



An Evolution in Flood Management:

An optimistic view from the left coast

ebbwater
CONSULTING INC

CWRA | March 2019 | Toronto, Ontario
Tamsin Lyle, P.Eng | Principal Engineer | Ebbwater Consulting Inc.

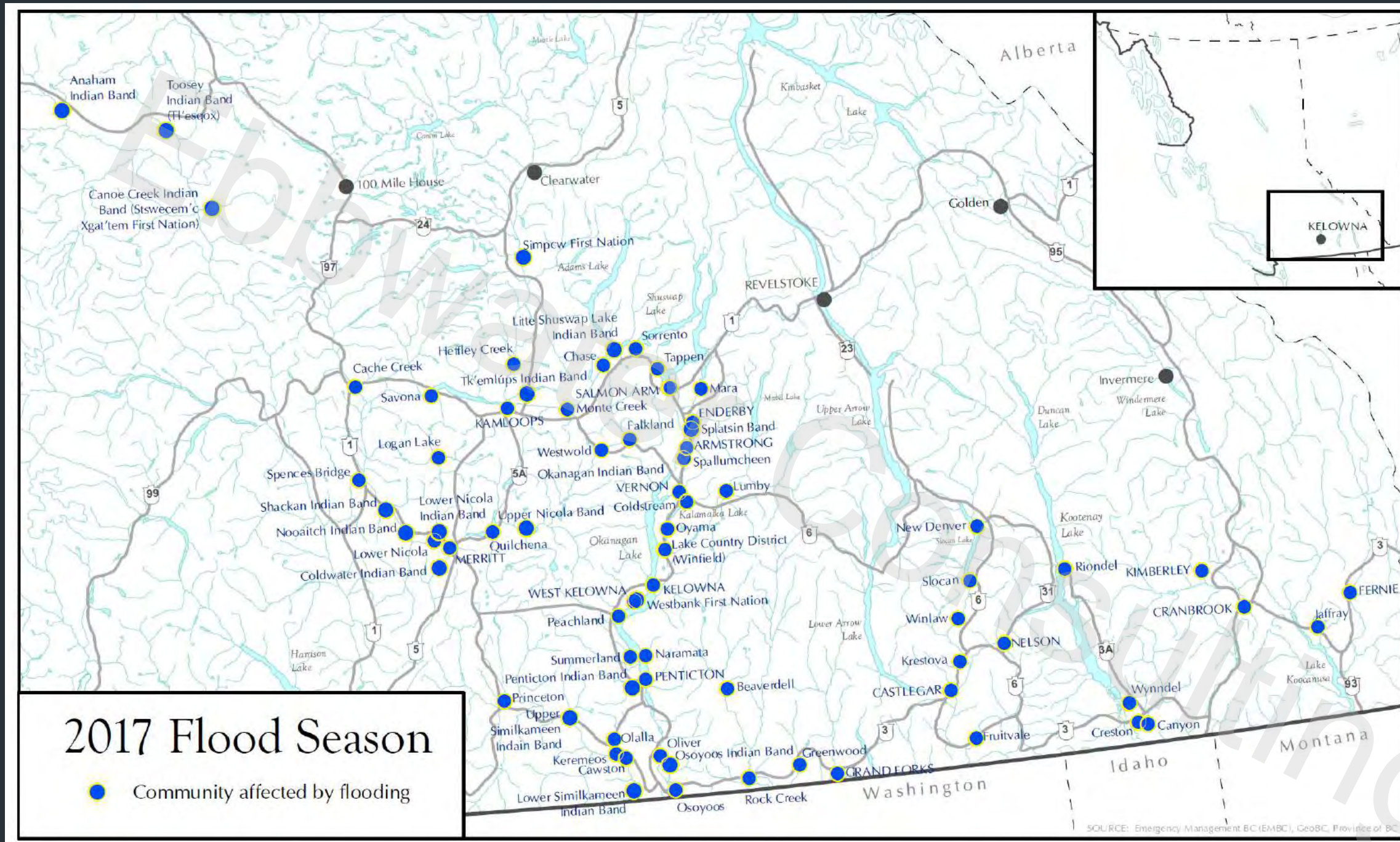


Image from BC Flood and Wildfire Review (Abbott and Chapman, 2018)

