Transport Canada – Atlantic Region's Climate Risk Assessment of Ferry Terminals

TARA Climate Risk Assessment Tools and Frameworks Webinar

22 March 2021

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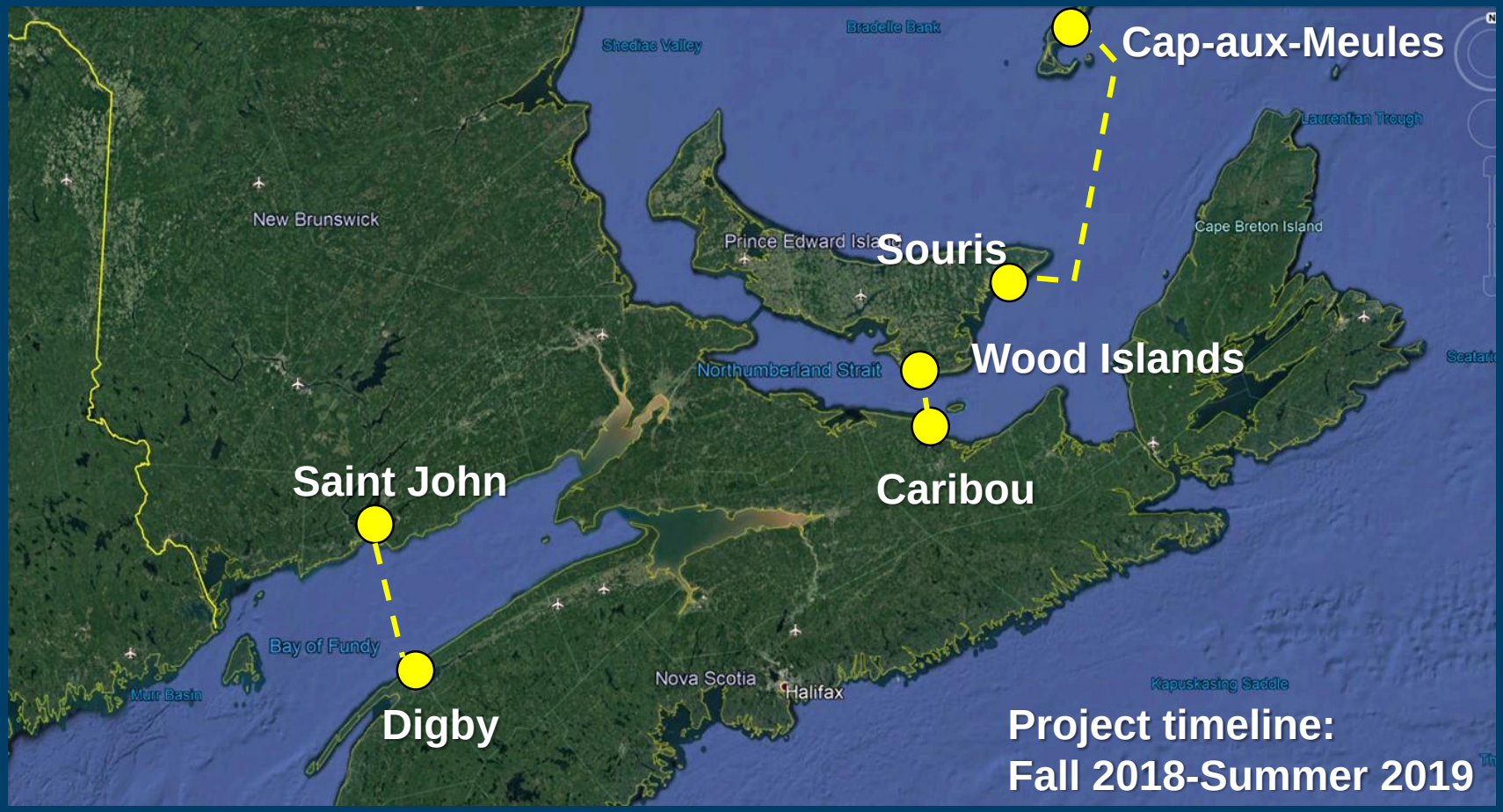
CBCL

Outline

- Goals of the TARA-funded project
- Selection of PIEVC Climate risk assessment tool
- Adapting the tool to facilitate decision making
- Q & A

Ferry Terminal Sites



Project goals

1. **Assess high-level climate change risks**
   Structural AND operational aspects

2. **Establish priorities** for:

- Maintenance and upgrades (remaining life cycle)
- Replacement with new infrastructure

Tool selection

Public Infrastructure Engineering Vulnerability Committee (PIEVC) – Engineers Canada

Risk Assessment tool designed for Infrastructure

- PIEVC Protocol leads practitioners through formal, documented process to identify vulnerabilities and resiliency
- Applies standard risk assessment processes to climate change concerns

PIEVC Risk Assessment

GOAL = DEFINE PRIORITIES

by answering 3 main questions

1. What can happen?
2. How likely is it to happen?
3. Given that it has happened, what are the consequences?

PIEVC Definition of Risk

Possibility of injury, loss or negative environmental impact created by a hazard.
Risk is quantified by

$$R = P \times S$$

P = Probability of a negative event **above a THRESHOLD**

S = Severity of the event, given that it has happened

Requires inputs from operator (from workshop) / designer / historical info

Risk Assessment Matrix

CLIMATE CHANGE

ADAPTATION

Flood

Flood

Flood

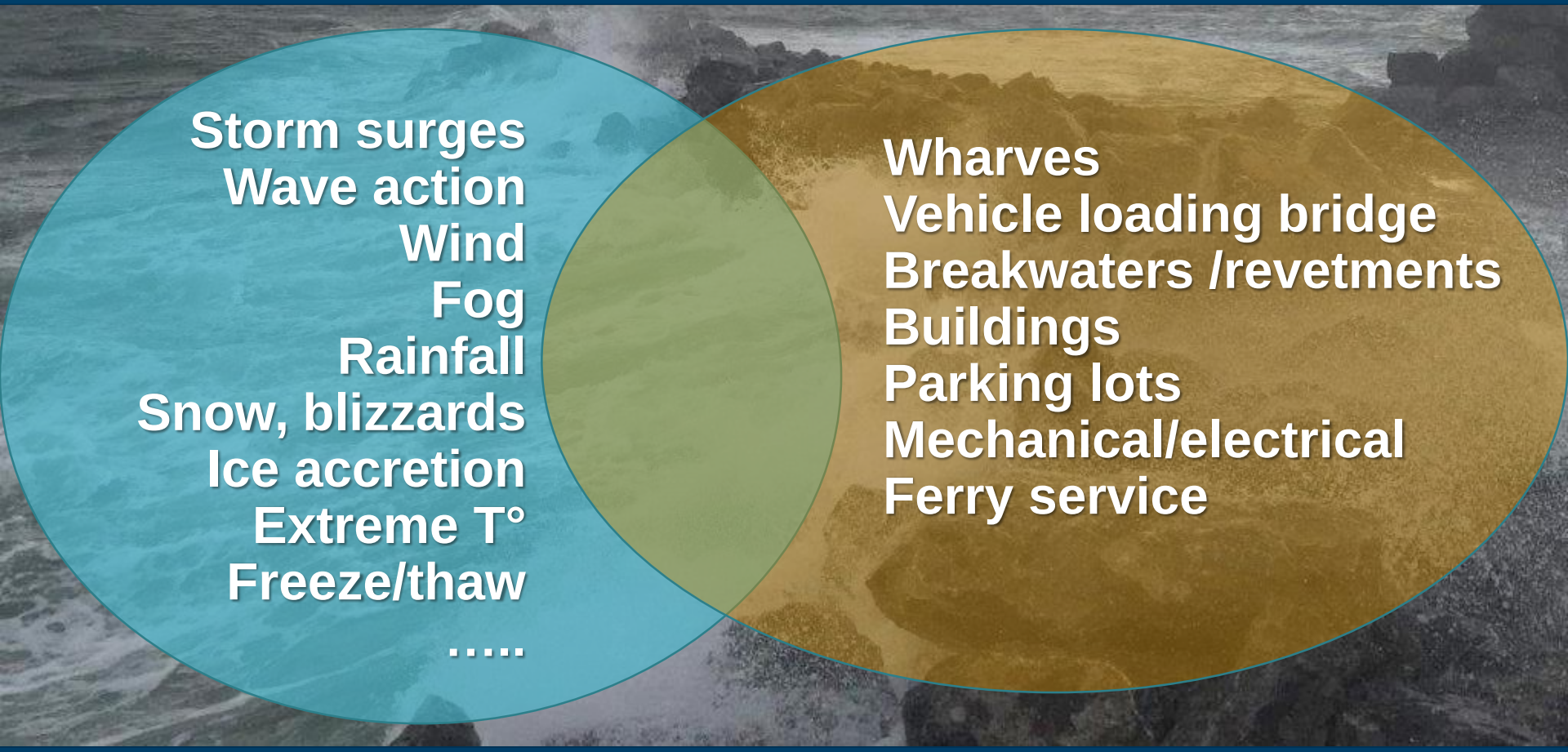
Consequence							
7							49
6	6	12	18	24	30		42
5	5	10	15	20	25		35
4	4	8	12	16	20		28
3	3	6	9	12	15		21
2	2	4	6	8	10		14
1	1	2	3	4	5		7
	1	2	3	4	5	6	7
	Probability of Occurrence						

