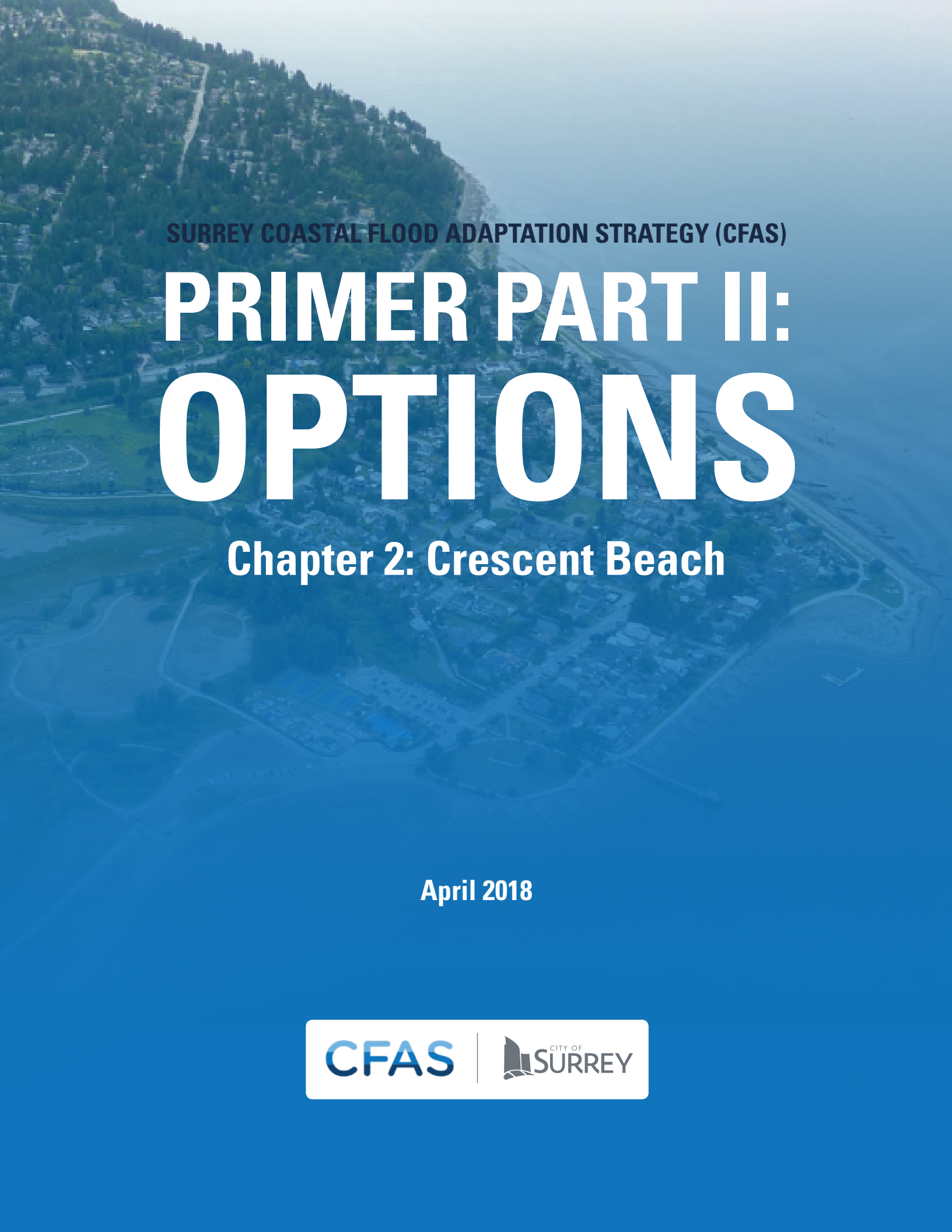


SURREY COASTAL FLOOD ADAPTATION STRATEGY (CFAS)

PRIMER PART II: OPTIONS

Chapter 2: Crescent Beach

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

Crescent Beach is a beachside residential community located at the mouth of the Nicomekl River in South Surrey. It is home to 1,200 residents, mostly in single-family homes.

TECHNICAL OVERVIEW

Situated downstream of Nicomekl sea dam, river flooding is not a concern and flood hazards are a direct function of ocean levels. Recent studies suggest that by 2070, the area is expected to flood annually. Furthermore, the lands closer to Blackie Spit Park are 2-3m lower than the lands adjacent to the southwest facing dyke. Any water that overtops the southwest facing dyke would cause severe erosion and then pond in the lands closer to Blackie Spit Park. Lands inside the northeast dyke may also flood from direct overtopping of the adjacent dyke. The sandy soils underlying Crescent Beach make structural flood protection measures more viable by providing a stronger foundation, compared to adjacent Mud Bay, however saline groundwater seepage is an ongoing concern.

VALUES IMPACTED

RESIDENTS

Home to about 1,200 residences, the area includes over 40 Heritage Sites, including numerous heritage properties, including historic Dunsmuir Farm.

ENVIRONMENT

Blackie Spit is an important wildlife area that offers some of the best bird watching areas in Canada. The sandy spit is surrounded by tidal marsh and eelgrass beds and is an important stop for migrating and wintering waterfowl and shorebirds.

INFRASTRUCTURE

The BNSF rail line runs over the Nicomekl River and along the eastern edge of the community. Crescent Road provides the only vehicular access into and out of the community.

ECONOMY

There is a small, neighbourhood commercial area with several shops, restaurants and businesses.

RECREATION

The area includes popular swimming beaches, the Surrey Sailing Club, the Crescent Beach Yacht Club, Alexandre Neighbourhood House. Blackie Spit is a regional recreation destination.

CULTURE

Though Crescent Beach is not a spiritual site (which are more commonly found on higher grounds) it has been used since time immemorial as an important food, resources, and medicine harvesting area. Unlike Mud Bay's acid soils that accelerate the decompositions of human remains and artifacts, Crescent Beach is of special cultural and archaeological importance, as the shell middens found in the area buffer the acidity and preserve thousands of years of artifacts and human remains. Therefore, any disturbance to the soils would negatively impact Semiahmoo First Nation.

