea level rise by year 2100. At a combined outlet channel for the Serpentine and Nicomekl Rivers, the barrier has a gate structure that is closed during storm surge events. As sea levels continue to rise, the time the barrier and existing sea dams remain open is shortened, resulting in higher river levels and increased flooding of agricultural lands. The environmental impacts of the option are extremely high during construction and into the future. Ecologically critical mud flats and salt marshes in the bay are lost, as land previously between the barrier and the existing shoreline is used for freshwater storage providing storm water and irrigation improvement.

WHAT THIS COULD LOOK LIKE

Louisiana surge barrier
CC-by, Team New Orleans US Army Corps of Engineers

Thames Barrier, London

INFRASTRUCTURE, EARTHQUAKE & LANDUSE CHANGES & DESIGN

Reduction in dyking: *None. Existing dykes maintained and raised slightly.*

New dykes: *4.5 km long, 10 metre high ocean barrier. As barrier is built on ocean bed with high settlement (50%) and subsidence potential, it must be about twice as high as dykes on land. Structure must be protected on both sides with riprap. Once built, difficult to raise.*

Changes to sea dams: *A new 350 metre long gated structure is added to the barrier to allow rivers to drain and permit navigation. Existing sea dams may no longer be required (to be determined).*

Earthquake design: *Barrier built using engineered materials but not able to withstand an earthquake. Mud Bay sea floor is soft and unstable and would require extensive, very deep pilings for better earthquake resistance. These pilings would be prohibitively expensive along the length of structure, but likely included for the sea gate structure. The joints between the barrier and gate are potential failure locations.*

Re-purposed land: *None. The area inland of the barrier provides flow storage that helps reduce the amount the river dykes need to be raised over time. Some silt deposit and build-up expected inside the barrier. Reduced tidal flushing of the bay will impact water quality and may affect habitat and swimming.*

Relocated roads/rail lines: *None.*

Runoff management: *Likely improved as storage area inside ocean gate provides additional freshwater storage while gates are closed (to be determined by modelling).*

OPTION 2: MUD BAY BARRIER

VALUES CRITERIA

		NO CHANGE: FAR WORSE ← → FAR BETTER
RESIDENTS	No residents are relocated. The land gained behind the barrier cannot be developed for residential purposes as the City of Surrey wants to ensure that no new homes are build on the flood plain.	***Indicator:*** *People permanently displaced* — NO CHANGE
AGRICULTURE	No agricultural land is lost. The land gained behind the barrier provides flow storage that helps reduce the amount the river dykes need to be raised over time.	***Indicator:*** *Permanent loss of agriculture land* — NO CHANGE
ENVIRONMENT	The tidal flats behind the barrier are subject to gradual material deposition. Eelgrass beds will be buried by sediment and riparian habitat will be lost. Any habitat within the roughly 100 metre wide and 4,500 metre long barrier footprint will be destroyed. Tidal flushing of the bay is severely reduced, water quality suffers significantly. The salt content is reduced and present species will unlikely survive.	***Indicator:*** *Impacts to wetland habitats, freshwater fish habitat & riparian areas* — FAR WORSE
INFRASTRUCTURE	All transportation corridors and utilities adapt alongside the option and citizens do not experience any change in infrastructure services.	***Indicator:*** *Percent of service/transportation infrastructure made vulnerable* — NO CHANGE
ECONOMY	The marinas may no longer be feasible, as the gates would need to be blocked off from recreational use to avoid accidents. Land behind the barrier cannot be used for agriculture or industry.	***Indicator:*** *Revenue* — NO CHANGE
RECREATION	The barrier could combine different recreational functions (trails/lookouts/kayak launch) to make the barrier a destination. However, likely deterioration of water quality behind the barrier would negatively impact current recreational uses of the area, especially Crescent Beach.	***Indicator:*** *Diversity of recreational opportunities* — SLIGHTLY WORSE
CULTURE	This option would likely disturb archeological artifacts and human remains.	***Indicator:*** *Opportunities for traditional practices* — MODERATELY WORSE