Source
engineerscanada
ingénieurscanada

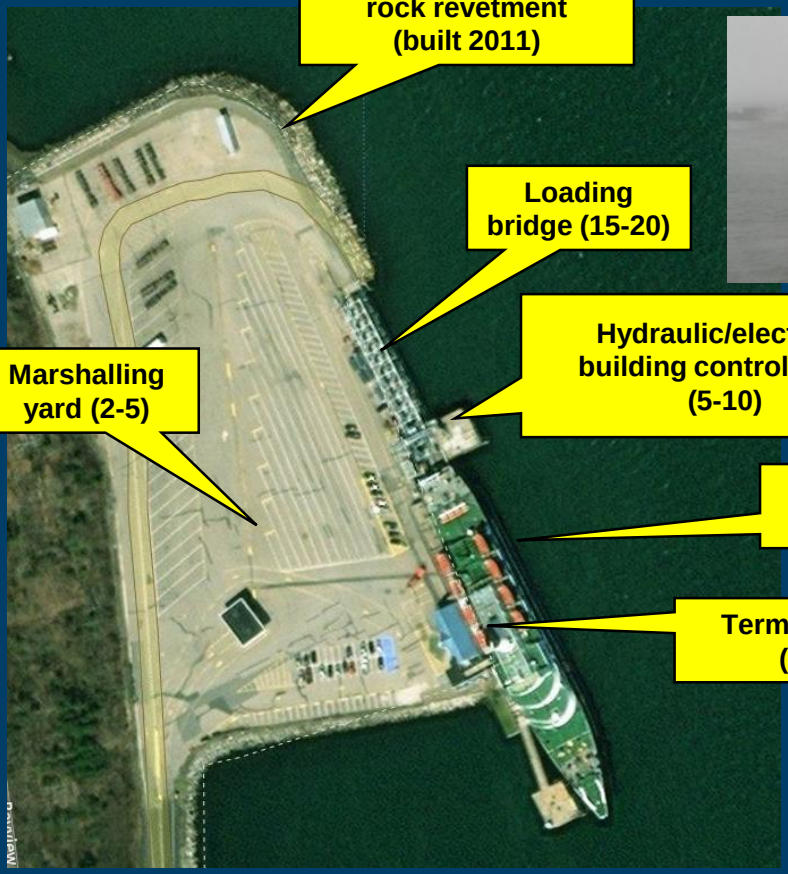
PIEVC Study Work Plan

1. Data gathering	Site infrastructure
2. Climate projections	Project Team
3. Site workshop	TC Mgmt, Engineers AND **O&M staff**
4. Structural & operational vulnerability assessments	Based on PIEVC protocol
5. Findings and Recommendations	

Climate vs. Infrastructure / Operations



Typical infrastructure (Digby NS)

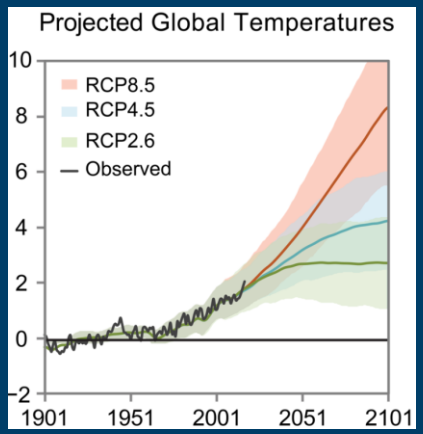


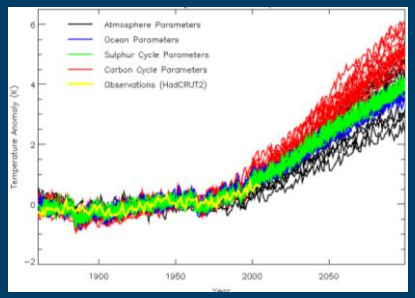
Assessment must include remaining service life (RSL)

Climate analyses

- Need understanding of atmospheric/climate processes, coastal processes, hydrology, and environmental
- Managing uncertainty - keep track of low/med/high estimates over multiple projection horizons and use ensemble of models
- Must use multiple data sources, ensemble of models
- Science and data availability is evolving rapidly

Variability :
- Emissions scenario
- Between climate models
- Within each model





Summary of Climate Projections

		Trend	
		Bay of Fundy	Gulf of St. Lawrence
Temperature	Higher temperatures	+	+
	Fewer frost days	-	- -
	Freeze-thaw cycles (with seasonal variations)	-	- -
Coastal processes	Sea level rise and extreme water levels	+	+
	Less sea ice	n/a	- -
	Wave action	+	++
	More sediment mobilization	+	++
Precipitation	Less snow	-	-
	More freezing rain	+	+
	Higher precipitation intensity	+	++
Wind	Possible increases in wind gusts, changes in direction		
	Warming favours conditions conducive to hurricanes		