Response Costs > \$73 Million

2017
Flood Season
Extensive -
Long Duration -
Impactful

2018 Flood Season

Extensive - Long Duration - Impactful

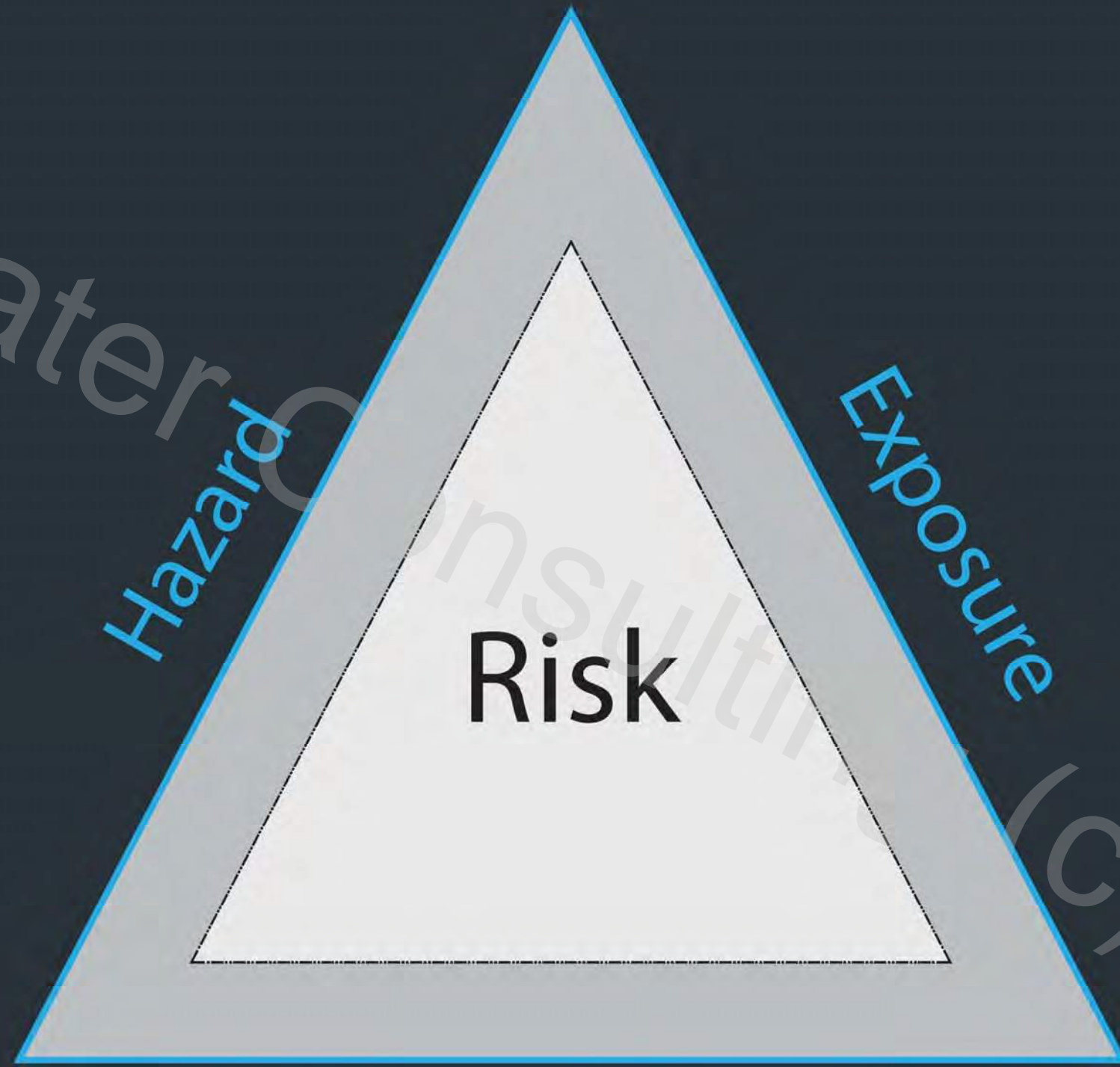


City of Dawson Creek Images

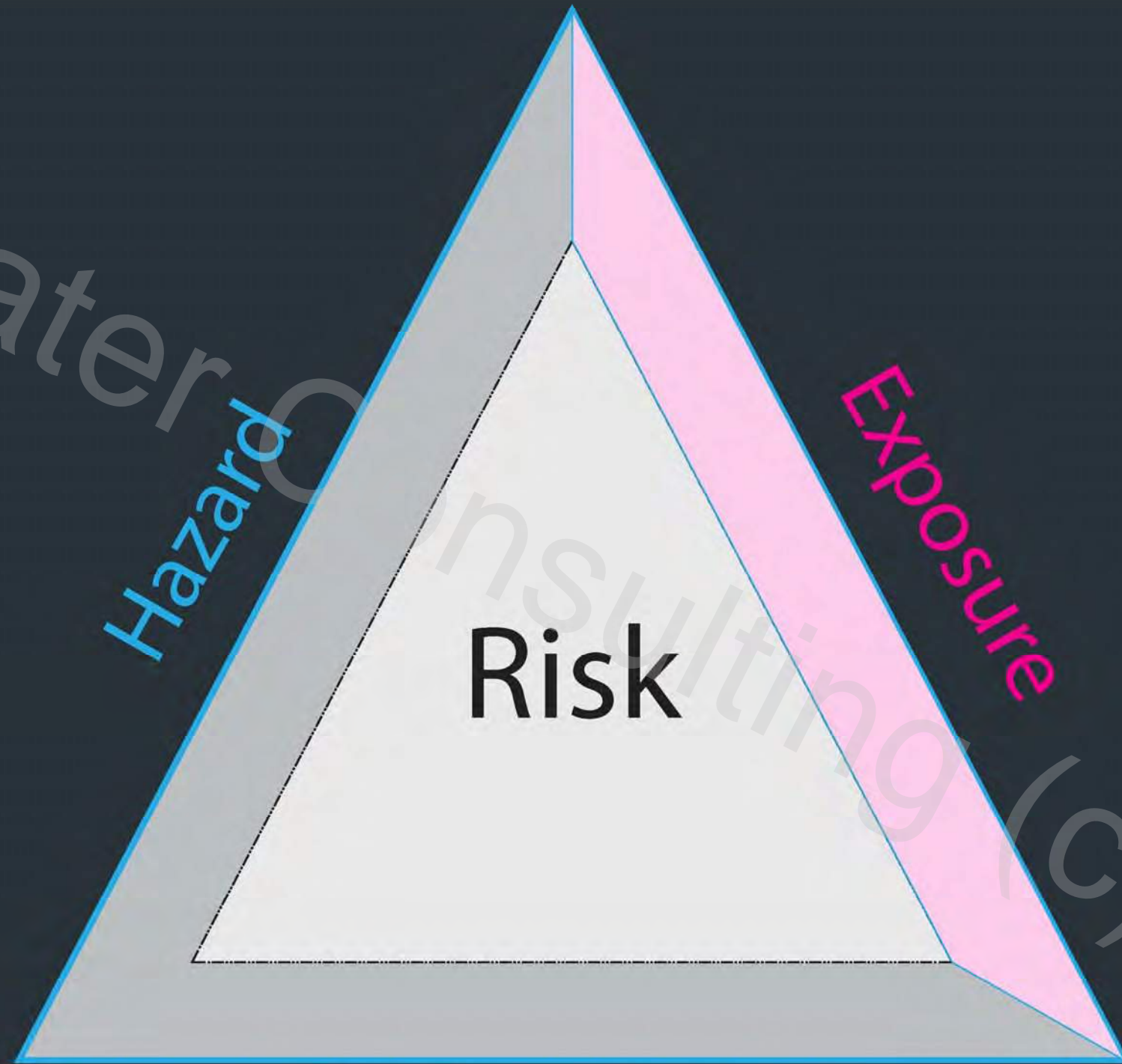


Geological Survey of Canada Images



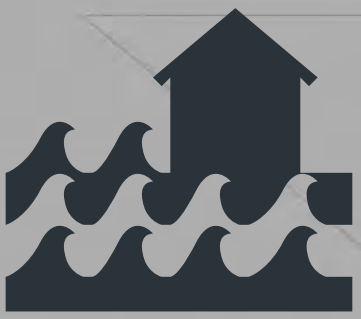


Vulnerability

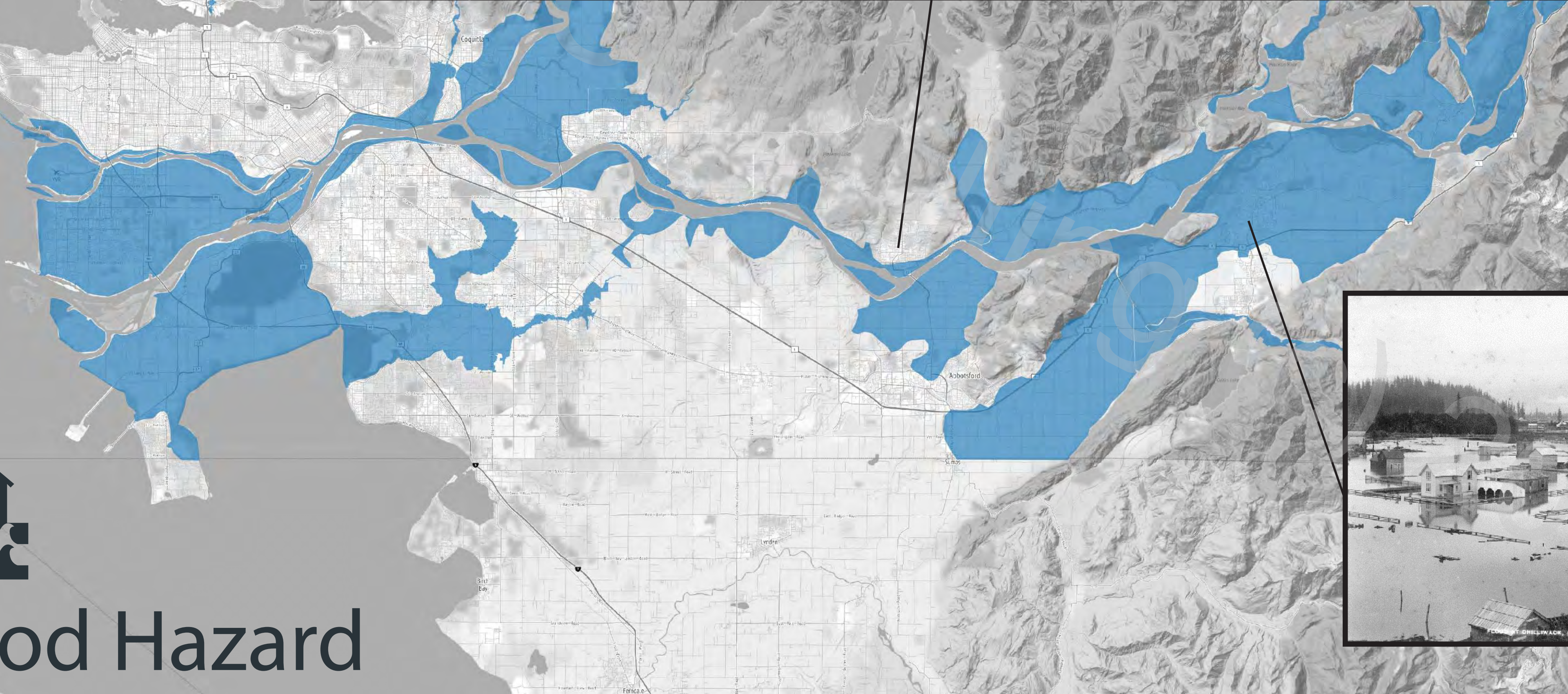


Vulnerability

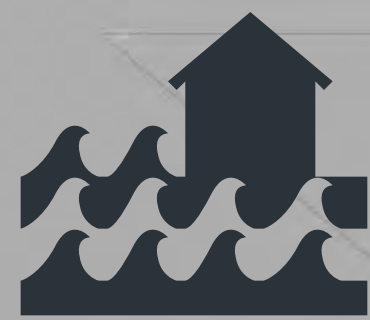
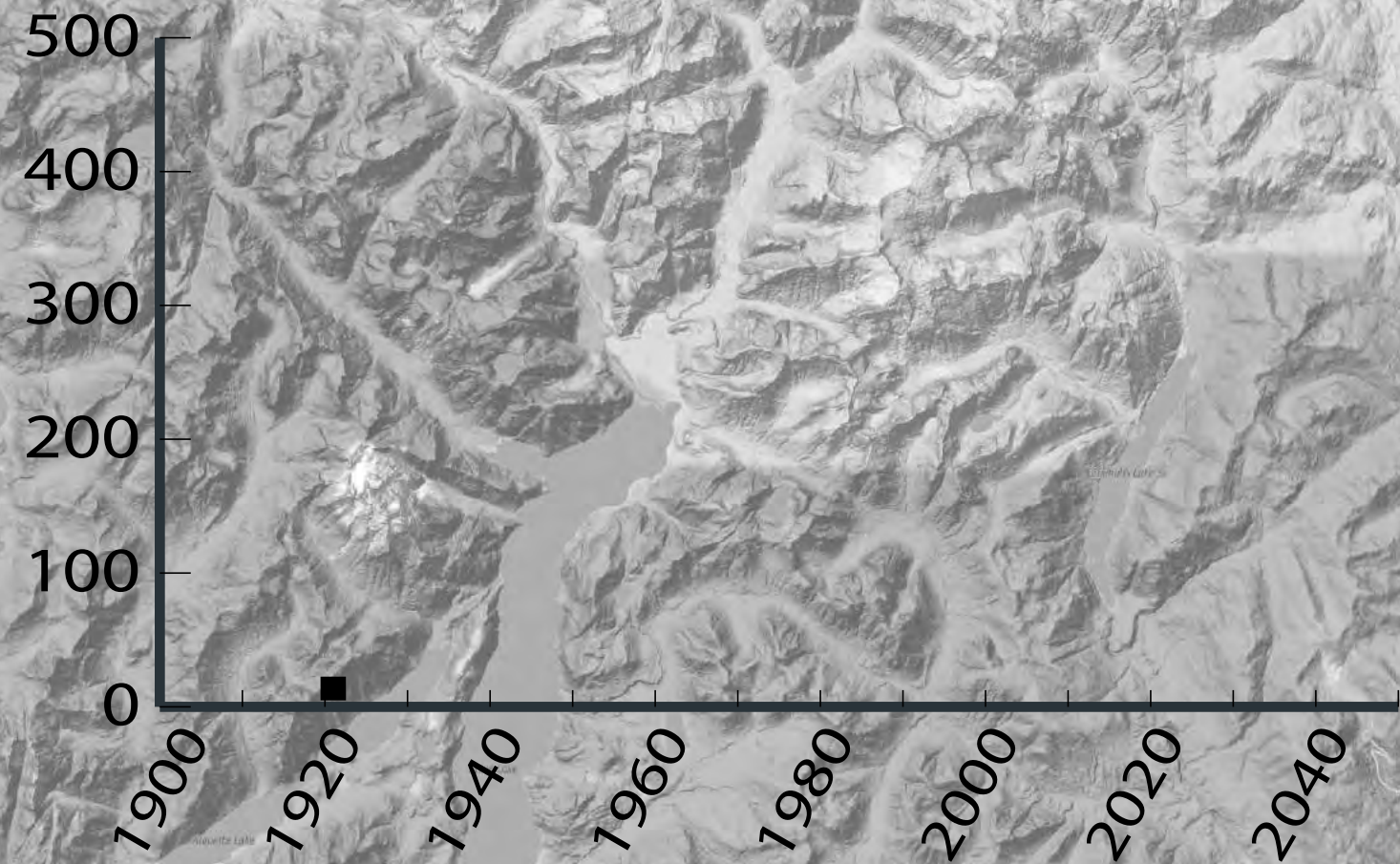
1894