COST CRITERIA

CAPITAL COST	OPERATION & MAINTENANCE COST	OTHER INFRASTRUCTURE COST	FUTURE ADAPTATION COST
more than $4B	*$1M - $10M*	*less than $10M*	*$1B - $4B*

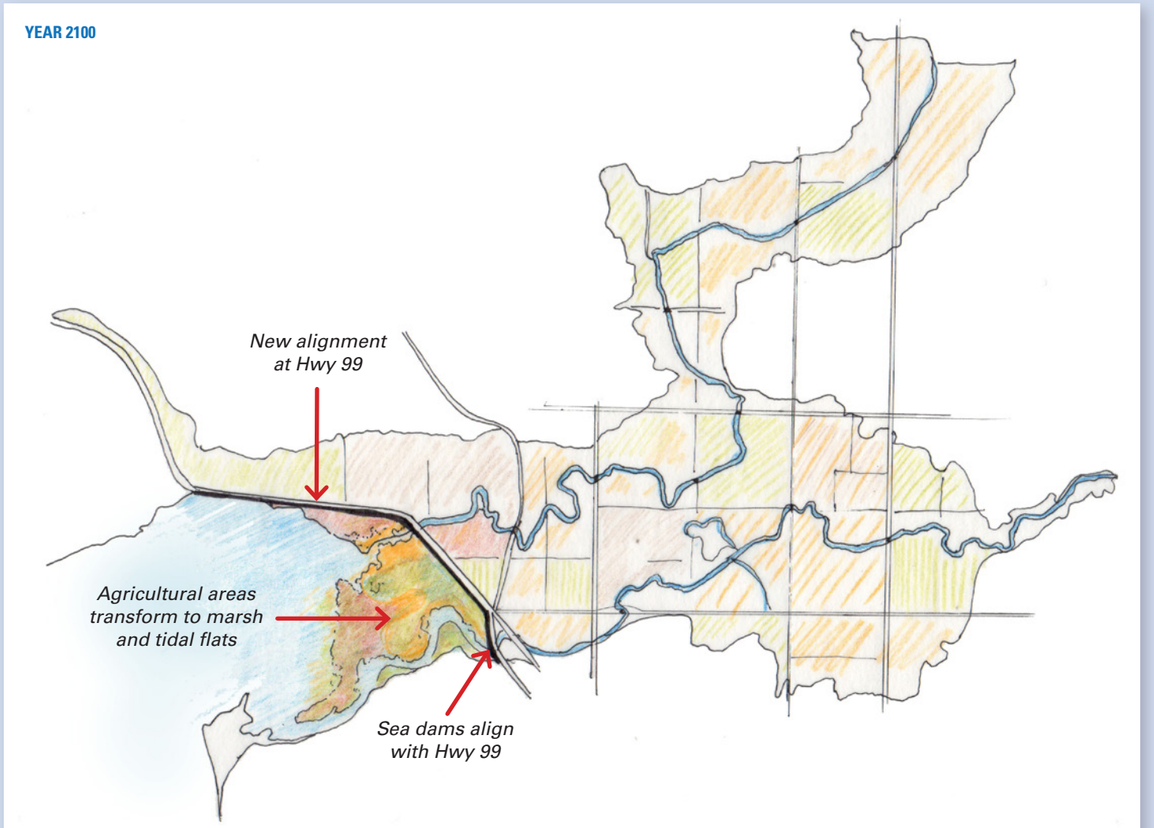
VERY LOW · LOW · MEDIUM · HIGH · VERY HIGH