More certainty

Less certainty

Joint probabilities: current limitations do not allow quantitative assessment

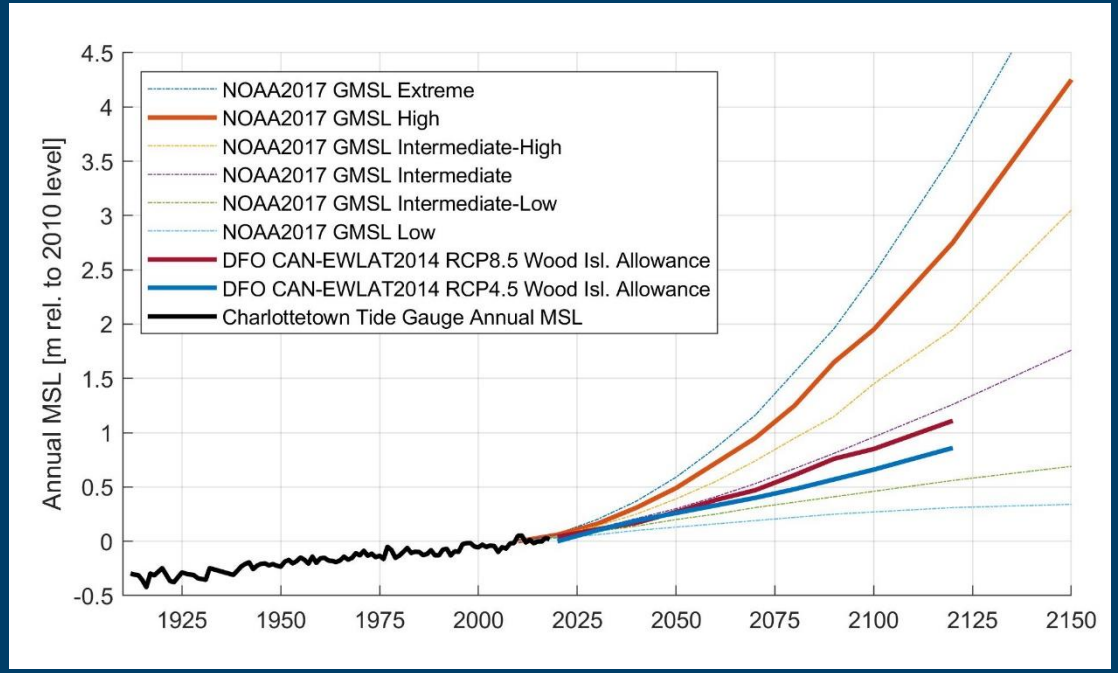
Adapting PIEVC Scoring to Project

PIEVC limitation: Severity may increase with the level of threshold exceedance

Probability modified from PIEVC to suit project goals, i.e. operations focus	Score	Severity
Negligible –*Once in 100 years*	0	Negligible Not Applicable
Highly Unlikely - *Once in 10 years*	1	Very Low Some Measurable Change
Remotely Possible - *Once in 2-5 years*	2	Low Slight Loss of Serviceability
Possible Occasional - *Once a years*	3	Moderate Loss of Serviceability
Somewhat Likely - *A few times per year*	4	Major Loss of Serviceability Some Loss of Capacity
Likely - *Monthly*	5	Loss of Capacity Some Loss of Function
Probably - *Weekly*	6	Major Loss of Function
Near certain – *Daily*	7	Extreme Loss of Asset

Adapting PIEVC Tool to Climate Projections

Example with sea level rise projections



Basic PIEVC:

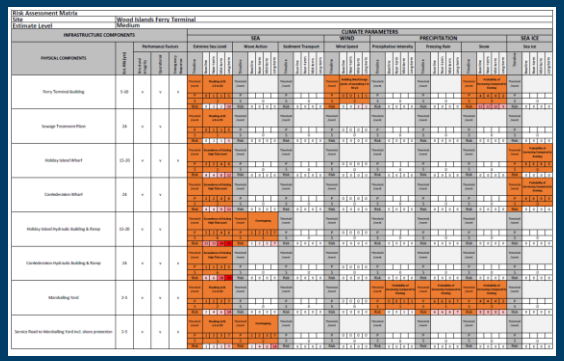
- **baseline climate**
- **'future' climate**

-> need to better define time horizons

Used 4 time horizons
2018 2040s 2070s 2120

Comparative Risk Rankings

Risk matrices



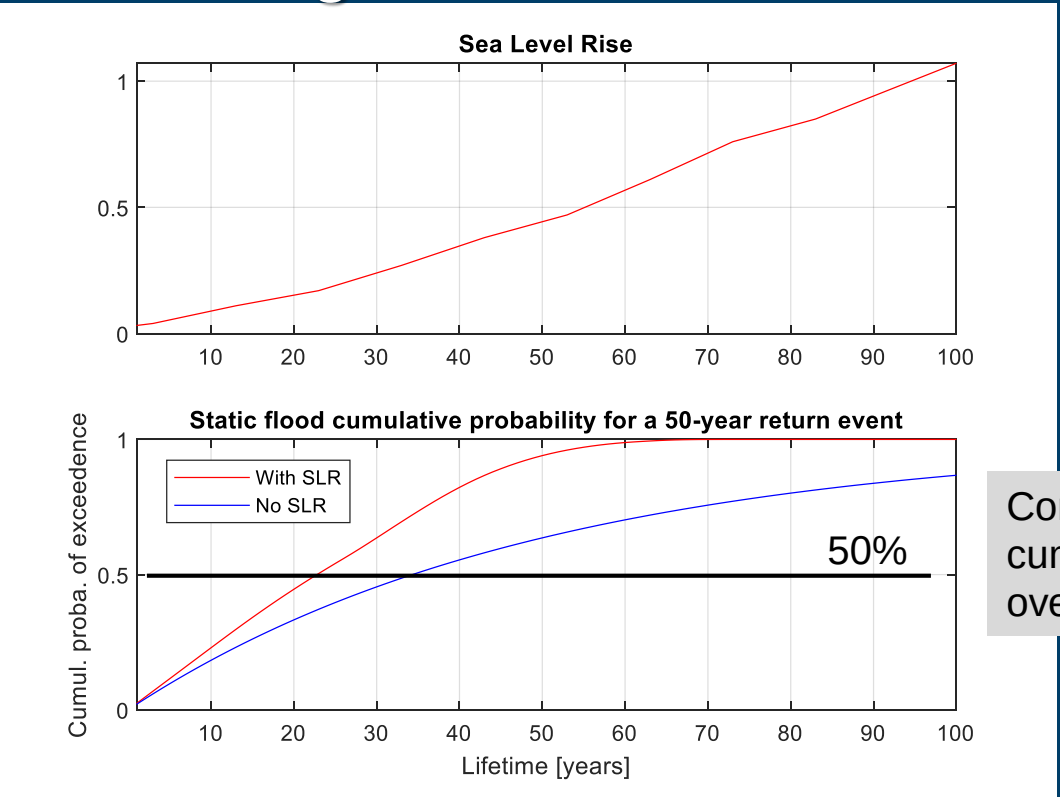
Factors of most concern

- **winds (operations)**
- **coastal flooding**

Assets (est. Remaining Service Life in years) and Operations		Climate Parameter	Timeline			
			Baseline	Near-term (20 yrs)	Mid-term (50 yrs)	Long-term (100 yrs)
Ferry Service	Summer	Wind	4	4	4	4
	Fall	**Wind**	20	20	20	20
		Sea Ice	4	4	4	0
Hydraulic Building & Ramp (15-20)		**Extreme sea level**	12	12	24	36
Terminal Building (5-10)		Extreme sea level	0	2	2	10
		Wind	0	0	3	3
		Snow	12	12	12	9
Wharf (15-20)		Extreme sea level	4	4	8	12
Marshalling Yard (2-5)		Extreme sea level	2	4	6	14
		Rain	0	0	1	1
		Freezing Rain & Ice Storms	6	6	6	7
		Snow	8	8	8	6
Wastewater Treatment Plant		Extreme sea level	0	1	1	5
Breakwaters (15-20)		Extreme sea level	1	2	3	7
		Wave Action	1	2	3	7
Dredging		Sediment Transport	4	4	6	6