Flood Hazard



1921

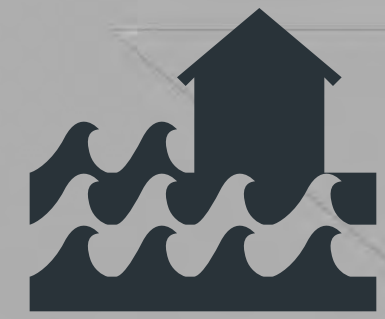
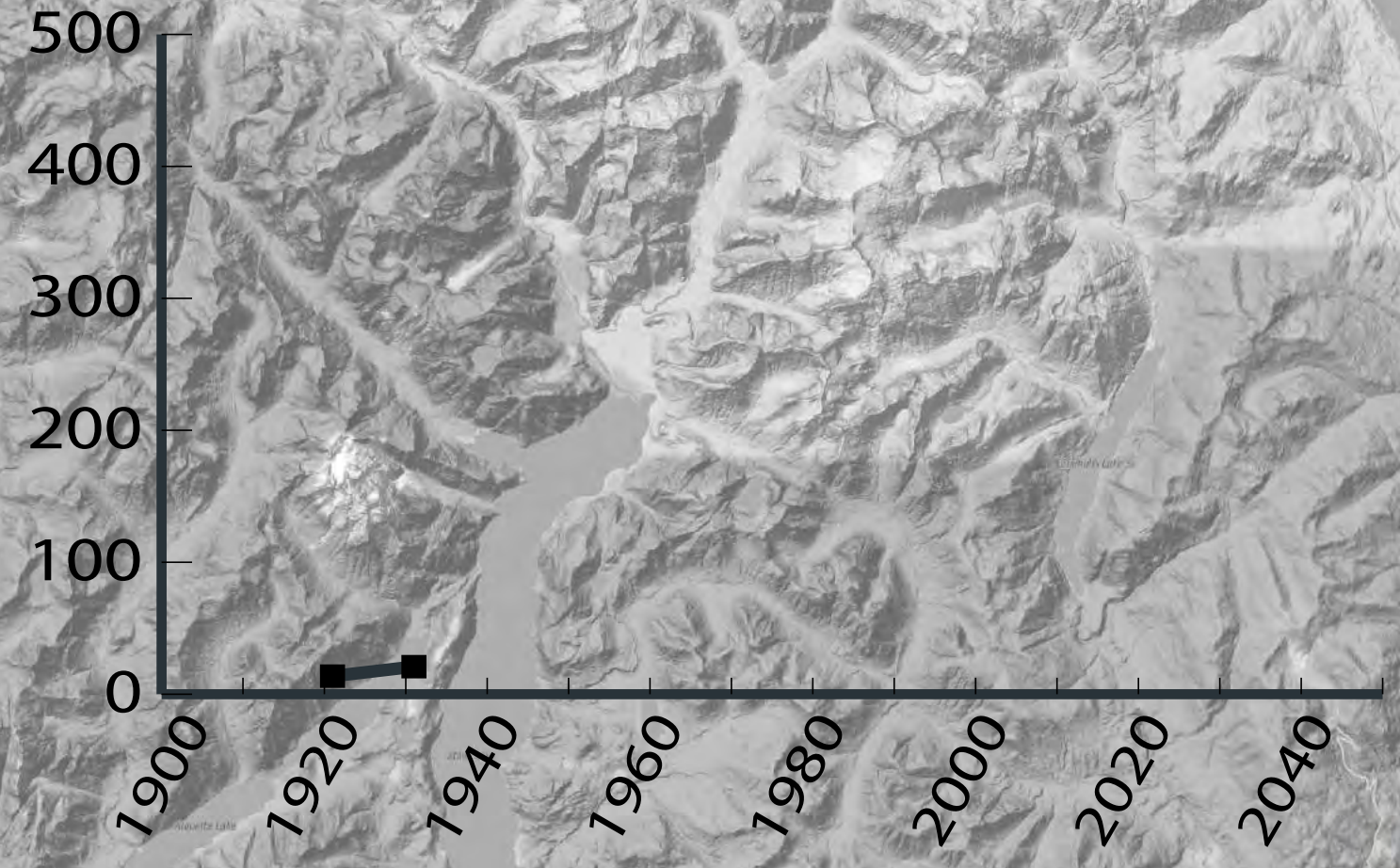


Flood Hazard



Exposed Population

1931

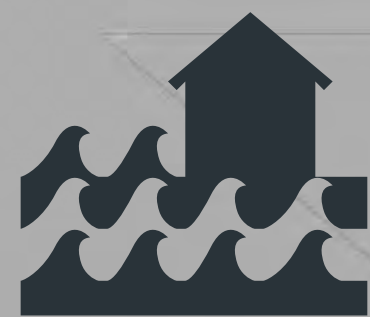
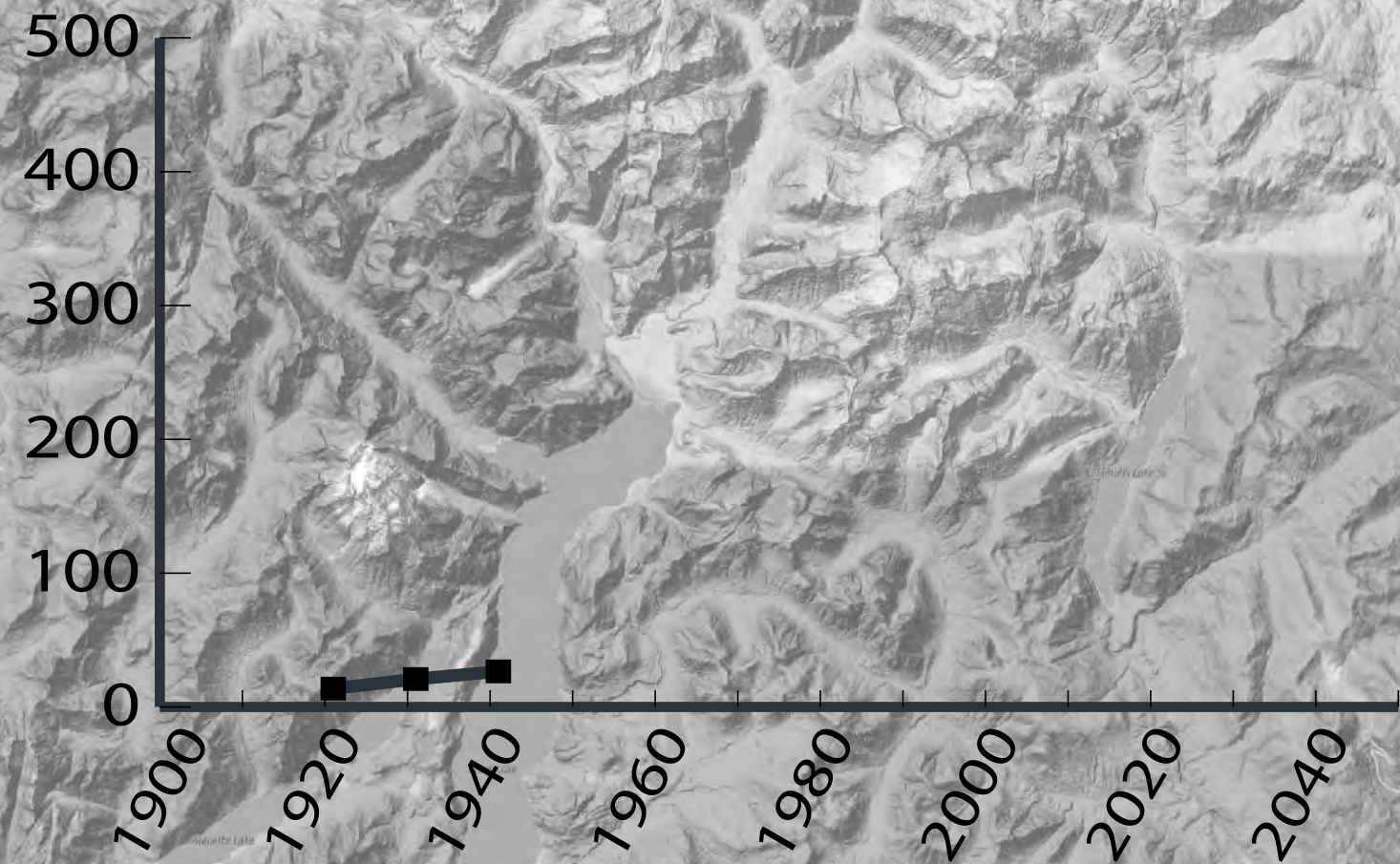