IMPACT & RISK OF FAILURE

		Impact of Failure on Value	x	Likelihood of Failure of Option	=	Risk
RESIDENTS	A barrier failure could lead to existing ocean and river dykes failing in multiple locations. In such an event, all housing within floodplain could be affected and there could be significant loss of life.	●		●		●
AGRICULTURE	All agricultural land within floodplain potentially affected but some land recoverable over time.	●		●		●
ENVIRONMENT	The entire floodplain would experience contamination from septic fields, sewage backflow, manure, and chemical storage.	●		●		●
INFRASTRUCTURE	A sudden barrier failure could severely impact and disrupt all transportation corridors and utilities within the floodplain.	●		●		●
ECONOMY	Extensive direct and indirect losses.	●		●		●
RECREATION	Permanent disruption to recreation areas and boat access would be limited.	●		●		●
CULTURE	A dyke breach and flood event would have limited archeological impacts.	●		●		●

Overall Risk: ●

OPTION 3: HIGHWAY 99 REALIGNMENT



OPTION DESCRIPTION

This option sets flood protection back from the ocean by building a 2.5 km long dyke along Highway 99. The dyke protects other inland routes, infrastructure, and land uses, while residents along the coastal side of Highway 99 in Mud Bay area are relocated or otherwise assisted in adapting to coastal flooding. The two sea dams are rebuilt and aligned with the Highway 99 super dyke. As sea levels continue to rise, the time the two sea dams remain open is shortened, resulting in higher river levels and increased flooding of agricultural lands. 14.5 km of dykes along the Serpentine and Nicomekl Rivers downstream of the sea dams are no longer needed and not maintained or upgraded. All other flood control works upstream of the sea dams require upgrades over time, including raising and widening of river dykes, and protection against erosion as the magnitude and frequency of floods increases. Some environmental benefits are realized on the coastal side of Highway 99, where former agricultural land is converted to coastal marsh and a new coastal multi-use trail is established to link Boundary Bay Park with the Nicomekl Greenway. Lands east of the dyke are maintained for their current uses, within the agricultural land reserve.

WHAT THIS COULD LOOK LIKE

Raised highway becomes flood barrier.

Aquaculture

Salt marsh created from breached agriculture land

INFRASTRUCTURE, EARTHQUAKE & LANDUSE CHANGES & DESIGN

Reduction in dyking: *9 km of river dykes, and 5.5 km of coastal dykes.*

New dykes: *4.5 km of a new 6 metre high, 53 metre wide dyke along Hwy 99 alignment.*

Changes to sea dams: *Existing sea dams de-commissioned. New sea dams constructed at highway alignment. Serpentine sea dam shifted downstream, leading to reduced river dyke heights behind the relocated sea dam.*

Earthquake design: *New dyke built with engineered materials with some earthquake resistance. Area soils which are very soft do not permit new dyke to meet full earthquake standards. New sea dams will meet earthquake standards.*

Re-purposed land: *About 5 km^2 of agricultural land, Nicowynd golf course, and some residential subdivision and housing areas to become salt marsh habitat.*

Relocated roads/rail lines: *The BNSF rail line either relocated or significantly raised (difficult to retrofit where line passes underneath Hwy 99). King George Boulevard near Nicomekl River crossing is protected. Crescent Road to be raised.*

Runoff management: *Pumps to be installed at new sea dams.*

OPTION 3: HIGHWAY 99 REALIGNMENT

VALUES CRITERIA

FAR WORSE ← NO CHANGE → FAR BETTER

RESIDENTS

Residents on coastal side of Highway 99 in Mud Bay and Inter-River Area are relocated. Approximately 150 homes are relocated from Mud Bay (20) and Nico-Wynd (130). Quality of life might be impacted in remaining homes as over time river dykes will need to be pushed back, widened, and raised.

Indicator: *People permanently displaced*

SLIGHTLY WORSE

AGRICULTURE

Agricultural land on coastal side of Highway 99 is lost. Soil salinization remains an issue in some areas. Agricultural land reduced approximately by 5 km^2.

Indicator: *Permanent loss of agriculture land*

SLIGHTLY WORSE

ENVIRONMENT

Agricultural land on coastal side of Highway 99 may be transformed and managed as coastal marsh through intentional breaches and riparian restoration. Wetlands and other coastal ecosystems may also develop. Approximately 5 km^2 of new habitat is created.