Dealing with Non-Stationary Processes

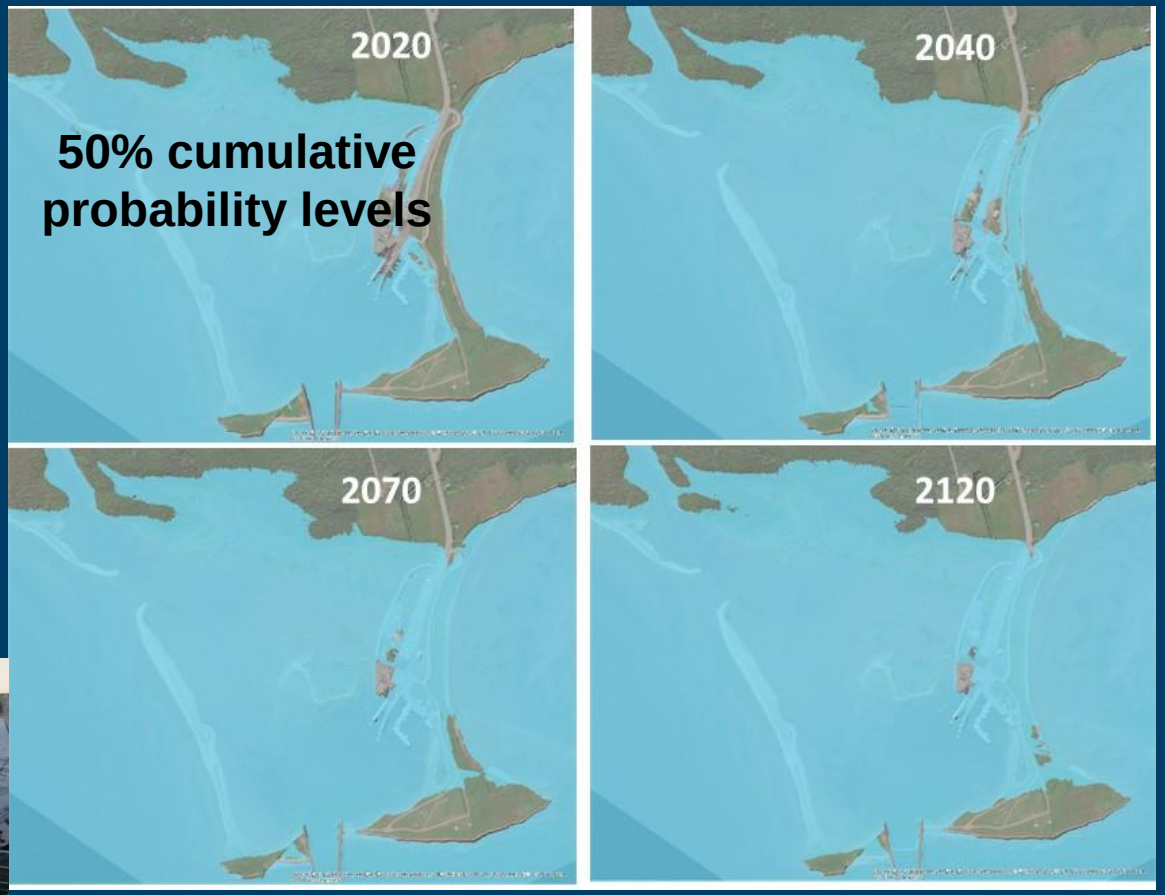
Coastal Flooding over Infrastructure Lifetime



Concept of cumulative probability over a given lifetime

Coastal Flood Mapping (example: Wood Islands)

To communicate future risks even when historical conditions have been manageable



Compared flood vulnerability over 100 years

Comparison across Ferry Terminal Sites PIEVC 0-7 proba scale

	Digby				Saint John			
	2018	2040	2070	2120	2018	2040	2070	2120
Low SLR	0.0	0.0	0.0	0.1	0.0	0.0	0.3	3.9
Med SLR	0.0	0.0	0.0	3.0	0.0	0.0	1.0	5.0
High SLR	0.0	0.0	0.3	7.0	0.0	0.2	4.3	7.0

	Caribou				Wood Islands			
	2018	2040	2070	2120	2018	2040	2070	2120
Low SLR	0.0	0.1	0.4	2.0	1.1	1.8	3.0	5.8
Med SLR	0.0	0.1	0.7	4.0	1.2	1.7	3.5	7.0
High SLR	0.0	0.3	2.4	7.0	1.2	2.8	6.5	7.0

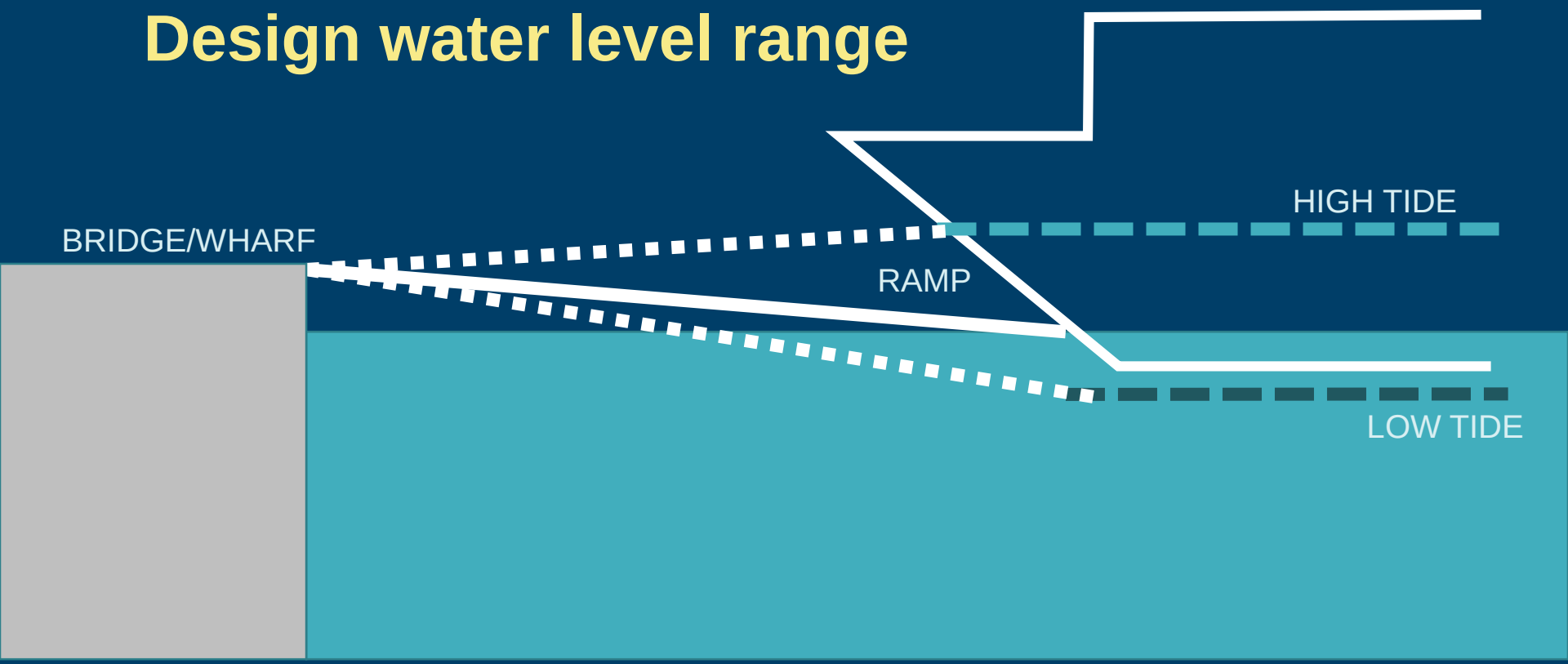
	Souris				Cap-aux-Meules			
	2018	2040	2070	2120	2018	2040	2070	2120
Low SLR	0.1	0.3	1.0	2.8	0.0	0.0	0.2	3.4
Med SLR	0.1	0.3	1.1	4.4	0.0	0.0	0.7	4.6
High SLR	0.2	0.9	3.7	7.0	0.0	0.1	3.3	7.0