Flood Hazard



Exposed Population

1941

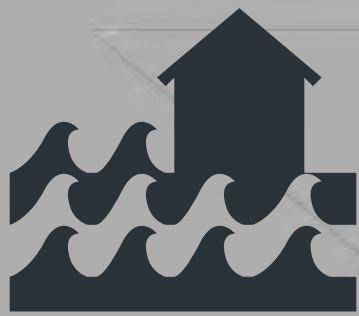


Flood Hazard



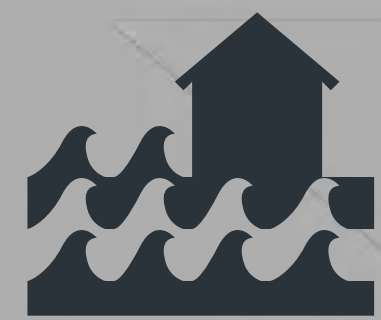
Exposed Population

1948



Flood Hazard

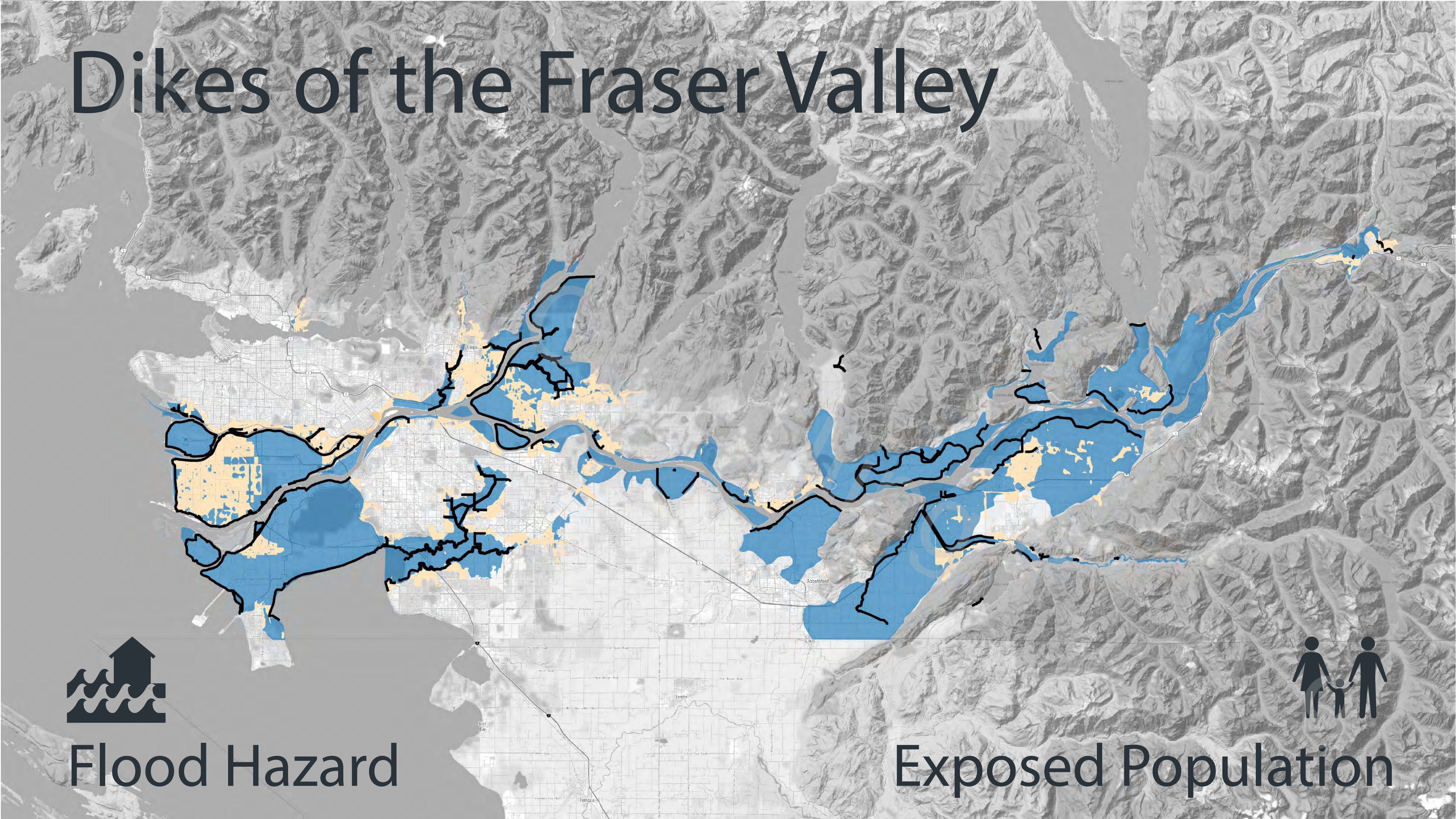
Dikes of the Fraser Valley

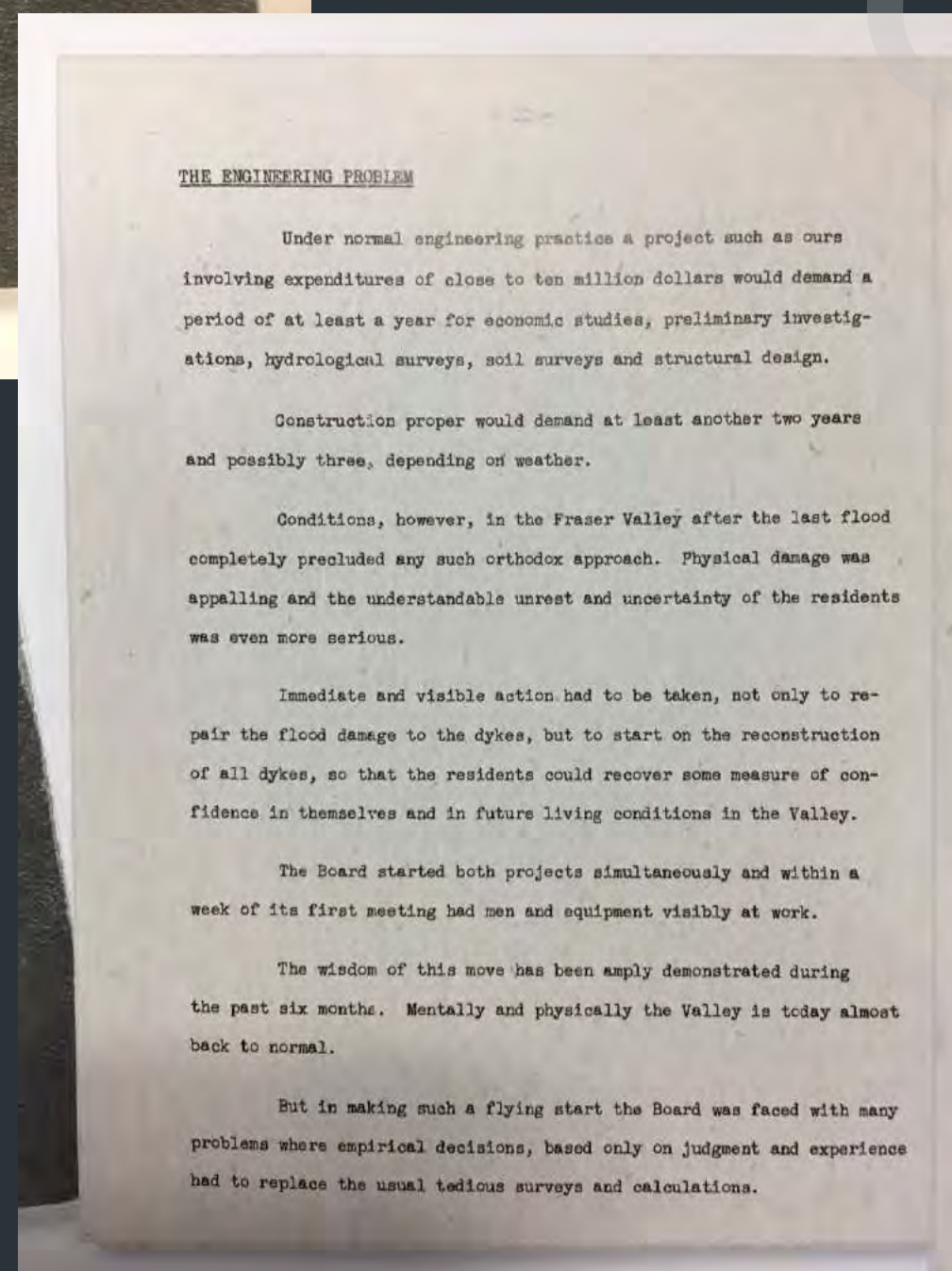
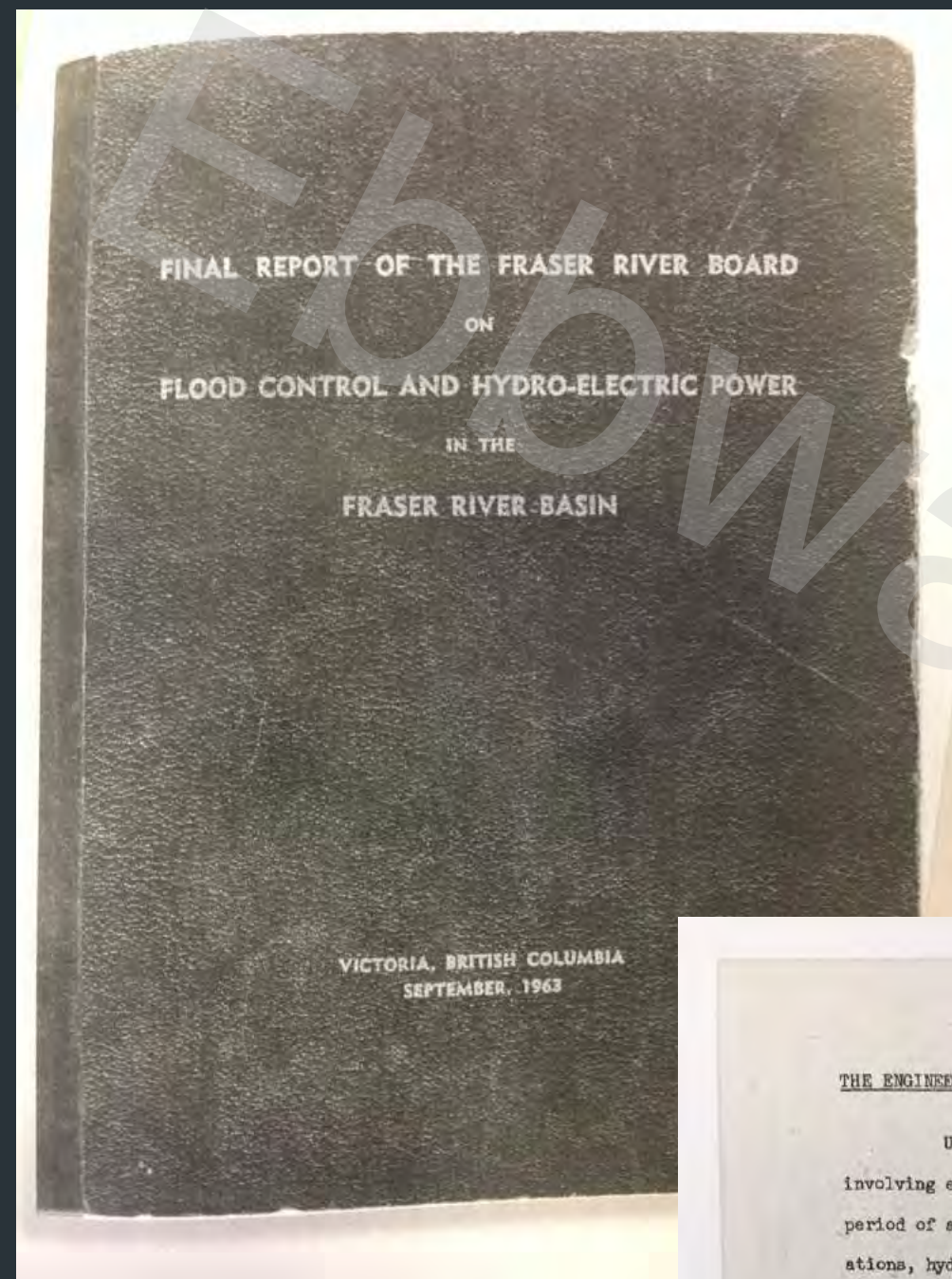