Indicator: *Impacts to wetland habitats, freshwater fish habitat & riparian areas*

SLIGHTLY BETTER

INFRASTRUCTURE

All transportation corridors and utilities adapt alongside the option and citizens do not experience any change in infrastructure services.

Indicator: *Percent of service/transportation infrastructure made vulnerable*

NO CHANGE

ECONOMY

Some agri-businesses are displaced and annual farm gate revenues are impacted by reductions in agricultural land. Approximately 150 direct jobs are displaced.

Indicator: *Revenue*

SLIGHTLY WORSE

RECREATION

New salt marsh could become regional recreational destination for bird watchers. The new area could support water-based recreational activities including kayaking and canoeing, along with a land-based trail network; however, access to recreational opportunities may be inaccessible during high water.

Indicator: *Diversity of recreational opportunities*

SLIGHTLY BETTER

CULTURE

New dykes would not disturb subsurface soils and therefore have limited archeological impacts.

Indicator: *Opportunities for traditional practices*

NO CHANGE

COST CRITERIA

CAPITAL COST	OPERATION & MAINTENANCE COST	OTHER INFRASTRUCTURE COST	FUTURE ADAPTATION COST
$1B - $4B	*$1M - $10M*	*$10M - $100M*	*$1B - $4B*

VERY LOW · LOW · MEDIUM · HIGH · VERY HIGH

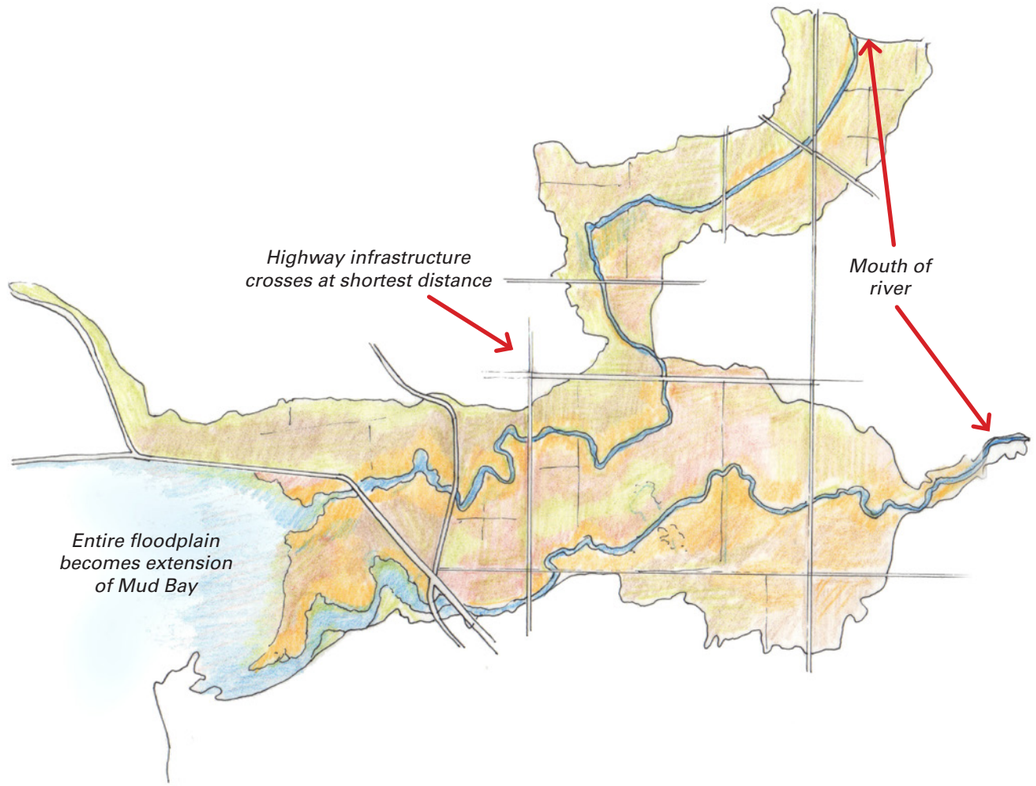
IMPACT & RISK OF FAILURE

	Impact of Failure on Value	x	Likelihood of Failure of Option	=	Risk
RESIDENTS	Housing within floodplain could be affected but most vulnerable housing west of Highway 99 would be removed through retreat of that area. Some loss of life possible from sudden dyke breach. Population density to be regulated to avoid increased risk over time.				
AGRICULTURE	Agricultural land potentially affected but some land recoverable over time.				
ENVIRONMENT	Potential contamination from septic fields, sewage backflow, manure, and chemical storage.				
INFRASTRUCTURE	A failure of a dyke would likely be of partial proportions and the structure would be more readily repairable. Disruptions to transportation corridors and utilities would be of medium impact.				
ECONOMY	Extensive direct and indirect losses.				
RECREATION	Temporary disruption to recreation, but recoverable.				
CULTURE	A dyke breach and flood event would have limited archeological impacts.				

Overall Risk:

OPTION 4: MANAGED RETREAT

YEAR 2100



OPTION DESCRIPTION