Sea Level Rise downtime analysis

for vehicle loading bridge

Sea Level Rise downtime analysis

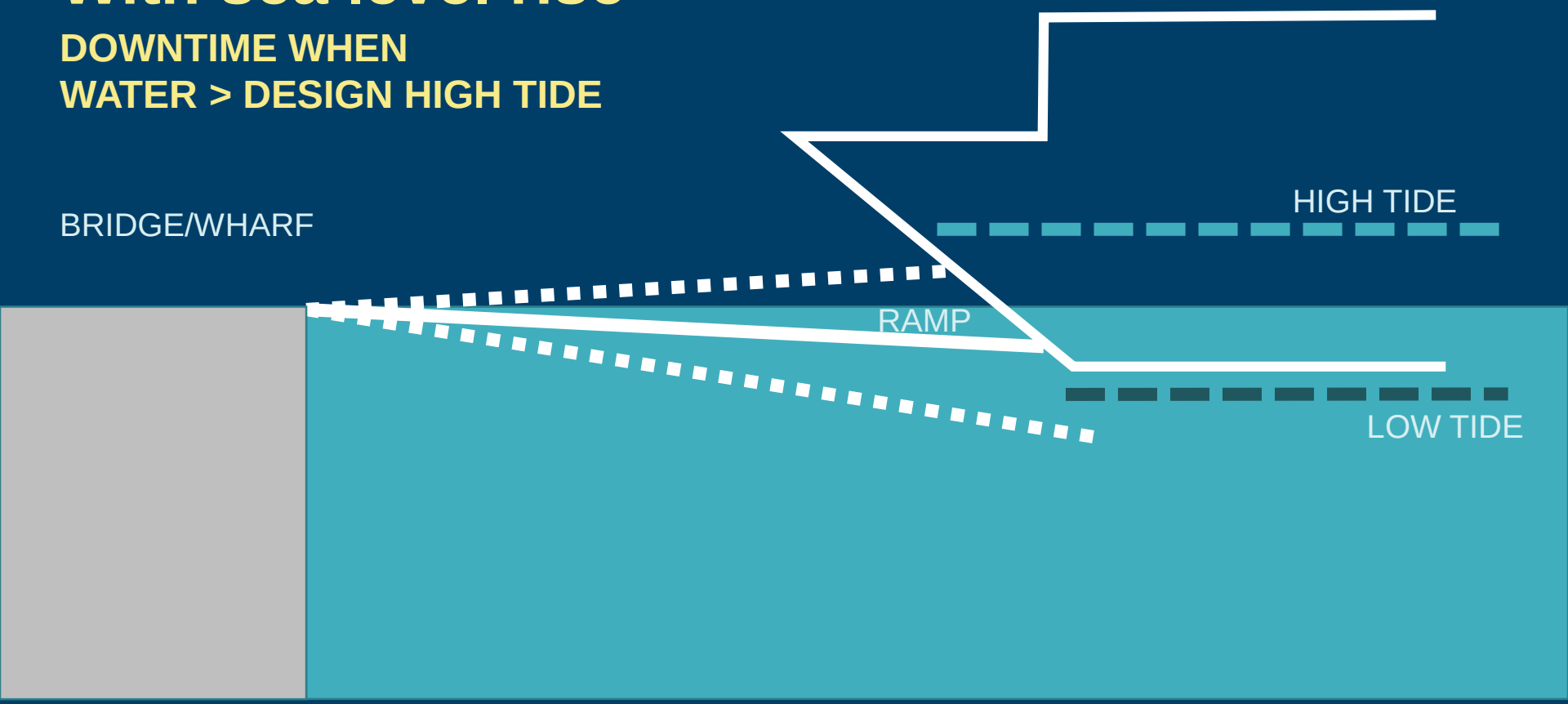
Design water level range



Sea Level Rise downtime analysis

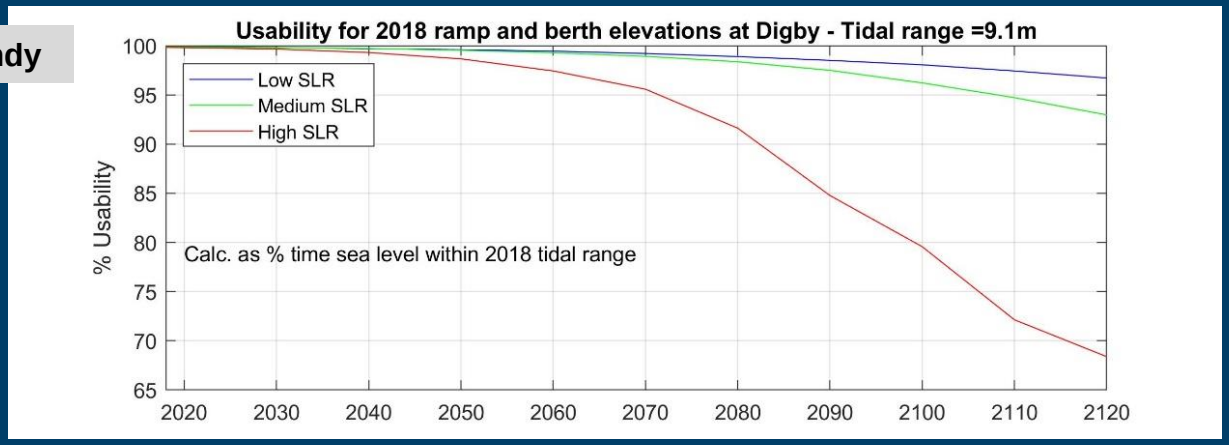
With sea level rise

DOWNTIME WHEN
WATER > DESIGN HIGH TIDE

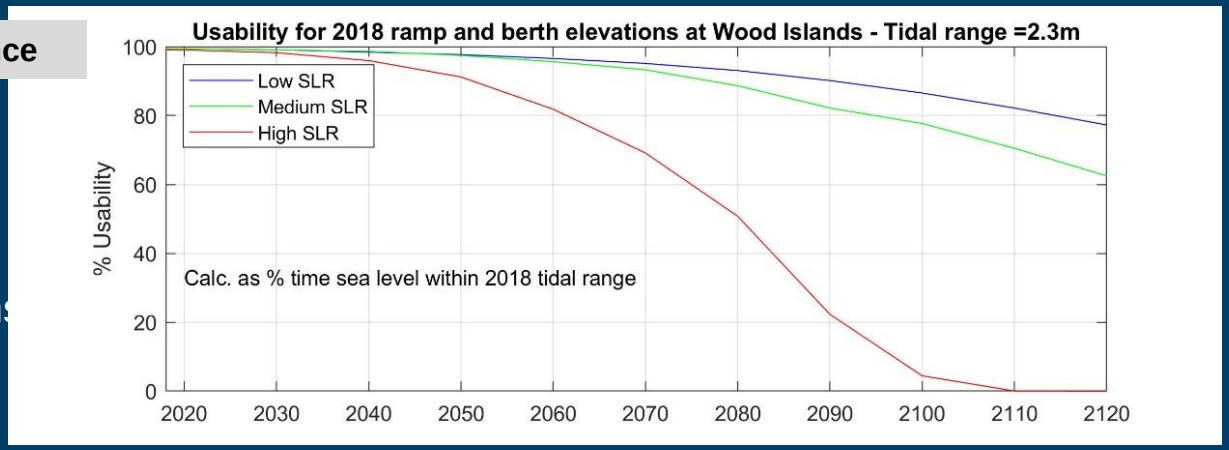


SLR downtime over 100 years

Bay of Fundy



Gulf of St Lawrence



Assuming constant infrastructure elevations similar to present

Vulnerabilities over Remaining Service Life

ACROSS SITES

Ramp downtime

Flood probabilities

Based on medium SLR scenario	B. Fundy		Gulf of St Lawrence		
			Wood Islands		
RAMP	**Digby**	**Saint John**	**Confederation ship**	**Holiday Island ship**	**Souris**
Remaining life (years)	15-20		24	5-10	30
Operating season length (months)	12	12	8	8	12
Estimated frequency of exceedence of baseline high tide level at end of remaining life [hours per season]	11	11	72	48	674
days			3	2	28
MARSHALLING YARD	**Digby**	**Saint John**	**Caribou**	**Wood Islands**	**Souris**
Remaining life (years)	2-5		2-5		20
Est. cumulative probability of coastal flooding over remaining life [%]	0	0	7	54	77
TERMINAL BUILDING					
Remaining life (years)	5-10		5-10		28
Est. cumulative probability of storm surge flooding over remaining life [%]	0	0	26	33	21

Asset Action Plans

Key asset information
- Remaining service life
- Climate thresholds (elevation, wind speed)

Main climate risks

Recommendations
- Maintenance of asset
- Design and siting of replacement asset

Infrastructure Component:		Ferry Marshalling Yard		
Surface Area (m2):	Construction Year:	Age (yrs):	Design Life (yrs):	Est. RSL (yrs):
8000	1970	49	20	2-5

Photograph:

Description of Asset:

Asphalt pavement.
Past upgrades have extended the design life.
New Marshaling yard upgrade design underway/construction over next 2 years.
El. 3.1m CD

Summary of Main Climate Risks
Based on current design and elevations, for medium CC estimate unless otherwise noted.