Flood Hazard



Exposed Population

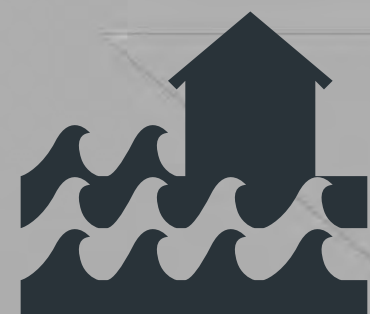
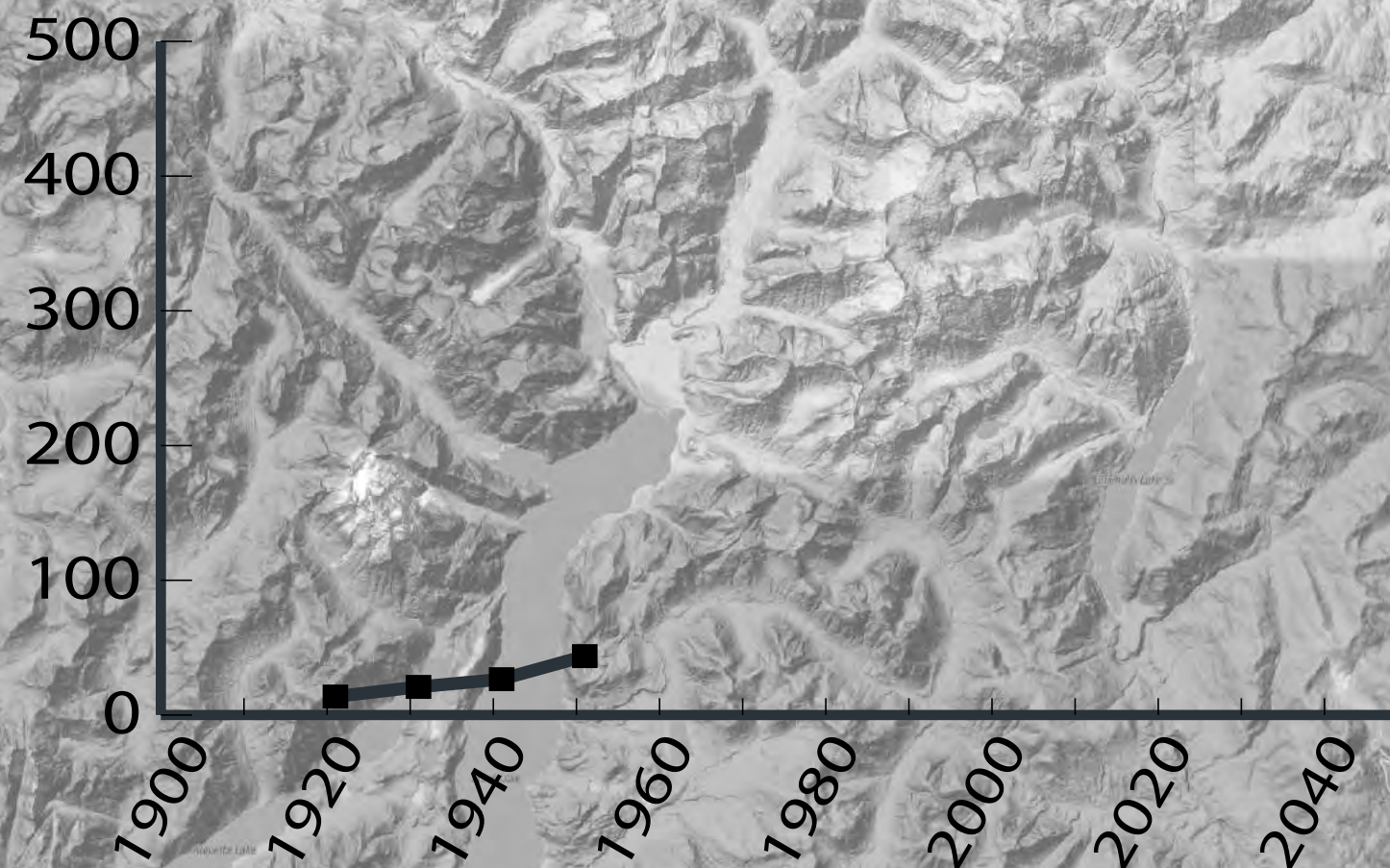




“the Board was faced with many problems where empirical decisions, based only on judgment and experience, had to replace the usual tedious surveys and calculations”

(as cited in Watt 2006)

1951

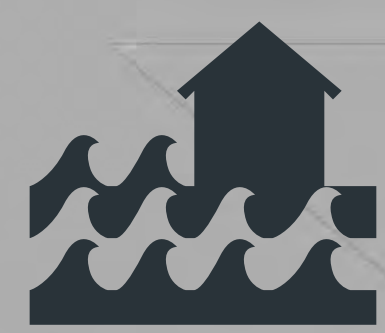
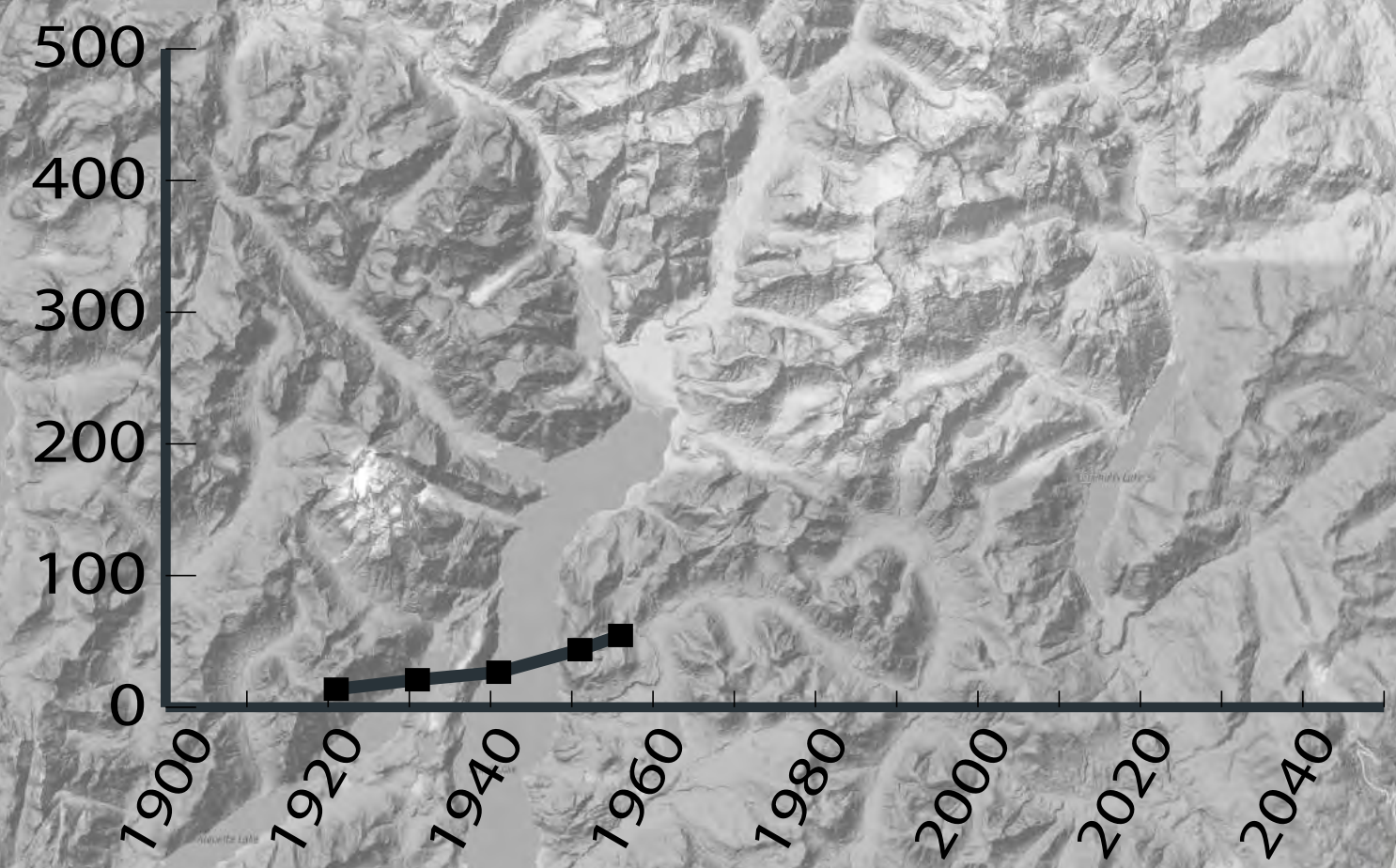


Flood Hazard



Exposed Population

1956

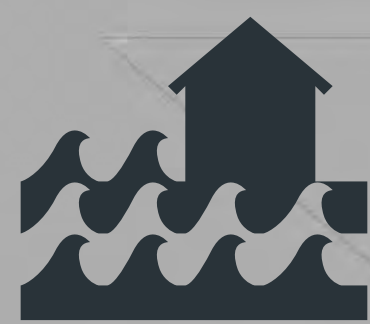
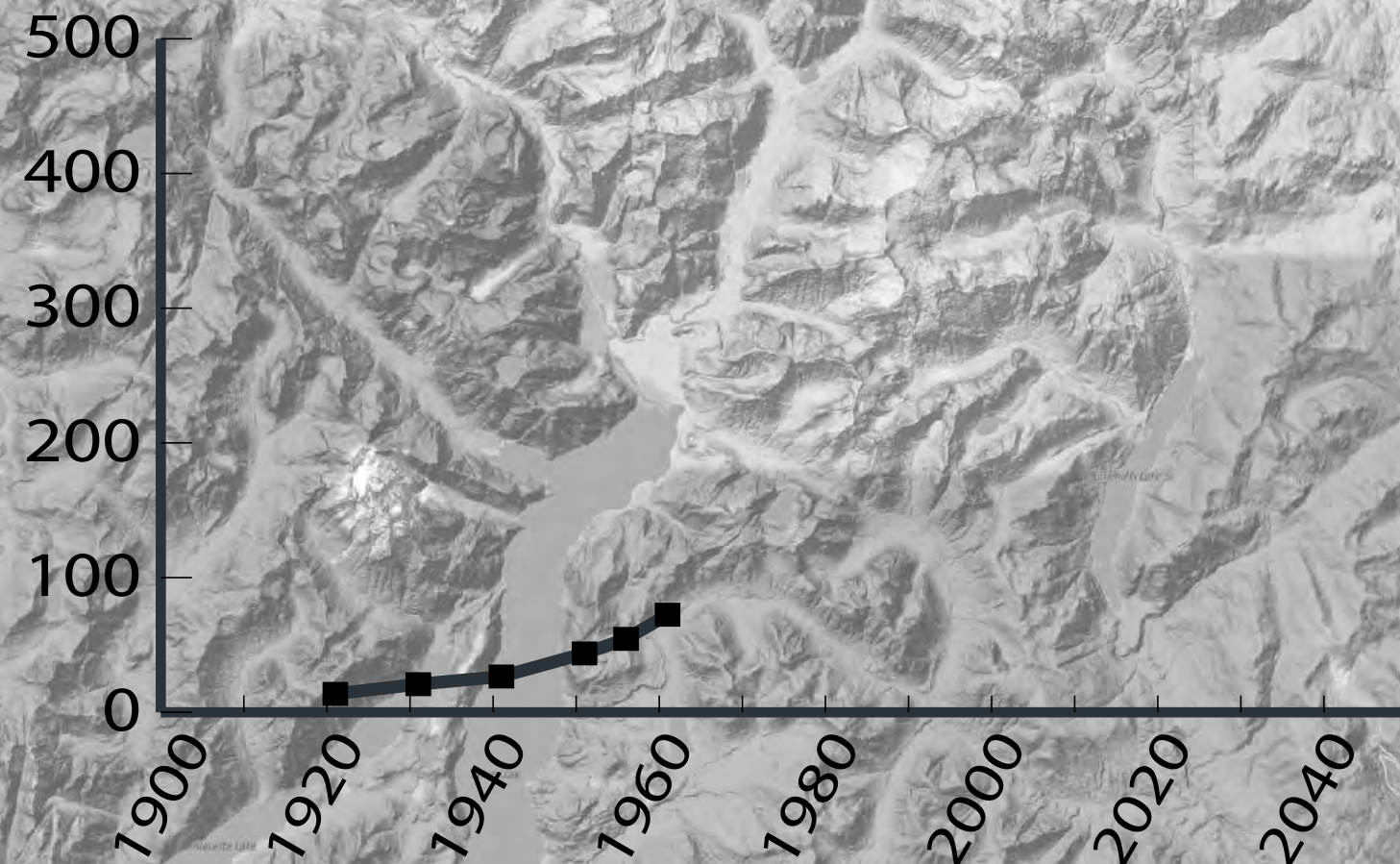