This option involves a carefully planned and managed retreat from the coastal flood plain as sea levels rise over time, dykes are increasingly overtopped, and the City's investment in flood control is gradually reduced. Where feasible and practical, floodplain residents and stakeholders are supported to adapt, including the reorganization of agricultural activities and with adaptive building approaches. New land uses are introduced over time, including new recreation opportunities and creating new ecosystems and habitat for wildlife, fish, and migratory birds. Key infrastructure, including Highway 99 and King George Boulevard, remain functional but require raising and other extensive improvements. Other infrastructure, buildings, and pump stations are removed and recycled in a phased and organized manner. With less investment in large scale flood control, more resources are available to help floodplain residents and stakeholders to adapt or relocate. While development over the past 140 years has significantly altered the land, this option would return much of the area to its original coastal floodplain, wetland environment.

WHAT THIS COULD LOOK LIKE

Recreation opportunities

Floating greenhouse opportunities

Diverse habitat

INFRASTRUCTURE, EARTHQUAKE & LANDUSE CHANGES & DESIGN

Reduction in dyking: *76 km of river dykes and 5.5 km of coastal dykes.*

New dykes: *1.3 km of new dyking to prevent flooding of Delta, plus about 2 km of dyking to prevent flooding of Langley.*

Changes to sea dams: *Existing sea dams de-commissioned.*

Earthquake design: *None required.*

Re-purposed land: *About 65 km^2 of agricultural land converted to natural floodplain over time, including areas south of Nicomekl River and north of Serpentine River.*

Relocated roads/rail lines: *Major transportation corridors raised or moved onto bridges. BNSF and other rail lines to be either raised or relocated.*

Runoff management: *Floodplain is open to the ocean. High tides move inland freely. There could be some implications for Langley (impacts to be determined by modelling). Cloverdale Town Centre largely outside floodplain.*

OPTION 4: MANAGED RETREAT

VALUES CRITERIA

NO CHANGE
FAR WORSE ← → FAR BETTER

RESIDENTS

All residents would be relocated from the floodplain over time. Approximately 550 homes are relocated from Panorama/Gray Creek, Cloverdale, Inter-River Area, Colebrook, Mud Bay, and Nico-Wynd/Crescent Road area.

Indicator: *People permanently displaced*

FAR WORSE

AGRICULTURE

Current agricultural practices would be phased out over time. Other forms of food production (e.g., aquaculture, floating greenhouses) could be explored, but land based agriculture would not be possible due to inundation.

Indicator: *Permanent loss of agriculture land*

FAR WORSE

ENVIRONMENT

There would be significant loss of habitat for land based wildlife and flora, but overall there are significant increases on scarce coastal habitat. Natural floodplain functions could return to pre-development performance levels. New ecosystems and habitat for wildlife and migratory birds are created. Soil remediation is required.