TECHNICAL OVERVIEW

EXPANDED EDGE

The raised and expanded dyke will provide protection against overtopping and erosion, but the risks are still high for this option. Given the porous ground, seepage issues will increase proportionally with sea level rise. To address seepage multiple actions need to be taken, including the installation of perforated piping with large pumps and the raising of all homes and roadways by about 1 metre by the year 2100. Continuing to adapt to higher sea levels beyond the year 2100 may be challenging from a seepage perspective.

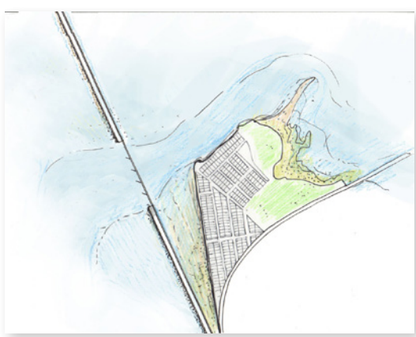
OVERALL ASSESSMENT: ***Views will be severely impacted, and seepage requires that roads and housing be raised. Option is more cost effective than barrier island/spit and is likely only feasible for this century.***
TECHNICAL RANKING: ***2nd***

BARRIER ISLAND/SPIT

The barrier island/spit needs to be high enough to avoid overtopping and to reduce wave action, but provides no additional protection to the low dykes on the west and north sides of Crescent Beach; these would need to be raised substantially. This option is associated with very high risk.

The barrier island/spit could provide some recreational and ecological value, but views from Crescent Beach would be impacted. The barrier island/spit does not address issues of seepage or groundwater flooding, and multiple actions need to be taken, including the installation of perforated piping with large pumps and the raising of all homes and roadways by about 1 metre by the year 2100.

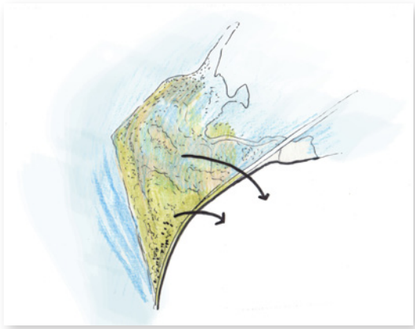
OVERALL ASSESSMENT: ***The barrier island/spit needs to be 6 metres above today's mean sea level, impacting views from the coast, and also requires raising existing dykes.. This option has limited merit from flood protection perspective.***
TECHNICAL RANKING: ***3rd***



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, impacts to boat traffic and swimming, and impacts to views for Crescent Beach residents.

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



MANAGED RETREAT

The option returns the area to its original natural state, before permanent development. The present population of Crescent Beach (approx. 1,200 residents and 200 employees) would need to relocate. Considering that the area represents 0.7% of Surrey's gross assessed value (2016) and 0.2% of Surrey's total residential floor space, the option is likely to offer the most viable, least-costly, long-term solution completely eliminating coastal risk in Crescent Beach.

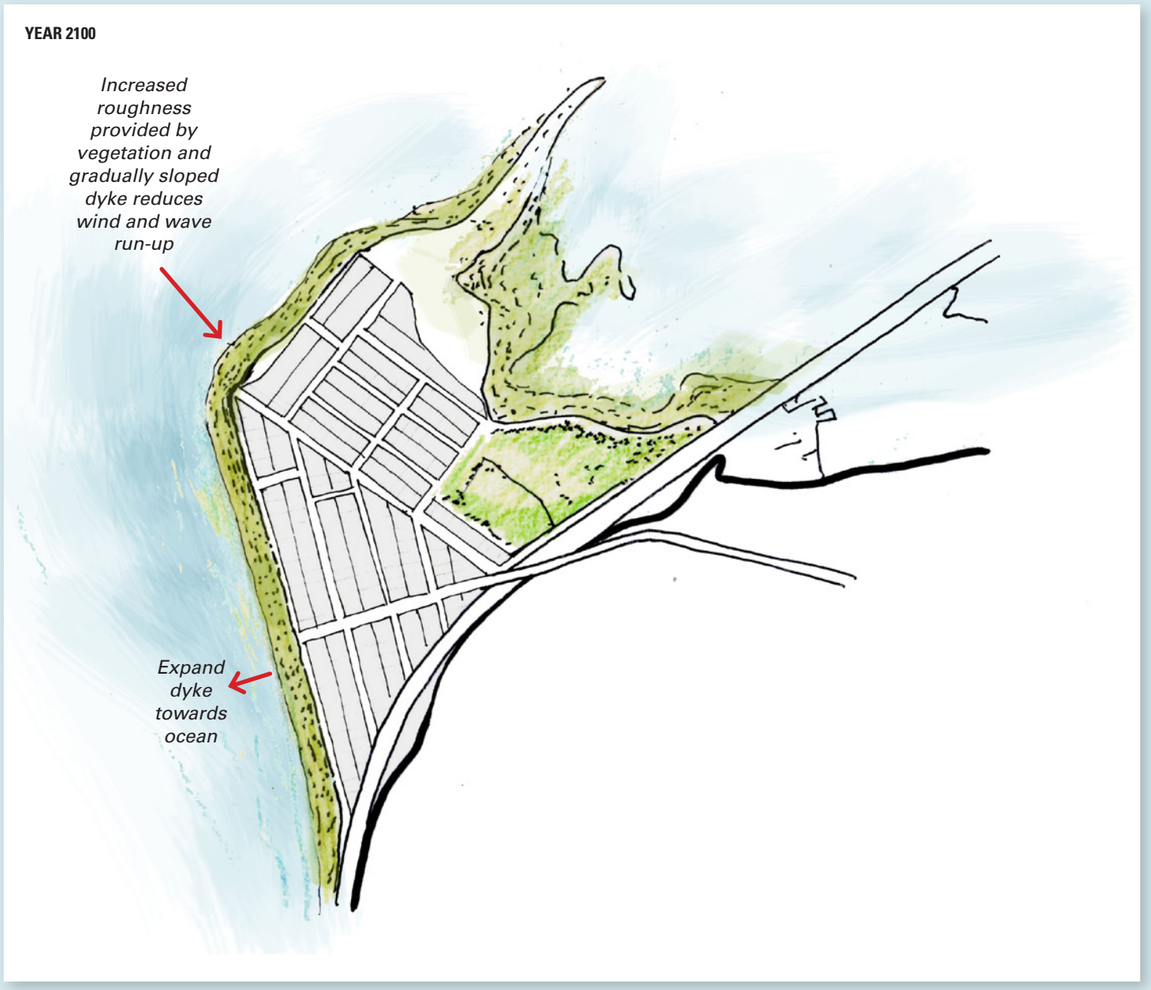
OVERALL ASSESSMENT: ***Most viable option in the long term.***
TECHNICAL RANKING: ***1st***