Flood Hazard



Exposed Population

1961

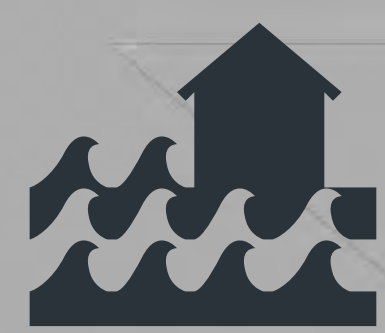
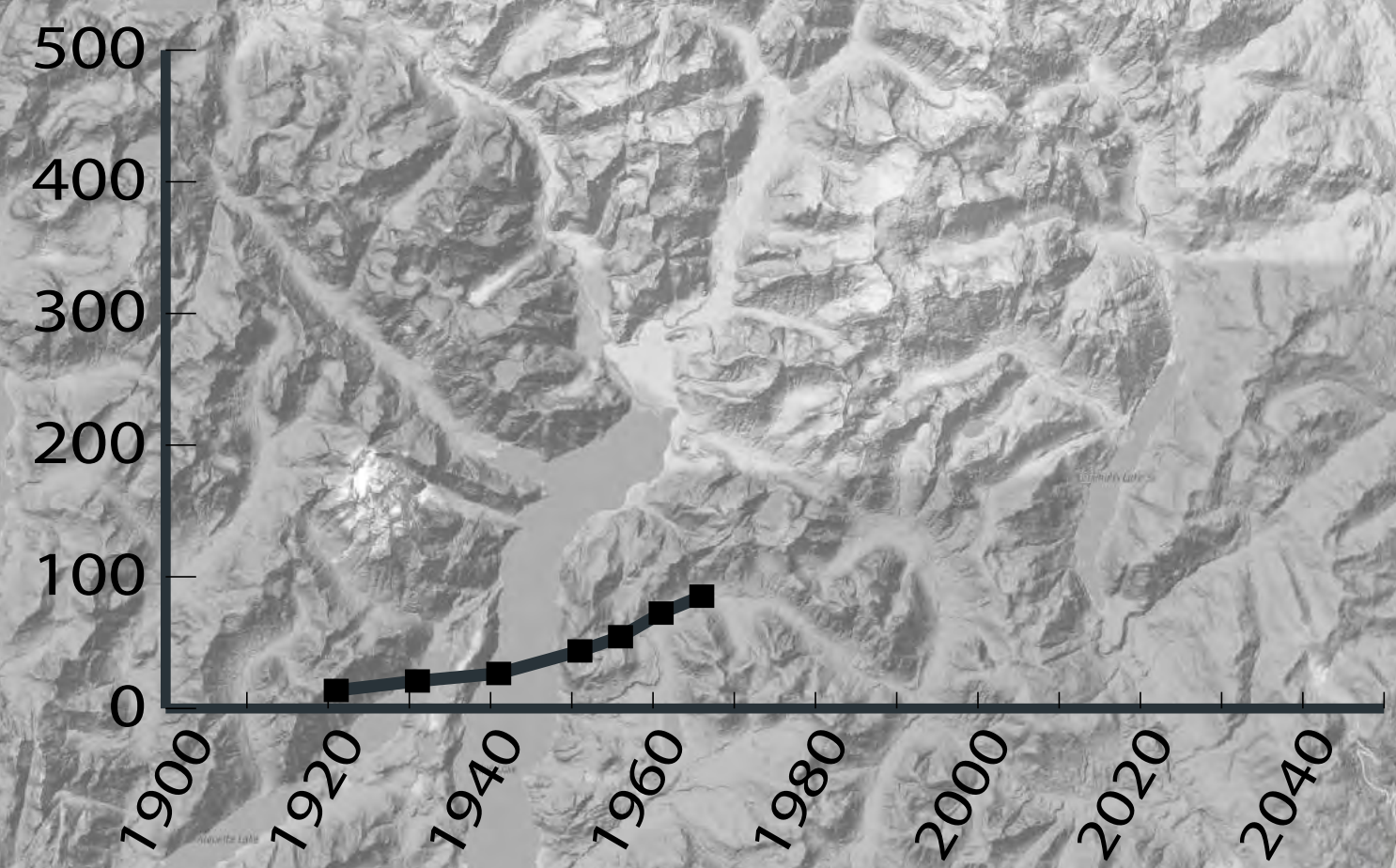


Flood Hazard



Exposed Population

1966

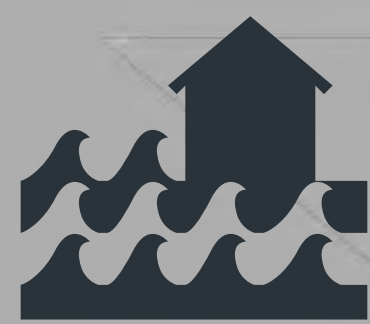
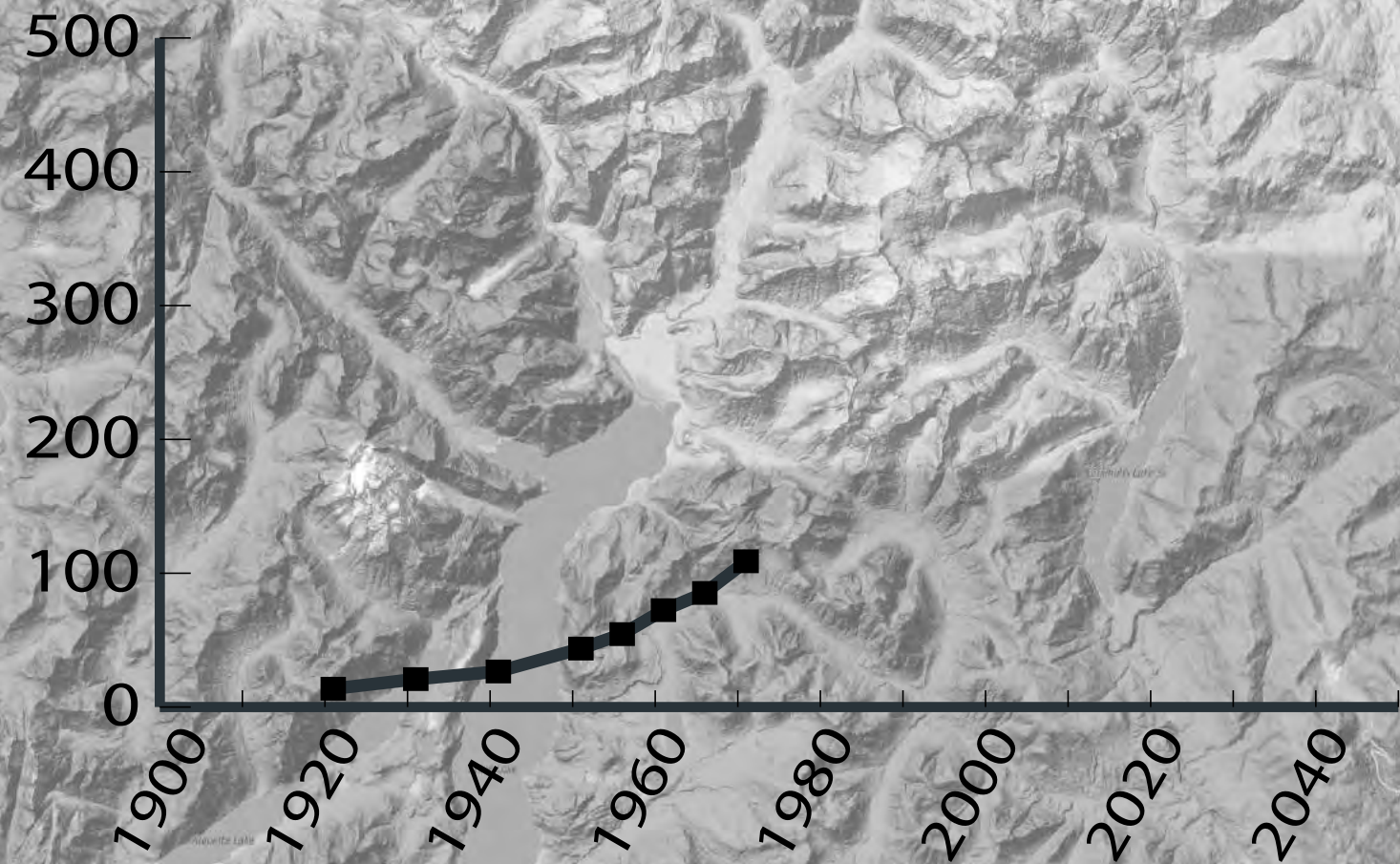