Indicator: *Impacts to wetland habitats, freshwater fish habitat & riparian areas*

FAR BETTER

INFRASTRUCTURE

Only the main transportation corridors (Hwy 99, King George, Hwy 15, Fraser Hwy, and Hwy 10) are adapted by raising, and all utilities adapt as needed along side the option. Citizens would be able to cross the flood plain across the main transportation corridors, but all other roads would be decommissioned.

Indicator: *Percent of service/transportation infrastructure made vulnerable*

SLIGHTLY WORSE

ECONOMY

All land-base agri-businesses is displaced. Over time, intensive agriculture on piers or floating greenhouses, experimental aquaculture, seaweed production, and other food production options would potentially develop. Potentially 3,500 direct jobs are displaced, but likely these would transition to other intensive forms of agriculture jobs.

Indicator: *Revenue*

MODERATELY WORSE

RECREATION

The new area could become a regional recreational destination for bird watchers, as well as support water-based recreational activities including kayaking and canoeing. Along the new coastline, a land-based trail network could be developed.

Indicator: *Diversity of recreational opportunities*

MODERATELY BETTER

CULTURE

No new dykes constructed, and the removal of existing infrastructure would only have limited archeological impacts.

Indicator: *Opportunities for traditional practices*

NO CHANGE

COST CRITERIA

CAPITAL COST	OPERATION & MAINTENANCE COST	OTHER INFRASTRUCTURE COST	FUTURE ADAPTATION COST
$1B - $4B	*less than $1M*	*more than $100M*	*less than $100M*

VERY LOW · LOW · MEDIUM · HIGH · VERY HIGH

IMPACT & RISK OF FAILURE

		Impact of Failure on Value	x	Likelihood of Failure of Option	=	Risk
RESIDENTS	No housing in Surrey floodplain impacted, potentially some housing in Langley could be marginally impacted. No loss of life expected.	●		●		●
AGRICULTURE	Any remaining agricultural land within floodplain potentially affected, but as retreat occurs this land is expected to be used as seasonal pasture only.	●		●		●
ENVIRONMENT	Managed retreat to remove primary sources of pollution.	●		●		●
INFRASTRUCTURE	The adapted transportation corridors and utilities could be impacted by scouring, but catastrophic and/or multiple failures at the same time would be uncommon.	●		●		●
ECONOMY	Given that there are no major dykes remaining to be breached and therefore no chance of sudden flooding, no negative economic impacts are expected from flooding.	●		●		●
RECREATION	Recreation options adapted to retreat.	●		●		●
CULTURE	Limited archeological impacts.	●		●		●