RISK ASSESSMENT HEAT MAP

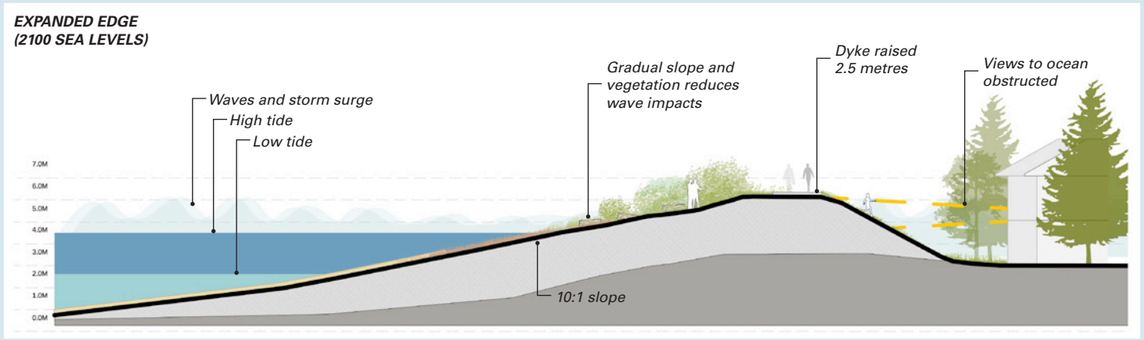
The table below provides a high-level overview of risk for each option. Risk is defined as the combination of the likelihood that an option will fail with the impact its failure would have on identified community values. A detailed description of how the likelihood of a failure was calculated is included 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				BARRIER ISLAND / SPIT	
High				EXPANDED EDGE	MUD BAY BARRIER
Medium					
Low					
Very Low	MANAGED RETREAT				

OPTION 1: EXPANDED EDGE



WHAT THIS COULD LOOK LIKE



Section of expanded edge and raised dyke

Raised dyke protects from storm surge and accommodates trails and other uses

Vegetated dykes reduce wind and wave run up

OPTION DESCRIPTION

This option proposes building the beach out in front of the existing shoreline to reduce the slope of the foreshore and, in turn, reduce wave run-up. By 2100, the dyke would be on average 2.5 metres higher than today with ocean front views severely impacted. The raised and expanded dyke will provide protection against overtopping and erosion. However, this option is considered high risk because of the high likelihood of failure of the dykes and potential detrimental impacts from flooding. Furthermore, given the sandy ground, seepage issues will accelerate with sea level rise. To help manage some seepage issues, perforated piping will need to be added over time to pump groundwater into the ocean. In addition, all homes and roadways will need to be raised by about 1 metre by the year 2100. The option would be phased over time, however, continuing to adapt to higher sea levels beyond the year 2100 may be challenging from a seepage perspective.

INFRASTRUCTURE, EARTHQUAKE & LANDUSE CHANGES & DESIGN

Reduction in dyking: *None.*

New dykes: *None. Existing dykes would be raised by 2.5 metres and the edge expanded towards the ocean with a 10:1 slope ratio.*

Earthquake design: *None.*

Re-purposed land: *Raising of roads lanes will require additional land on the sides of existing roads as the footprint of a raised road is greater.*

Relocated roads/rail lines: *None. However, 14 km of road lanes in Crescent Beach need to be raised by 1 metre or more to remain usable due to high degree of ground seepage.*

OPTION 1: EXPANDED EDGE

VERY LOW | LOW | MEDIUM | HIGH | VERY HIGH

VALUES CRITERIA

FAR WORSE ← NO CHANGE → FAR BETTER

RESIDENTS

No residents are relocated. Views of oceanfront properties would be impacted by raising current on-shore dykes by 2.5 metres. All housing is raised by about 1 metre due to seepage issues.

Indicator: *People permanently displaced*

SLIGHTLY WORSE

ENVIRONMENT

Even though shoreline habitats could be improved using a Green Shores approach, building out into the ocean would disrupt coastal processes and critical habitat areas, including eelgrass beds.

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

SLIGHTLY WORSE

INFRASTRUCTURE

All roads and utilities adapt by raising or floodproofing and residents do not experience any change in infrastructure services.

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

NO CHANGE

ECONOMY

Local businesses would likely not be impacted, and furthermore, the expanded beach area might encourage more tourists to visit the area.

Indicator: *Revenue*

SLIGHTLY BETTER

RECREATION

Coastal recreation opportunities could be improved through a trail network, lookouts, and an expanded shoreline for recreation and enhanced accessibility using a more gradual slope.

Indicator: *Diversity of recreational opportunities*

MODERATELY BETTER

CULTURE

Construction could disturb archaeological artifacts and human remains.