Flood Hazard



Exposed Population

1971

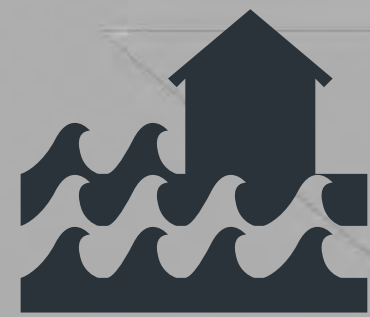
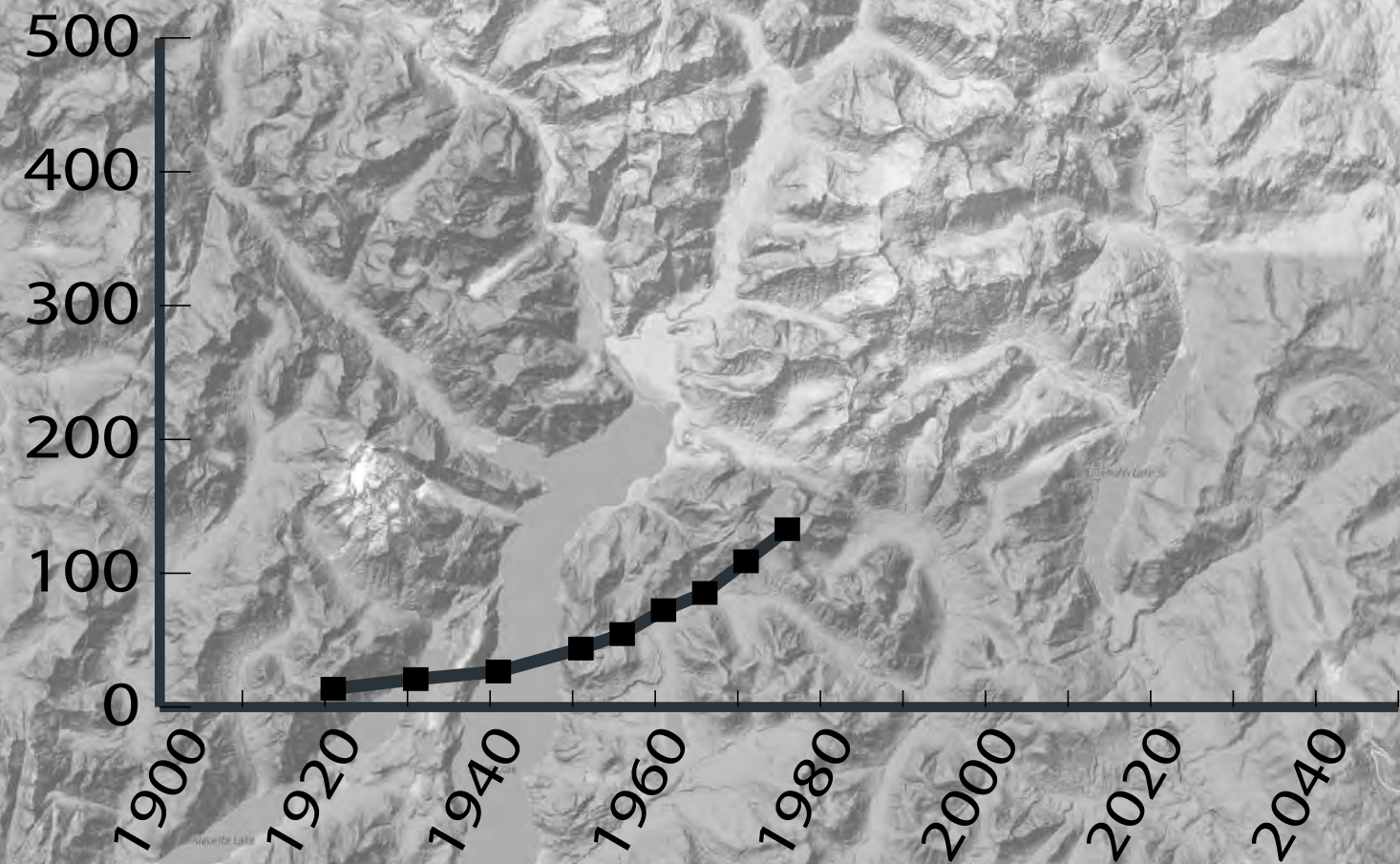


Flood Hazard



Exposed Population

1976

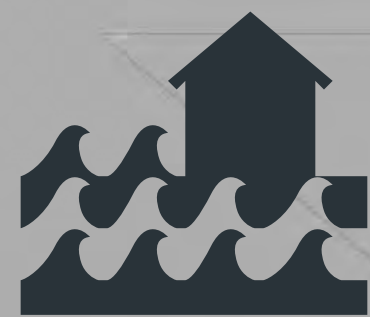
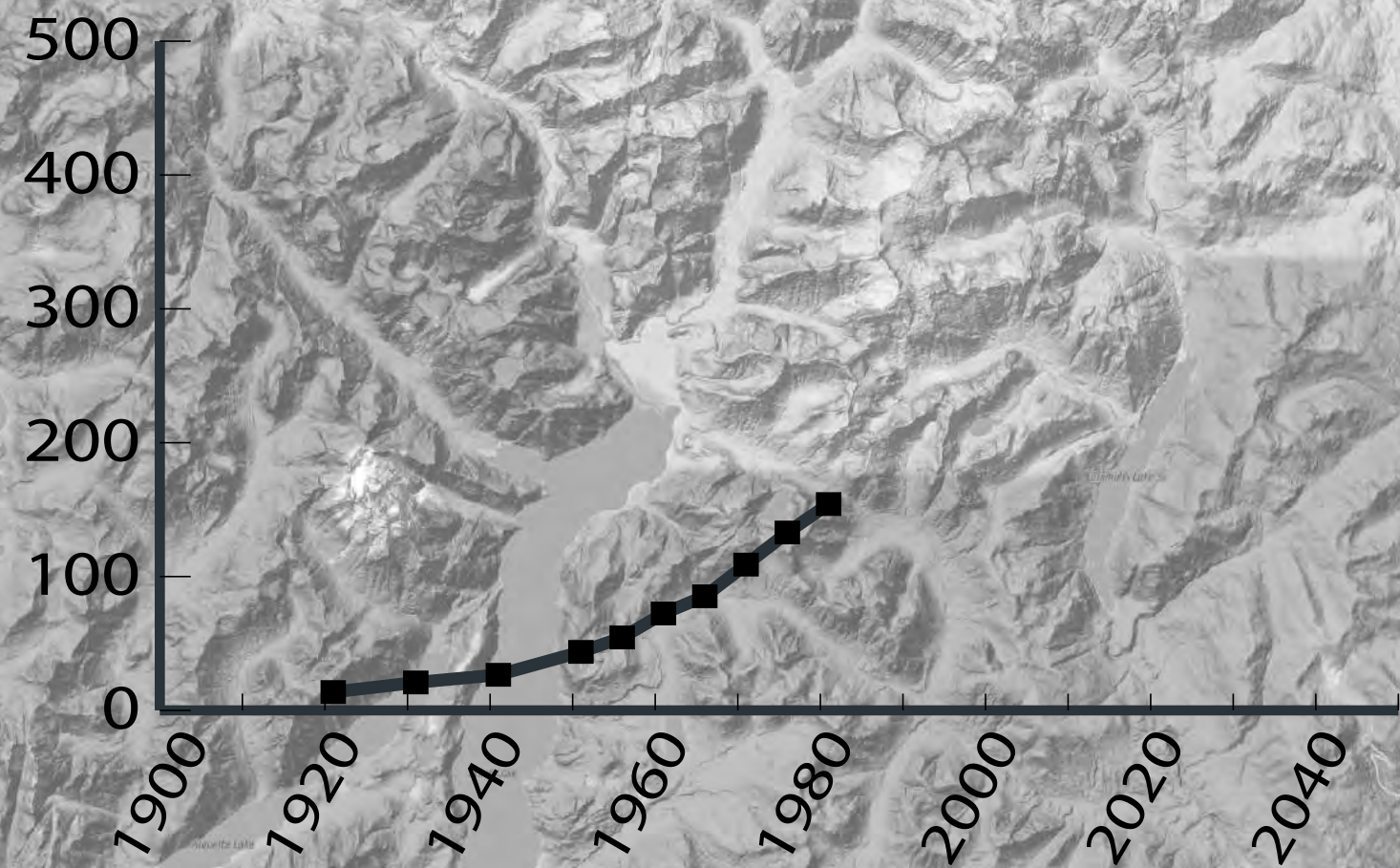


Flood Hazard



Exposed Population

1981

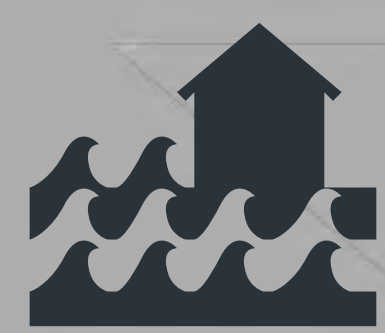
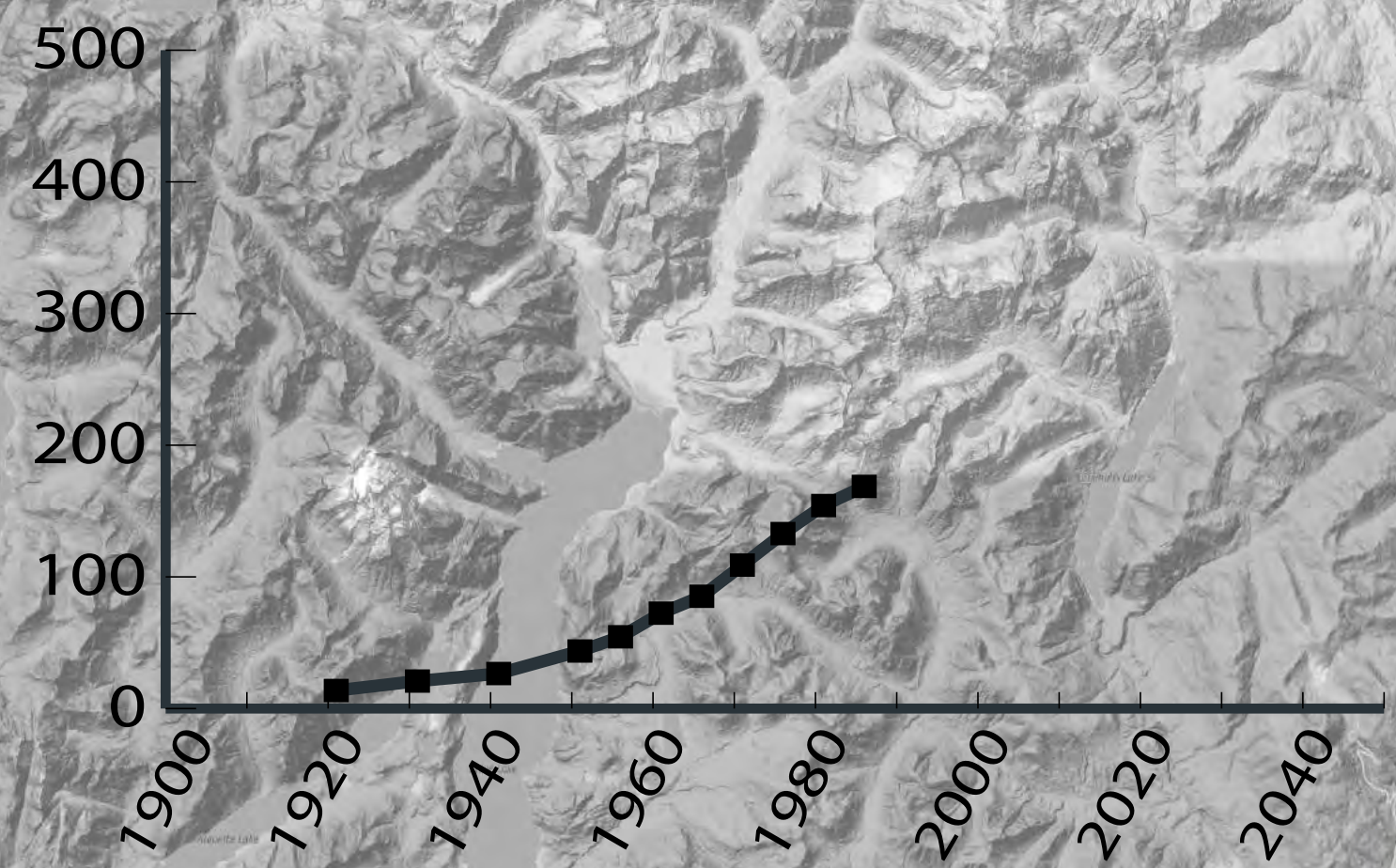