Overall Risk: ●

2100 PRELIMINARY IMPACT EVALUATION

VALUES CRITERIA RANKING

FAR WORSE ← NO CHANGE → FAR BETTER

TECHNICAL CRITERIA RANKING

VERY LOW · LOW · MEDIUM · HIGH · VERY HIGH

	BASELINE - NO ADAPTATION	CURRENT CONVENTIONS	MUD BAY BARRIER	HIGHWAY 99 REALIGNMENT	MANAGED RETREAT
VALUES CRITERIA					
RESIDENTS *People permanently displaced*	FAR WORSE	SLIGHTLY WORSE	NO CHANGE	SLIGHTLY WORSE	FAR WORSE
AGRICULTURE *Permanent loss of agriculture land*	FAR WORSE	SLIGHTLY WORSE	NO CHANGE	SLIGHTLY WORSE	FAR WORSE
ENVIRONMENT *Impacts to wetland habitats, freshwater fish habitat & riparian areas*	MODERATELY WORSE	FAR WORSE	FAR WORSE	SLIGHTLY BETTER	FAR BETTER
INFRASTRUCTURE *Percent of service/ transportation infrastructure made vulnerable*	FAR WORSE	NO CHANGE	NO CHANGE	NO CHANGE	SLIGHTLY WORSE
ECONOMY *Revenue*	FAR WORSE	SLIGHTLY WORSE	NO CHANGE	SLIGHTLY WORSE	MODERATELY WORSE
RECREATION *Diversity of recreational opportunities*	FAR WORSE	NO CHANGE	SLIGHTLY WORSE	SLIGHTLY BETTER	MODERATELY BETTER
CULTURE *Opportunities for traditional practices*	SLIGHTLY WORSE	NO CHANGE	MODERATELY WORSE	NO CHANGE	NO CHANGE
IMPACT & RISK OF FAILURE					
OVERALL RISK	VERY HIGH	VERY HIGH	VERY HIGH	MEDIUM	VERY LOW
COST CRITERIA					
CAPITAL COST	—	$100M - $1B	MORE THAN $4B	$1B - $4B	$1B - $4B
OPERATION & MAINTENANCE COST	MORE THAN $10M	MORE THAN $10M	$1M - $10M	$1M - $10M	LESS THAN $1M
OTHER INFRASTRUCTURE COST	MORE THAN $100M	$10M - $100M	LESS THAN $10M	$10M - $100M	MORE THAN $100M
FUTURE ADAPTATION COST	$1B - $4B	$1B - $4B	$1B - $4B	$1B - $4B	LESS THAN $100M

NOTES

APPENDIX

VERY LOW LOW MEDIUM HIGH VERY HIGH

CURRENT CONVENTIONS

Likelihood of Failure

Dyke overtopping: High - Even if extensively raised, dyke core material remains sub-standard and settlement and slumping will occur.

Dyke erosion failure: Very High - Present dykes are located adjacent to ocean and rivers. On-going improvements and repairs required.

Earthquake failure: Very High – Dykes are not designed for earthquakes.

Mechanical failure: High - Aging sea dams, flood boxes and pump stations. Upgrades would likely lag behind actual requirements.

Seepage Increase: Very High - Seepage will increase with sea level rise. No prevention measures are practical.

Precipitation flooding: High - Increased precipitation expected by 2100. This risk can be lessened by adding substantial pumping capacity at the sea dams and creating upland retention lakes.

Costs

Capital Cost of Implementation: Includes cost for sea dam replacement, new dyke along BNSF embarkment, upgrades to dykes along south bank of Nicomekl River, upgrades to pump stations, and adding erosion protection along existing dykes

O&M Cost: Cost will increase exponentially over time to meet continued upgrade requirements.

Other Infrastructure Cost: Although some costs can be considered part of regular upgrades, there still will be additional infrastructure costs, including potential relocation of BNSF line and the raising of several existing bridges.

Future Adaptation Cost: To maintain acceptable degree of protection under climate change, beyond the year 2100, dykes must continue to be raised, improvements to erosion protection updated, and expanded pumping capacity added to the sea dams. As both ocean and river dykes are raised, property squeeze will become an issue.

MUD BAY BARRIER

Likelihood of Failure

Dyke overtopping: Low - Assuming gated barrier will reduce high tide and surge levels, the existing ocean and river dykes will largely be protected.

Dyke erosion failure: Very High - Existing ocean dykes will still be exposed to wave action since the barrier would be set back from the shore by some 4 km. Flow velocities may increase for river dykes leading to higher erosion. The barrier will be designed for wave erosion.

Earthquake failure: Very High - The barrier would not be designed for earthquakes and could fail catastrophically over its entire length. Existing ocean and river dykes and the present sea dams consequently have very high failure potential.

Mechanical failure: High - High potential for failure at gated structure due to barrier settlement. Evaluation assumes aging sea dams, flood boxes and pump stations are upgraded over time, if not the scoring would be Very High.

Seepage Increase: Medium – Sea level rise impacts are largely controlled by barrier.

Precipitation Flooding: Low - Increased flow storage area inside barrier addresses this issue.