Climate Parameter	Timeline			
	Baseline	Near-term (20 yrs)	Mid-term (50 yrs)	Long-term (100 yrs)
Extreme sea level				
medium SLR	2	4	6	14
high SLR	2	6	14	14
Rain	0	0	1	1
Freezing Rain & Ice Storms	6	6	6	7
Snow	8	8	8	6

Recommendations, based on risk timeline vs. estimated Remaining Service Life (RSL)

Maintenance of existing asset	- Continue existing practices, including but not limited to increase capacity of stormwater drainage. - Note re. water levels: Est. cumulative probability of storm surge flooding over remaining life = 54 %.
Design and siting of replacement asset	- Incrementally raise using extreme sea level projections commensurate with desired lifetime and risk tolerance. - Consider the sequencing of new construction with interdependent assets including the terminal building and ramps.

Lessons learned

- Coastal flooding and winds (service delays, interruptions) causing most concern

- Worst long-term climate impacts to hit after end of remaining service life of most assets -> there is time to plan

- Future requirements depend on projected demand for ferry service, specifications of future vessels.

Factor climate change in
- maintenance and upgrades
- long-term planning, costing and design.

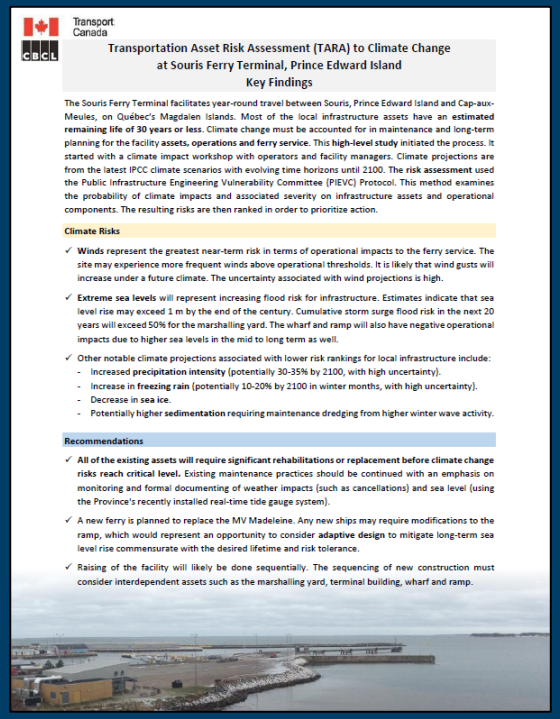
Considerations for Next Projects

TARA Study Scope

- Adapt risk assessment protocol (multiple time horizons, non-stationarity, remaining service life)
- 2nd second workshop would be beneficial

Report and Communications

- 'Asset Action Plans' within the report
- Value-added deliverables:
  - Short stand-alone summary with key facts and/or summary infographics for public sharing (e.g. social media, public reports, strategic plans …)
  - Renderings of flood scenarios for effective risk communication



Transport Canada

Transportation Asset Risk Assessment (TARA) to Climate Change at Souris Ferry Terminal, Prince Edward Island
Key Findings

The Souris Ferry Terminal facilitates year-round travel between Souris, Prince Edward Island and Cap-aux-Meules, on Québec's Magdalen Islands. Most of the local infrastructure assets have an **estimated remaining life of 30 years or less**. Climate change must be accounted for in maintenance and long-term planning for the facility **assets, operations and ferry service**. This **high-level study** initiated the process. It started with a climate impact workshop with operators and facility managers. Climate projections are from the latest IPCC climate scenarios with evolving time horizons until 2100. The **risk assessment** used the Public Infrastructure Engineering Vulnerability Committee (PIEVC) Protocol. This method examines the probability of climate impacts and associated severity on infrastructure assets and operational components. The resulting risks are then ranked in order to prioritize action.

Climate Risks

- ✓ **Winds** represent the greatest near-term risk in terms of operational impacts to the ferry service. The site may experience more frequent winds above operational thresholds. It is likely that wind gusts will increase under a future climate. The uncertainty associated with wind projections is high.
- ✓ **Extreme sea levels** will represent increasing flood risk for infrastructure. Estimates indicate that sea level rise may exceed 1 m by the end of the century. Cumulative storm surge flood risk in the next 20 years will exceed 50% for the marshalling yard. The wharf and ramp will also have negative operational impacts due to higher sea levels in the mid to long term as well.
- ✓ Other notable climate projections associated with lower risk rankings for local infrastructure include:
  - Increased **precipitation intensity** (potentially 30-35% by 2100, with high uncertainty).
  - Increase in **freezing rain** (potentially 10-20% by 2100 in winter months, with high uncertainty).
  - Decrease in **sea ice**.
  - Potentially higher **sedimentation** requiring maintenance dredging from higher winter wave activity.

Recommendations

- ✓ **All of the existing assets will require significant rehabilitations or replacement before climate change risks reach critical level.** Existing maintenance practices should be continued with an emphasis on monitoring and formal documenting of weather impacts (such as cancellations) and sea level (using the Province's recently installed real-time tide gauge system).
- ✓ A new ferry is planned to replace the MV Madeleine. Any new ships may require modifications to the ramp, which would represent an opportunity to consider **adaptive design** to mitigate long-term sea level rise commensurate with the desired lifetime and risk tolerance.
- ✓ Raising of the facility will likely be done sequentially. The sequencing of new construction must consider interdependent assets such as the marshalling yard, terminal building, wharf and ramp.

Thank you
Merci

Questions, discussion

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TARA: Climate Risk Assessment Tools and Frameworks Webinar

March | 2021

YYC CALGARY AIRPORT AUTHORITY

AGENDA

- **Project Purpose & Outcomes**
- **Project Steps & Developing our Framework**
  - Asset & Operations Inventory
  - Climate Impacts and Thresholds
  - Climate Projections
  - Stakeholder Engagement
  - Risk Scoring & Analysis
- **Creating in-house capacity**

PROJECT PURPOSE AND ~~OUTCO~~MES

Tools and information to support robust decision making & assure asset and operational resilience.

- **Infrastructure**
- **Land use**
- **Environmental management**
- **Long-range operations and**
- **Corporate strategy and investments**
- **Occupational health and safety**
- **Emergency response resourcing**

DELIVERABLES:

(1) Updated climate data and projections for YYC and YBW

(2) Preliminary risk register to translate projections into meaning for airport decisions

YYC CALGARY AIRPORT AUTHORITY

HOW WE SEE A CLIMATE RISK ASSESSMENT:

- **Inform the prioritization and sequencing of actions, resource allocation and other changes needed to address changes in climate hazards.**
- **Current and long-term risks (2050's and 2080's).**