Indicator: *Opportunities for traditional practices*

SLIGHTLY WORSE

COST CRITERIA

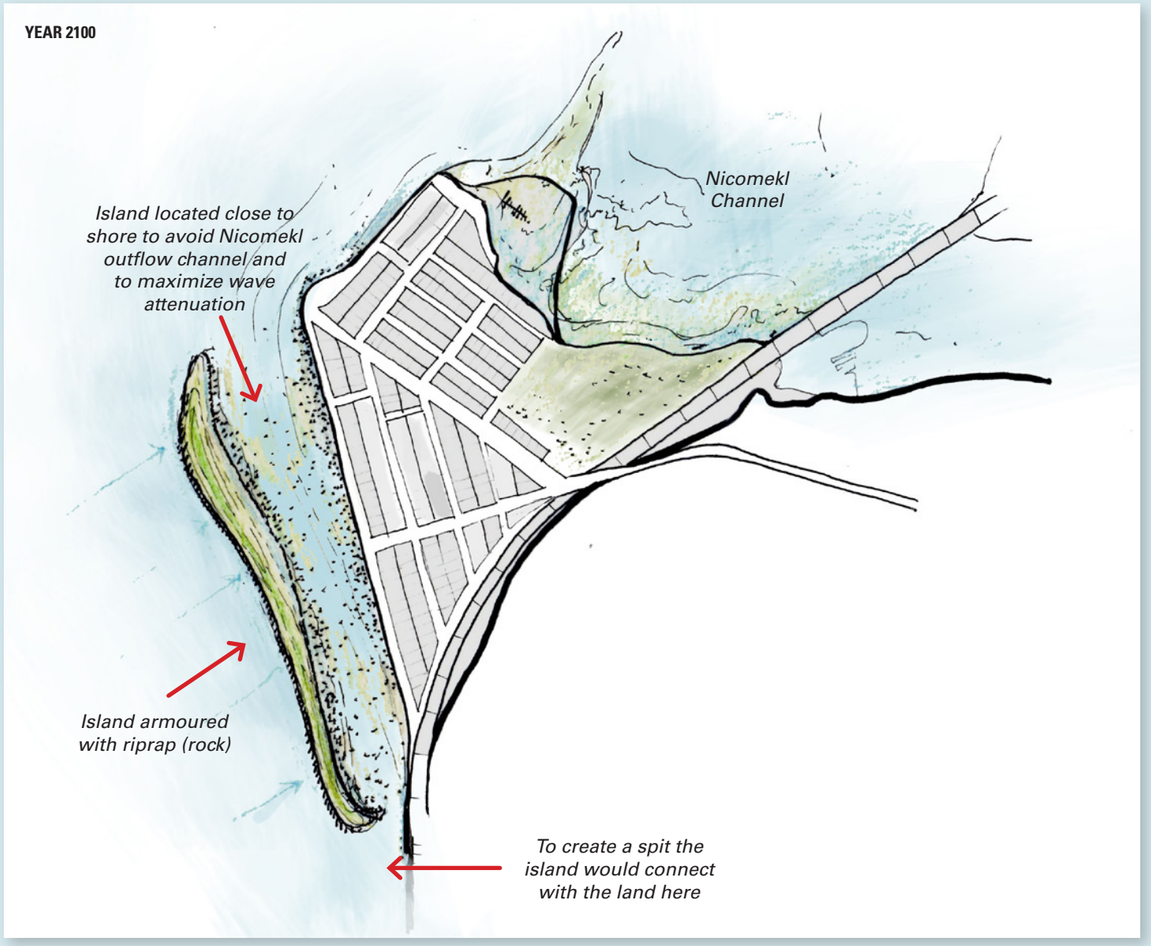
CAPITAL COST	OPERATION & MAINTENANCE COST	OTHER INFRASTRUCTURE COST	FUTURE ADAPTATION COST
$100M - $1B	*$1M - $10M*	*$10M - $100M*	*$100M - $1B*

IMPACT & RISK OF FAILURE

		Impact of Failure on Value	x	Likelihood of Failure of Option	=	Risk
RESIDENTS	Although the dykes would be raised and widened, a breach would affect all housing in Crescent Beach, likely leading to some loss of life.					
ENVIRONMENT	Contamination from debris and garbage. Recoverable without permanent harm to species.					
INFRASTRUCTURE	The entire area is cutoff. Roads inundated and potentially severely eroded. Other services, such as sewer, water, gas, cable, hydro, etc. will also be impacted.					
ECONOMY	Extensive direct and indirect losses.					
RECREATION	Temporary disruption to recreation amenities (shoreline trails, boat park, tennis courts, and parks), but recoverable.					
CULTURE	A dyke breach and flood event would have low archeological impacts.					

Overall Risk:

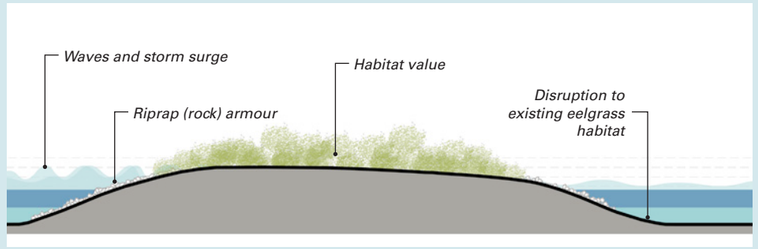
OPTION 2: BARRIER ISLAND/SPIT

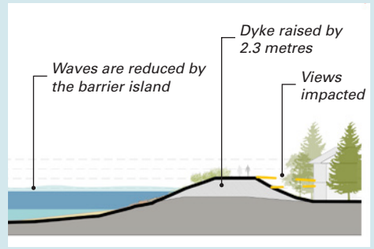


OPTION DESCRIPTION

A kilometre-long barrier island or spit parallel to the southern portion of Crescent Beach between the Nicomekl outflow channel and the shoreline that is 6 metres above sea level by 2100 is constructed offshore to reduce onshore wave action. The barrier island or spit needs to be located close to the shore to effectively reduce wave run-up, impacting views from the coastline. Existing onshore dykes need to be raised throughout Crescent Beach as the barrier island alone is not enough to prevent future flooding. The southwest dykes would be raised by 2.3 metres, about 30 centimetres lower than required by the Expanded Edge option, and the northwest and northeast dykes would be raised by up to 3 metres,. This option is considered very high risk because of the very high likelihood of failure of the dykes and potential detrimental impacts from flooding. The Barrier Island or Spit does not address issues of seepage or groundwater flooding, and perforated piping will need to be added over time to pump groundwater into the ocean. In addition, all homes and roadways will need to be raised by about 1 metre by the year 2100. Continuing to adapt to higher sea levels beyond the year 2100 may be challenging from a seepage perspective.