Costs

Capital Cost of Implementation: Cost of barrier with sea-gates is very high. Additional costs for raising low river dykes, upgrading sea dams, flood boxes and pump stations.

O&M Cost: Existing ocean and river dykes would require ongoing maintenance. Barrier and gated structure would be rated high-consequence if a failure occurred and require a high degree of maintenance. Some dredging likely required.

Other Infrastructure Cost: All costs considered part of regular upgrades. Relatively minor upgrades required.

Future Adaptation Cost: Some upgrades to existing ocean and river dyke erosion protection will be required over time as sea level rise reduces periods of low water. Raising the barrier and modifying its gated structure to accommodate more than 1 m of sea level rise and extensive settlement would be extremely costly. Some dredging likely required.

HIGHWAY 99 REALIGNMENT

Likelihood of Failure

Dyke overtopping: Low - Assuming extensive upgrades for new coastal dykes, and new sea dams with pumps. New salt marsh habitat and remnants of existing coastal dykes and BNSF embankment provide wave attenuation.

Dyke erosion failure: Low for coastal dykes and High for riverine dykes - New coastal alignment dyke has extensive salt marsh at toe and is riprap protected, whereas riverine dykes continue to face erosion issues. The risk of erosion failure for riverine dykes can be lessened by creating set back dykes (i.e., dykes set back from the river), but properties bordering dykes will be squeezed

Earthquake failure: High - New coastal dyke will have improved standards but still not able to withstand earthquakes. Sea dams will be designed to seismic standards.

Mechanical failure: Medium – Assuming new flood boxes and pump stations are added.

Seepage Increase: High - Seepage will increase with sea level rise and although no prevention measures are practical the dyke will be wider and reduce seepage to some degree.

Precipitation flooding: Medium - Assumes substantial pumping capacity added at sea dams.

Costs

Capital Cost of Implementation: Estimated capital costs include sea dam decommissions, new sea dams with pump stations, new dyke built along Highway 99, and Crescent Road raised. Compensation costs for affected landowners (primarily agricultural, golf course, residential).

O&M Cost: Costs to maintain and operate dykes, sea dams, pumps, flood boxes are reduced after option is implemented

Other Infrastructure Cost: Incremental costs in the short- to medium-term. Infrastructure to the east of Highway 99 is protected. BNSF railway likely relocated. Some infrastructure, such as Metro Vancouver water/ sewer lines, would require upgrades or relocation.

Future Adaptation Cost: Post 2100, costly upgrades will be required. Dykes and sea dams will need to be raised. Sea dams will be closed for longer periods requiring higher pumping capacity for the rivers. Lake storage, raised set-back dykes, river diversions are also likely needed beyond 2100. Potential for property squeeze in many areas.

MANAGED RETREAT

Likelihood of Failure

Dyke overtopping: Very Low - No dykes required.

Dyke erosion failure: Very Low - No ocean dykes or river dykes remaining.

Earthquake failure: Low - Development along floodplain edge potentially affected.

Mechanical failure: Very Low - Option removes the need to operate pumps and flood boxes.

Seepage Increase: Very Low - Retreat above the flood plain, so no concern.

Precipitation flooding: Low - Development removed from Surrey floodplain. Impacts to Langley to be determined

Costs

Capital Cost of Implementation: High cost to compensate for land acquisitions and business losses. Other costs are low. Existing coastal dykes can be left in place, with some manufactured breaches introduced to allow natural flooding and enhancement of salt marsh. Sea dams and pump stations to be decommissioned. River dykes to be partially removed. Implementation cost is function of policy decisions regarding compensation.

O&M Cost: Costs to operate dykes, sea dams, pump stations, and flood boxes no longer required. Inspections no longer required. Some habitat improvements.

Other Infrastructure Cost: Major infrastructure relocation and/or upgrades are required

Future Adaptation Cost: Minor shoreline protection works may be required along edge of the floodplain. Retreat gradually progresses but valley walls are relatively steep so little additional land needs to be abandoned.

MORE INFORMATION

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