Likelihood of change in weather / climate hazard

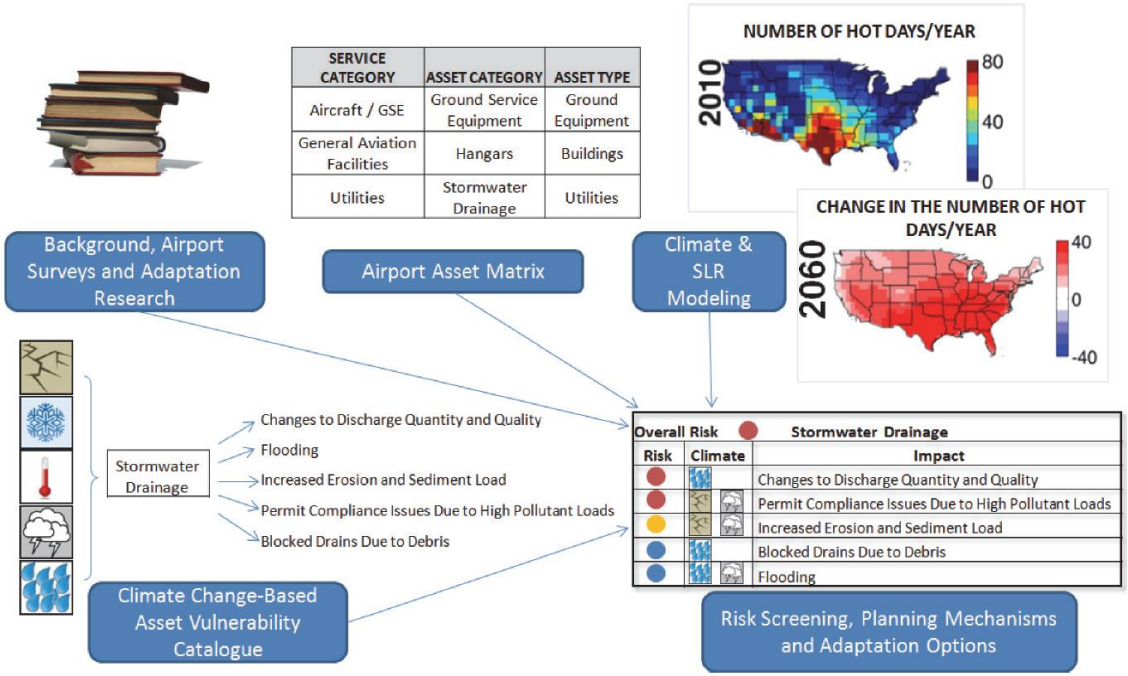
x

Consequences of the change

STEPS INVOLVED

1. Inventory of airport assets and operations
2. Research of climate impacts and thresholds: • YYC - consultation • Other airports • Other local industries and the City of Calgary
3. Development of a baseline and historical climate profile and climate projections
4. Workshops and interviews with YYC Crew and airport partners to validate and contribute to findings
5. Risk scoring and analysis
6. Risk treatment recommendations

ACROS (Airport Climate Risk Operational Screening)



HOW WE MADE ACROS WORK FOR US

Select Location

View regional climate projections and hazardous (US only)

Climate Projections by GHD (in partnership with the City of Calgary)

Select Assets & Operations

ACROS is populated with lists of possible assets and operations, but can be customized

Define Criticality

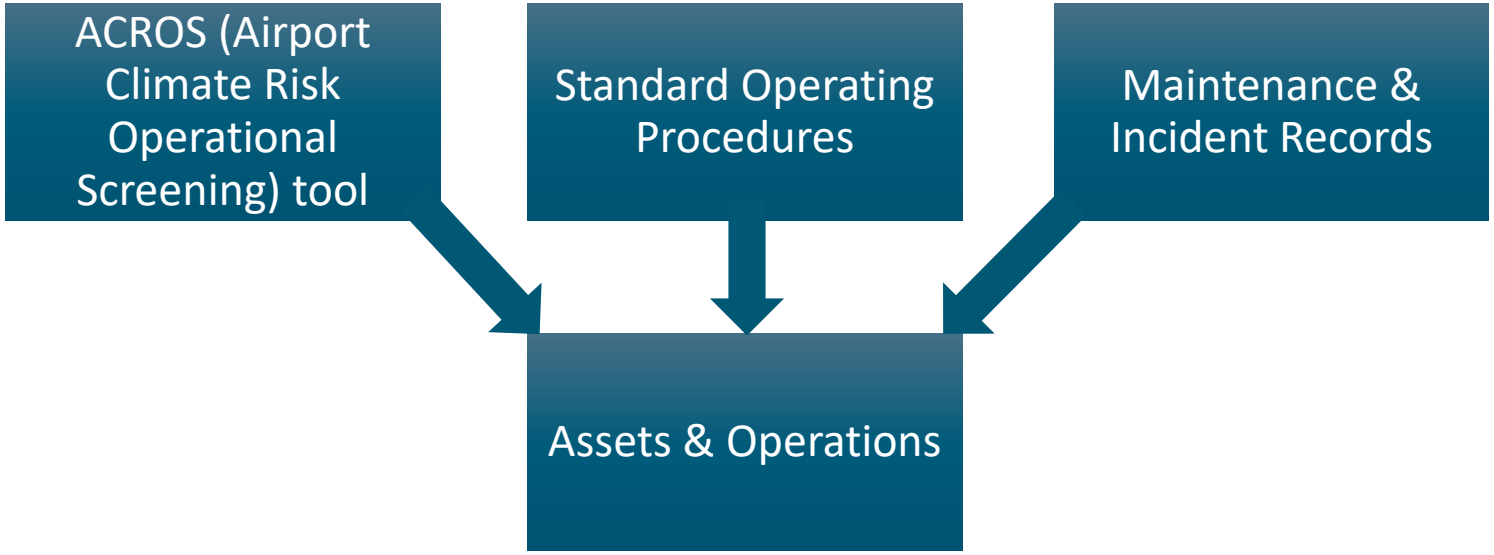
Define the importance of asset or operation to the airport system

Estimate Vulnerability

Estimate the likelihood of asset or operation failure upon exposure to impacts

Internal Enterprise Risk Framework

INVENTORY OF AIRPORT ASSETS & OPERATIONS



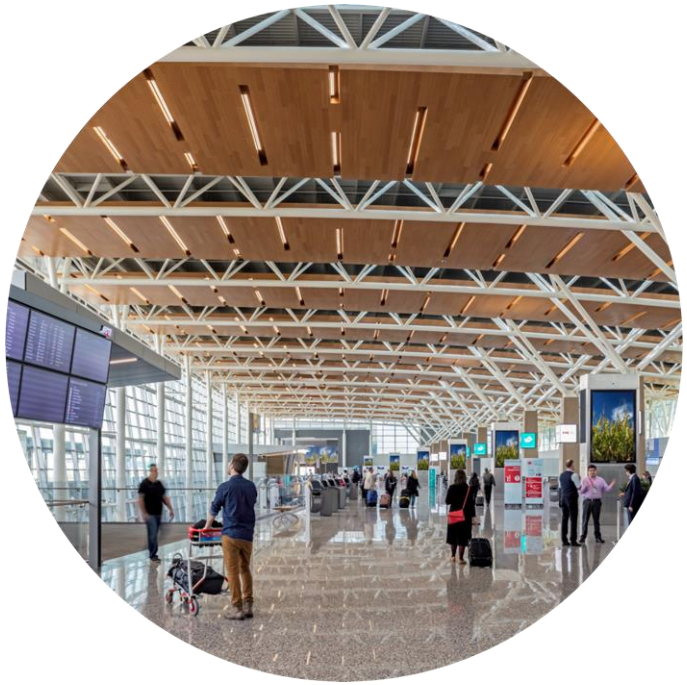
ACROS (Airport Climate Risk Operational Screening)

Pros:

- **Airport specific**
- **Included operations in inventory (not just assets)**
- **Easy to use and understand**

Cons:

- **US based**
- **Didn’t account for other functions of an airport authority (e.g. land use and development)**
- **Generic categorization that needed to be adjusted**



RESEARCH OF CLIMATE IMPACTS AND THRESHOLDS

ACROS (AIRPORT CLIMATE RISK OPERATIONAL SCREENING)

LITERATURE REVIEW

MUNICIPALITIES – CALGARY & EDMONTON

YYC INTERNAL WORKSHOPS

ESTABLISHED WEATHER FORECASTING THRESHOLDS

YYC CALGARY AIRPORT AUTHORITY

CLIMATE PROJECTIONS

- **Created in partnership with The City of Calgary by GHD**
- **Will be used in City planning and design**
- **Database will be used in Airport projects**
- **Full ensemble of up to 40 models**
- **Emphasis was placed on characterizing uncertainty**