WHAT THIS COULD LOOK LIKE





Section of barrier island/spit and raised dyke

Shady Island, Richmond BC

INFRASTRUCTURE, EARTHQUAKE & LANDUSE CHANGES & DESIGN

Reduction in dyking: *None.*

New dykes: *None. The new barrier island would be 1 km long and 7 m high (6 metres above mean sea level). Existing dykes on the southwest would be raised by 2.3 metres, and dykes on northwest and northeast sides would be raised by 2 to 3 metres, as the barrier island does not protect that side.*

Earthquake design: *None.*

Re-purposed land: *Raising of roads lanes will require additional land on the sides of existing roads as the footprint of a raised road is greater.*

Relocated roads/rail lines: *None; however, 14 km of road lanes in Crescent Beach need to be raised by more than 1m to remain usable due to high groundwater seepage.*

OPTION 2: BARRIER ISLAND/SPIT

VERY LOW | LOW | MEDIUM | HIGH | VERY HIGH

VALUES CRITERIA

FAR WORSE ← NO CHANGE → FAR BETTER

RESIDENTS

No residents are relocated. Views are significantly impacted by both the 7 metre high, 1 km long barrier island/spit and by the raising of current on-shore dykes 2.3 metres. All housing is raised by about 1 metre due to seepage issues.

Indicator: *People permanently displaced*

MODERATELY WORSE

ENVIRONMENT

Even though the barrier island/spit could be designed as a habitat island it would likely displace eelgrass habitat and would affect beach shape and sedimentation processes as well as water quality landward.

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

MODERATELY WORSE

INFRASTRUCTURE

All roads and utilities adapt by raising or floodproofing and residents do not experience any change in infrastructure services.

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

NO CHANGE

ECONOMY

Local businesses would likely not be impacted. Even though the barrier island might encourage more tourists to visit the area, the changes would not be significant.

Indicator: *Revenue*

NO CHANGE

RECREATION

At low tide, visitors could walk out to the island and at high tide, the island is a destination by boat or paddle board.

Indicator: *Diversity of recreational opportunities*

SLIGHTLY BETTER

CULTURE

Construction could disturb archeological artifacts and human remains.

Indicator: *Opportunities for traditional practices*

SLIGHTLY WORSE

COST CRITERIA

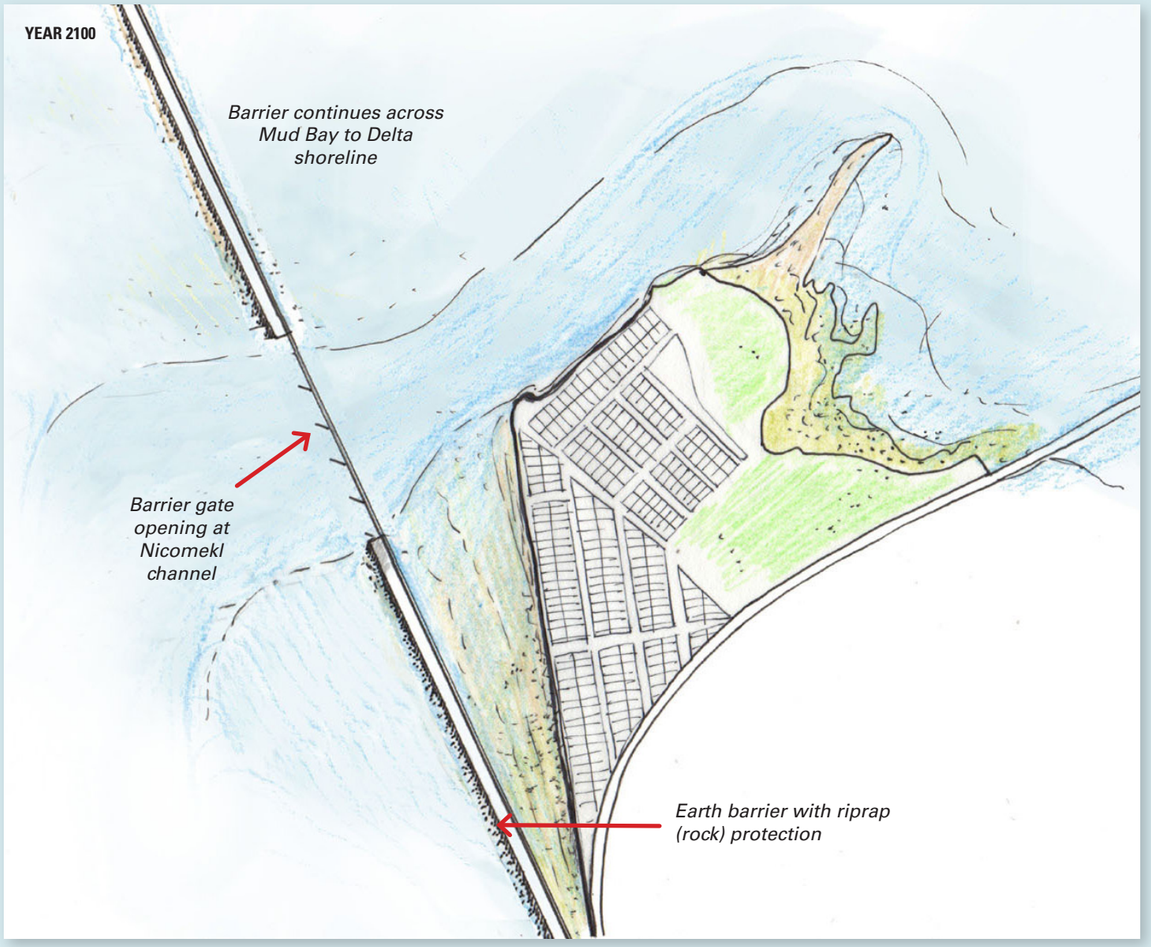
CAPITAL COST	OPERATION & MAINTENANCE COST	OTHER INFRASTRUCTURE COST	FUTURE ADAPTATION COST
$1B - $4B	*$1M - $10M*	*$10M - $100M*	*$1B - $4B*

IMPACT & RISK OF FAILURE

		Impact of Failure on Value	x	Likelihood of Failure of Option	=	Risk
RESIDENTS	All housing within coastal floodplain could be affected, and a sudden dyke breach could lead to significant loss of life from both inundation and erosion.					
ENVIRONMENT	Some contamination from debris and garbage. Recoverable without permanent harm to species.					
INFRASTRUCTURE	The entire area is cutoff. Roads are inundated and potentially severely eroded. Other services, such as sewer, water, gas, cable, hydro, etc. will also be impacted.					
ECONOMY	Extensive direct and indirect losses.					
RECREATION	Temporary disruption to recreation, but recoverable over time.					
CULTURE	A dyke breach and flood event would have low archeological impacts.					

Overall Risk:

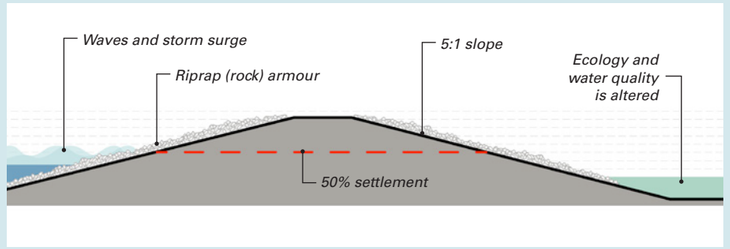
OPTION 3: MUD BAY BARRIER

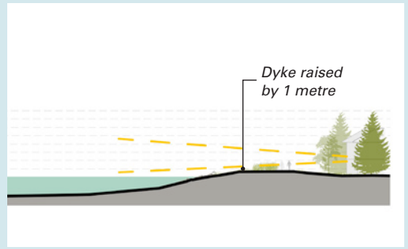


OPTION DESCRIPTION

A 4.5 km 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 is built at an average height of 10 metres above present sea level ***to allow the barrier to settle into the mud by half of its constructed height****. The height of the structure will impact views from Crescent Beach. All of the existing dykes in Crescent Beach need to be maintained; however existing dyke raising* ***would be significantly reduced****. 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. This is the only option that responds to flood hazards beyond Crescent Beach and reduces dyke upgrade requirements in Mud Bay and along the Nicomekl and Serpentine Rivers. The option is associated with very high risk to the entire floodplain population. Even a moderate earthquake would likely cause damage to the barrier resulting in compromised flood control until costly repairs can be made.*

WHAT THIS COULD LOOK LIKE





Section of Mud Bay barrier

Louisiana surge barrier under construction
CC-by, Team New Orleans US Army Corps of Engineers, flickr.com

Thames Barrier, London

INFRASTRUCTURE, EARTHQUAKE & LANDUSE CHANGES & DESIGN

Reduction in dyking: *None. Existing dykes need to be maintained and probably raised (exact height to be determined with further modeling).*

New dykes: *4.5 km long, 11 m high ocean barrier (crest elevation = 10 m). 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 rock. Once built, it is difficult to raise. A new 350 metre long gated structure is added to the barrier to allow rivers to drain and permit navigation.*

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 would likely be 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. Marina traffic affected by barrier gates. Roads will likely require some raising but probably less than for the other dyking options.*

OPTION 3: MUD BAY BARRIER

VERY LOW | LOW | MEDIUM | HIGH | VERY HIGH

VALUES CRITERIA

FAR WORSE ← NO CHANGE → FAR BETTER

RESIDENTS

No residents are forced to relocate, but views from shore and homes are negatively impacted. All housing needs to be raised due to seepage issues, but not as high as other options.

Indicator: *People permanently displaced*

MODERATELY WORSE

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 m wide and 5,000 m 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 roads and utilities adapt by raising or floodproofing and residents do not experience any change in infrastructure services.

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

NO CHANGE

ECONOMY

No businesses are displaced or relocated. Businesses relying on Beach recreation or ocean views may be impacted.

Indicator: *Revenue*

SLIGHTLY WORSE

RECREATION

Even though the barrier could combine different recreational functions (trails/lookouts/kayak launch) to make the barrier a destination, it is likely that deterioration of water quality and beach quality will reduce overall recreation in Crescent Beach.

Indicator: *Diversity of recreational opportunities*

SLIGHTLY WORSE

CULTURE

This option could disturb archeological artifacts and human remains.