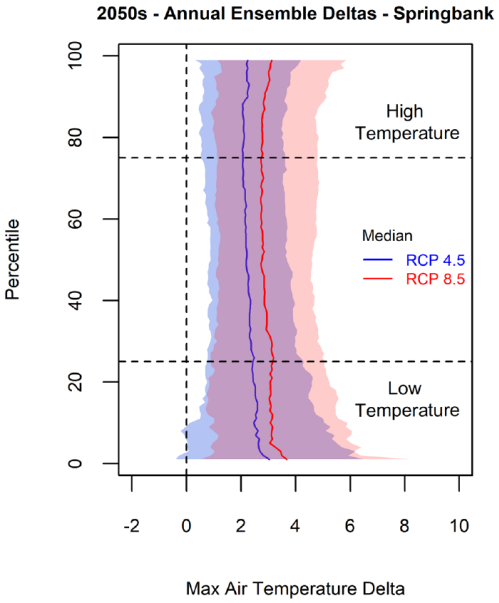
CLIMATE DATA

Number	Name	Description of Data	Time Horizons	Location(s)
1	Time Series Datasets	Precipitation: Hourly, Daily Snowfall: Daily Convective Rainfall: Daily Air Temperature: Hourly, Daily Maximum, Daily Minimum Wind Speed: Hourly, Daily, Monthly Wind Direction: Daily Solar Radiation: Hourly, Daily Evapotranspiration: Hourly, Monthly Shallow Lake Evaporation: Hourly, Monthly	Historical 2050s 2080s	Calgary International Airport, Springbank Airport
2	Typical Year Analysis	Average, wet, and dry typical precipitation years	Historical 2050s 2080s	Calgary International Airport
3	IDF Curve	Single station IDF curve for the Calgary International Airport	Historical 2050s 2080s	Calgary International Airport
4	Regional IDF Curve	One or two IDF curves corresponding to the homogeneous region(s) containing the Calgary International Airport and the Springbank Airport	Historical 2050s 2080s	Calgary International Airport, Springbank Airport

TEMPERATURE

Climate indicator	1981-2010 Normals	2050s (2041-2070)			2050s (2041-2070)		
		Mean	Low[1]	High[1]	Mean	Low[1]	High[1]
Annual Maximum Temperature	31.8	36.3	34.5	38.5	38.9	36.5	42.8
Days ≥ 29°C	6	27.5	18.9	38.2	48.7	30.9	68.9
Number of heat Waves	0	4.8	3	6.6	7.7	4.6	10.2
Number of Cooling Degree days	46.1	209.6	136.6	278.8	415.3	238.5	601.1

[1]Indicates the 10th and 90th percentiles across the regionally downscaled modelled projections (GHD, 2020).

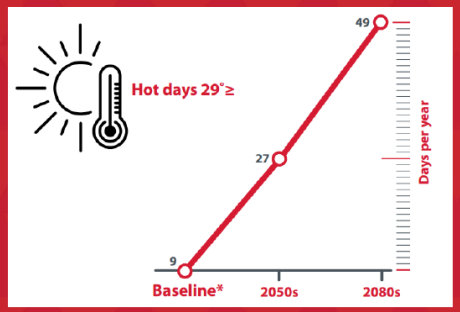


VALIDATING INITIAL FINDINGS

1. **General comments about the scenario**
   - Does the trigger and potential impact seem accurate?
2. **In your expert opinion how will this effect YYC?**

Extreme Heat

Trigger: Events of 3 consecutive days when maximum daily temperature is greater than or equal to 29°C (without humidex)



Potential Impacts:

- Increase in heat-related illness
- Increased demand on HVAC systems
- Air and water quality effects
- Stress on vegetation and wildlife
- Pavement deterioration
- Decrease in aircraft lift
- Possible brown-outs and black-outs
- Increase in diseases, invasive species, and food safety concerns

USING THE YYC ENTERPRISE RISK FRAMEWORK FOR CLIMATE CHANGE

Likelihood	Revenue / Cost	Regulatory	Environment
Health / Safety	Reputation / Image	Passenger Traffic	Business Continuity

For each risk in the inventory:

- Categorized by climate variable and asset/operational impact type
- Scored against each criterion in the risk framework
- Rationale for scores based on research, consultation and desktop analysis
- Scoring includes a factor related to overall confidence in the information
- Initial validation was done (ongoing process)

CREATING CAPACITY IN-~~HOUSE~~

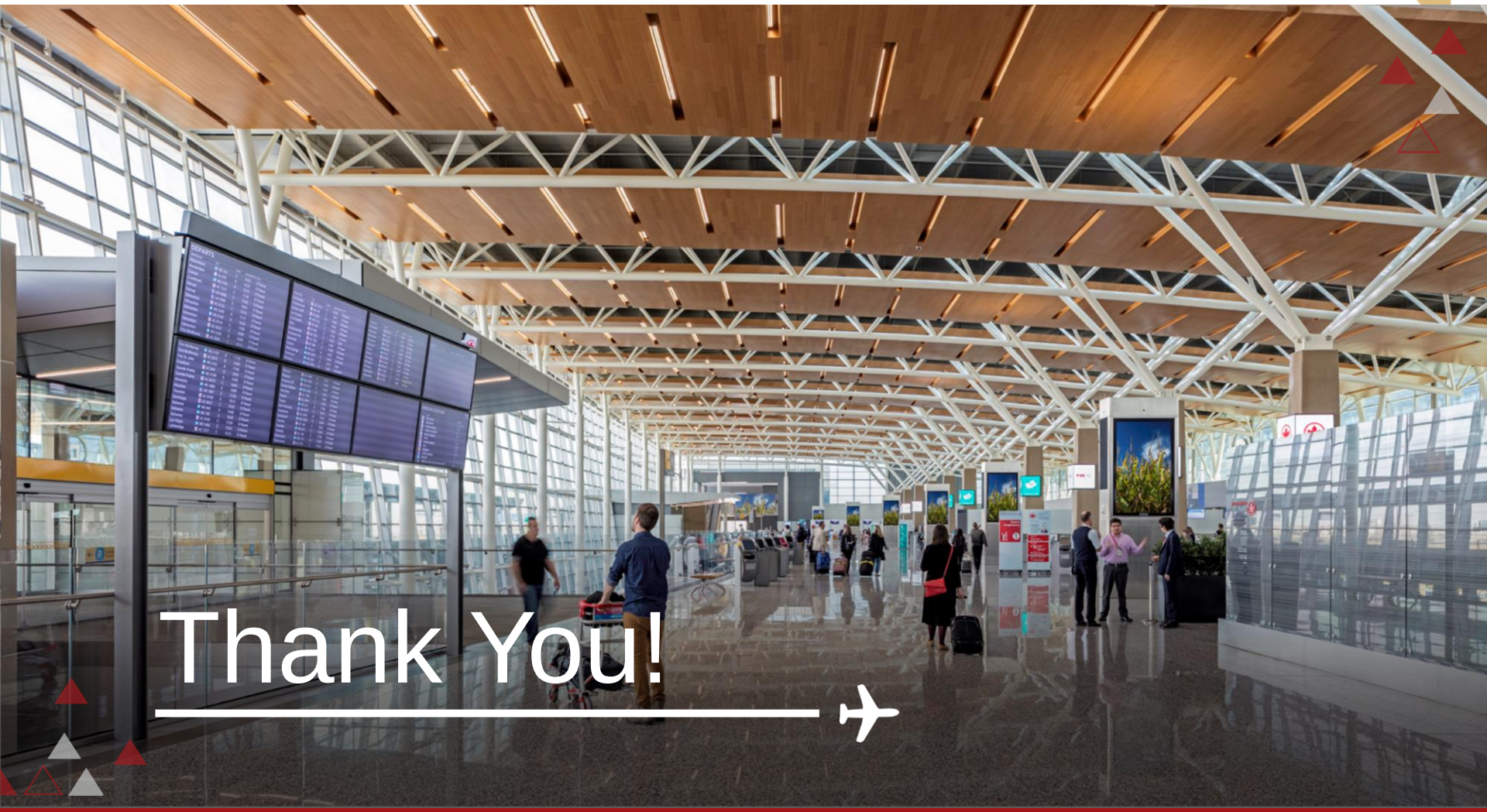
Pros:

- **Continued climate risk support for the organization**
- **More control and insight into the project**
- **More continuity in incorporating climate change decisions over the longer term**
- **Building competency in-house (organization and individuals)**

Cons:

- **Slower process**
  - **Learning curve**
  - **Side-tracked to other projects and assignments**

YYC CALGARY AIRPORT AUTHORITY



Thank You!

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Q & A

Please pose your questions via the chatbox or by unmuting your line

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Thank you for joining us today

Stay tuned for upcoming webinars!

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