Indicator: *Opportunities for traditional practices*

MODERATELY WORSE

COST CRITERIA

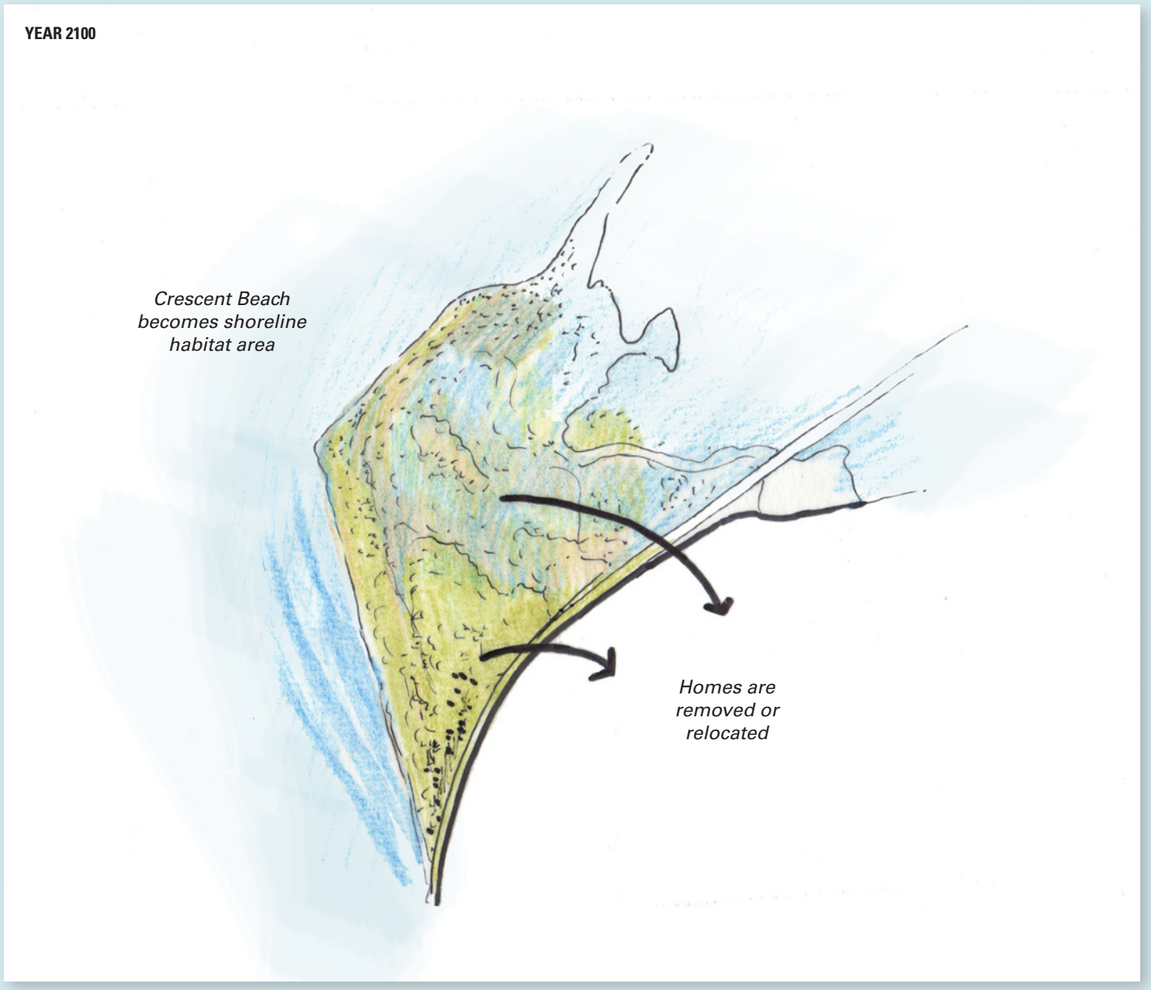
CAPITAL COST	OPERATION & MAINTENANCE COST	OTHER INFRASTRUCTURE COST	FUTURE ADAPTATION COST
more than $4B	*$1M - $10M*	*less than $10M*	*$1B - $4B*

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 dykes failing in multiple locations. In the event of sudden barrier failure there could be significant loss of life.					
ENVIRONMENT	Contamination from debris and garbage. Recoverable without permanent harm to species.					
INFRASTRUCTURE	A sudden barrier failure could severely impact all infrastructure within the floodplain. High overland erosion hazard.					
ECONOMY	Extensive direct and indirect losses.					
RECREATION	Permanent disruption to recreation areas.					
CULTURE	A dyke breach and flood event would have low archeological impacts.					

Overall Risk:

OPTION 4: MANAGED RETREAT



WHAT THIS COULD LOOK LIKE

Crescent beach becomes habitat area

House relocated from seaside in New Zealand
CC-by Sid Mosdell, flickr.com

Environmental management of coastal habitats at Crescent Beach

OPTION DESCRIPTION

Over time, as sea levels continue to rise and flooding worsens, residents and businesses relocate from Crescent Beach and the area returns to its original natural state, before European Settlement in the 1900's. The option assumes that other areas are made available for residents, businesses and institutions and the approximately 1,400 people who live and work in Crescent Beach. The community represents 0.7% of Surrey's gross assessed value (2016) and 0.2% of Surrey's total residential floor space. By the end of the century the area is turned into a flood tolerant park with enhanced environmental habitat and limited seasonal hiking trails. Managed Retreat is likely to offer the most viable, long-term solution in this high flood and earthquake hazard area.

INFRASTRUCTURE, EARTHQUAKE & LANDUSE CHANGES & DESIGN

Reduction in dyking: *2.5 km of dykes surrounding Crescent Beach.*

New dykes: *None.*

Earthquake design: *None.*

Re-purposed land: *0.54 km^2 of residential and park land at Crescent Beach converted to natural habitat.*

Relocated roads/rail lines: *Local roads in Crescent Beach removed. Bayview Street would be raised to avoid flooding. Adjacent services and housing would be floodproofed as necessary. Beach access may be retained in some areas, with roads converted to seasonal hiking trails.*

OPTION 4: MANAGED RETREAT

VALUES CRITERIA

NO CHANGE
FAR WORSE ← → FAR BETTER

RESIDENTS

Approximately 500 homes are relocated from Crescent Beach over time, representing 15% of Surrey's Heritage Sites.

Indicator: *People permanently displaced*

FAR WORSE

ENVIRONMENT

Through a managed retreat, there would be more room available for eelgrass and salt marsh to migrate with sea level rise, and further improvements to shoreline habitat could be made.

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

FAR BETTER

INFRASTRUCTURE

Bayview Street adapts by being raised, and all utilities adapt as needed. Citizens would no longer be able to access the old beach areas by car, but new beaches will form.

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

NO CHANGE

ECONOMY

Businesses would be relocated or closed over time. Over time a business will develop on the edge of the bluffs and serve people wanting to visit new shoreline habitat area.

Indicator: *Revenue*

MODERATELY WORSE

RECREATION

Beach access could be maintained in some areas. In time, most of Crescent Beach would be accessible along the new shoreline or by boat or paddle board only.

Indicator: *Diversity of recreational opportunities*

FAR BETTER

CULTURE

With retreat, natural erosion would disturb subsurface soils and therefore 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
$1B - $4B	—	*less than $10M*	—

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 the Crescent Beach area would be at risk. No loss of life expected.	●		●		●
ENVIRONMENT	Managed retreat will include removal of primary sources of pollution.	●		●		●
INFRASTRUCTURE	Limited infrastructure is left in place. Metro Vancouver water and sewage mains would be floodproofed, as would servicing to homes along Bayview Road, which would be raised.	●		●		●
ECONOMY	Given that there are no dykes remaining to be breached, no negative economic impacts are expected from flooding.	●		●		●
RECREATION	Recreation features (e.g., trails) adapted to retreat, however a large flood event might temporarily disrupt a new trail system.	●		●		●
CULTURE	Retreat, would likely disturb archeological artifacts and human remains, but large flooding events are not expected to create additional 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	EXPANDED EDGE	BARRIER ISLAND/ SPIT	MUD BAY BARRIER	MANAGED RETREAT
VALUES CRITERIA					
RESIDENTS *People permanently displaced*	FAR WORSE	SLIGHTLY WORSE	MODERATELY WORSE	MODERATELY WORSE	FAR WORSE
ENVIRONMENT *Impacts to wetland habitats, freshwater fish habitat & riparian areas*	FAR WORSE	SLIGHTLY WORSE	MODERATELY WORSE	FAR WORSE	FAR BETTER
INFRASTRUCTURE *Percent of service/ transportation infrastructure made vulnerable*	FAR WORSE	NO CHANGE	NO CHANGE	NO CHANGE	NO CHANGE
ECONOMY *Revenue*	FAR WORSE	SLIGHTLY BETTER	NO CHANGE	SLIGHTLY WORSE	MODERATELY WORSE
RECREATION *Diversity of recreational opportunities*	FAR WORSE	MODERATELY BETTER	SLIGHTLY BETTER	SLIGHTLY WORSE	FAR BETTER
CULTURE *Opportunities for traditional practices*	MODERATELY WORSE	SLIGHTLY WORSE	SLIGHTLY WORSE	MODERATELY WORSE	MODERATELY WORSE
IMPACT & RISK OF FAILURE					
OVERALL RISK	VERY HIGH	HIGH	VERY HIGH	VERY HIGH	VERY LOW
COST CRITERIA					
CAPITAL COST	—	$100M - $1B	$1B - $4B	MORE THAN $4B	$1B - $4B
OPERATION & MAINTENANCE COST	MORE THAN $10M	$1M - $10M	$1M - $10M	$1M - $10M	—
OTHER INFRASTRUCTURE COST	MORE THAN $100M	$10M - $100M	$10M - $100M	LESS THAN $10M	LESS THAN $10M
FUTURE ADAPTATION COST	$1B - $4B	$100M - $1B	$1B - $4B	$1B - $4B	—

NOTES

APPENDIX

VERY LOW LOW MEDIUM HIGH VERY HIGH

EXPANDED EDGE

Likelihood of Failure

Dyke overtopping: Medium – Dyke is raised and has gentler side slope reducing wave runup issues.

Dyke erosion failure: Low - Dyke has high level of vegetation and gentle side slope.

Earthquake failure: High - Widened dyke built to better standards but still will not meet earthquake requirements.

Mechanical failure: High - Very poor drainage requires pumps to work almost continuously, making whole area vulnerable to pump station failure.

Seepage Increase: Very High - The ground is highly porous and although dykes are widened, ground seepage is not reduced. Roads, housing and other infrastructure such as sewer, water, gas, cable, and hydro must be raised.

Costs

Capital Cost of Implementation: Cost associated with raising dykes, expanding the edge and providing erosion protection.

O&M Cost: Upgrade erosion protection as needed. Replace pump station. Clear drainage pipes (significant deposition expected).

Other Infrastructure Cost: Raise roads, install perforated piping and deal with high seepage. Raise all remaining housing and other structures as necessary over time to avoid flooding by seepage.

Future Adaptation Cost: Beyond the year 2100, and with additional sea level rise all dykes must be raised again, erosion protection improved, and seepage addressed by raising house and infrastructure again.

BARRIER ISLAND/SPIT

Likelihood of Failure

Dyke overtopping: High - Would mitigate wave effects only on south side of Crescent Beach, and only by 0.5m. The option assumes that all dykes are raised.

Dyke erosion failure: Very High – For the dykes not protected by the Barrier Island/Spit.

Earthquake failure: Very High – Given soil conditions dykes cannot be designed for earthquakes.

Mechanical failure: High - Very poor drainage require pumps to work almost continuously, making area vulnerable to pump station failure.

Seepage Increase: Very High - Ground is highly porous and ground seepage is not reduced with this option. Roads, housing and other infrastructure such as sewer, water, gas, cable, and hydro must all be raised.

Costs

Capital Cost of Implementation: Raise dykes, improve erosion protection. Relocate existing services along dykes. Build island.

O&M Cost: Maintain dykes and upgrade erosion protection. Replace pump station. Clear drainage pipes (significant deposition expected). Barrier island/spit will require erosion protection upgrades and maintenance.

Other Infrastructure Cost: Raise roads, install perforated piping and deal with high seepage. Raise all remaining housing and structures as necessary over time to avoid flooding by seepage.

Future Adaptation Cost: Beyond the year 2100, and with additional sea level rise all the dykes and barrier island/spit must be raised, erosion protection improved, and seepage addressed by raising house and infrastructure again.

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: High - Flow velocities along Crescent Beach may increase (depending on capacity and location of barrier gates, there may be boating limitations and no more swimming). The barrier would be designed against wave erosion.

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

Mechanical failure: High - High potential for failure at gated structure due to barrier settlement.

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

Costs

Capital Cost of Implementation: Cost of Barrier with sea-gates is very high. Some additional costs for local drainage.

O&M Cost: Barrier and gated structure would be rated high-consequence if a failure occurred and require a high degree of maintenance.

Other Infrastructure Cost: Most costs considered part of regular upgrades.

Future Adaptation Cost: Some upgrades to existing ocean dykes 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.

MANAGED RETREAT

Likelihood of Failure

Dyke overtopping: Very Low - No dykes required.

Dyke erosion failure: Very Low - No protection required.

Earthquake failure: Very Low - Nothing to protect.

Mechanical failure: Very Low - Nothing to protect.

Seepage Increase: Very Low - No prevention measures needed.

Costs

Capital Cost of Implementation: Dependent on land compensation costs and costs to demolish, deconstruct and relocate houses and remove infrastructure.

O&M Cost: No maintenance required.

Other Infrastructure Cost: Minor costs to enhance overland flow to reduce erosion. Over time upgrades and/or relocation of BNSF line and Metro Vancouver water and sewage lines will be needed.

Future Adaptation Cost: Marginal costs associated with habitat improvement.

MORE INFORMATION

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