Flood Hazard



Exposed Population

1986

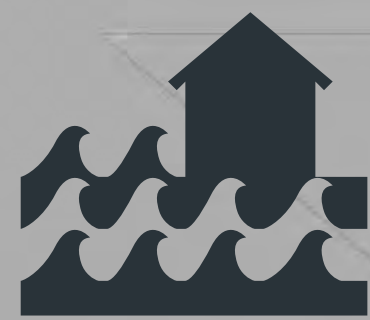
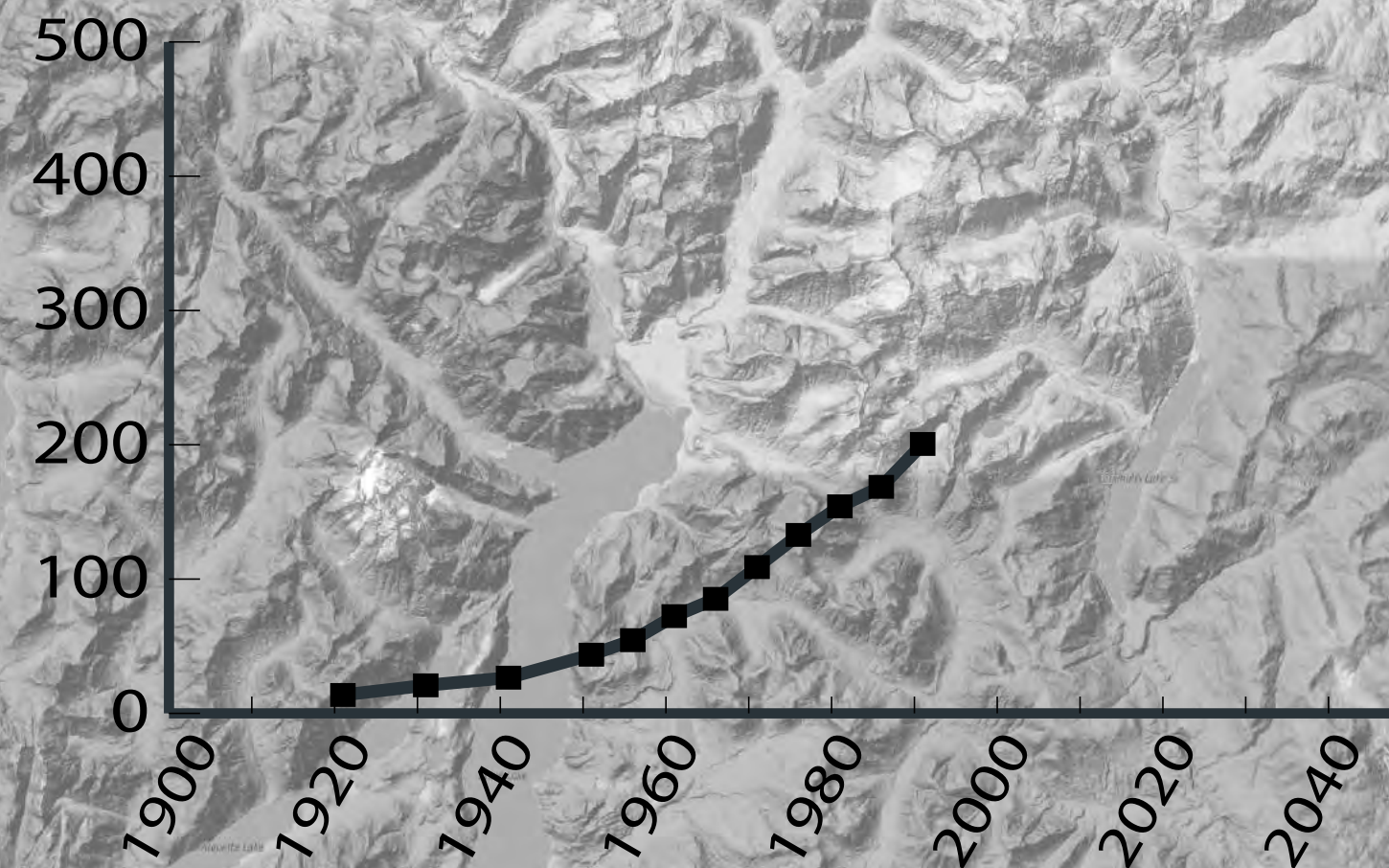


Flood Hazard



Exposed Population

1991

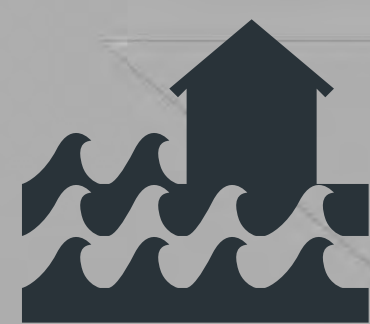
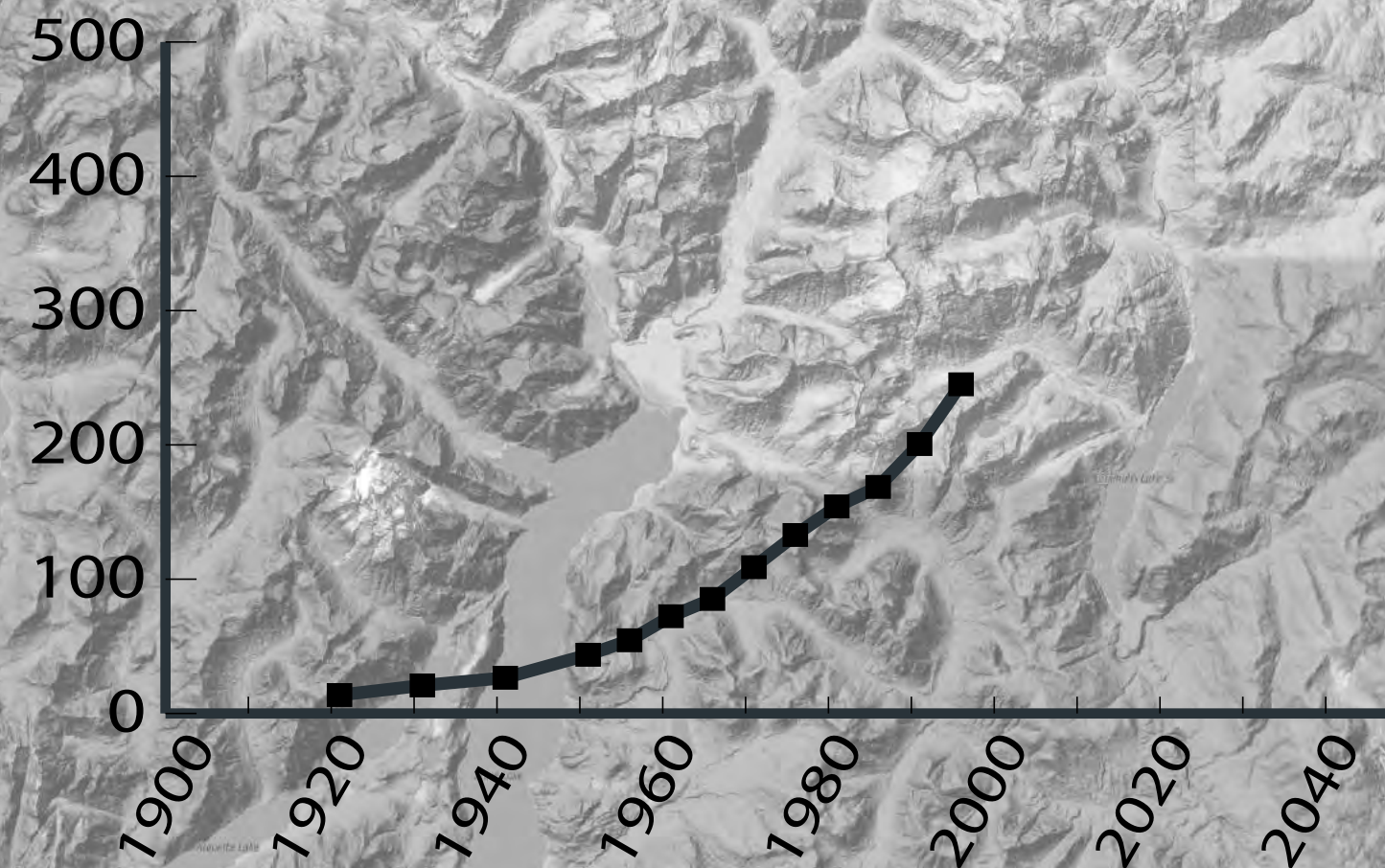


Flood Hazard



Exposed Population

1996

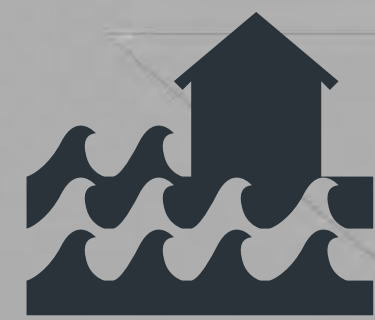
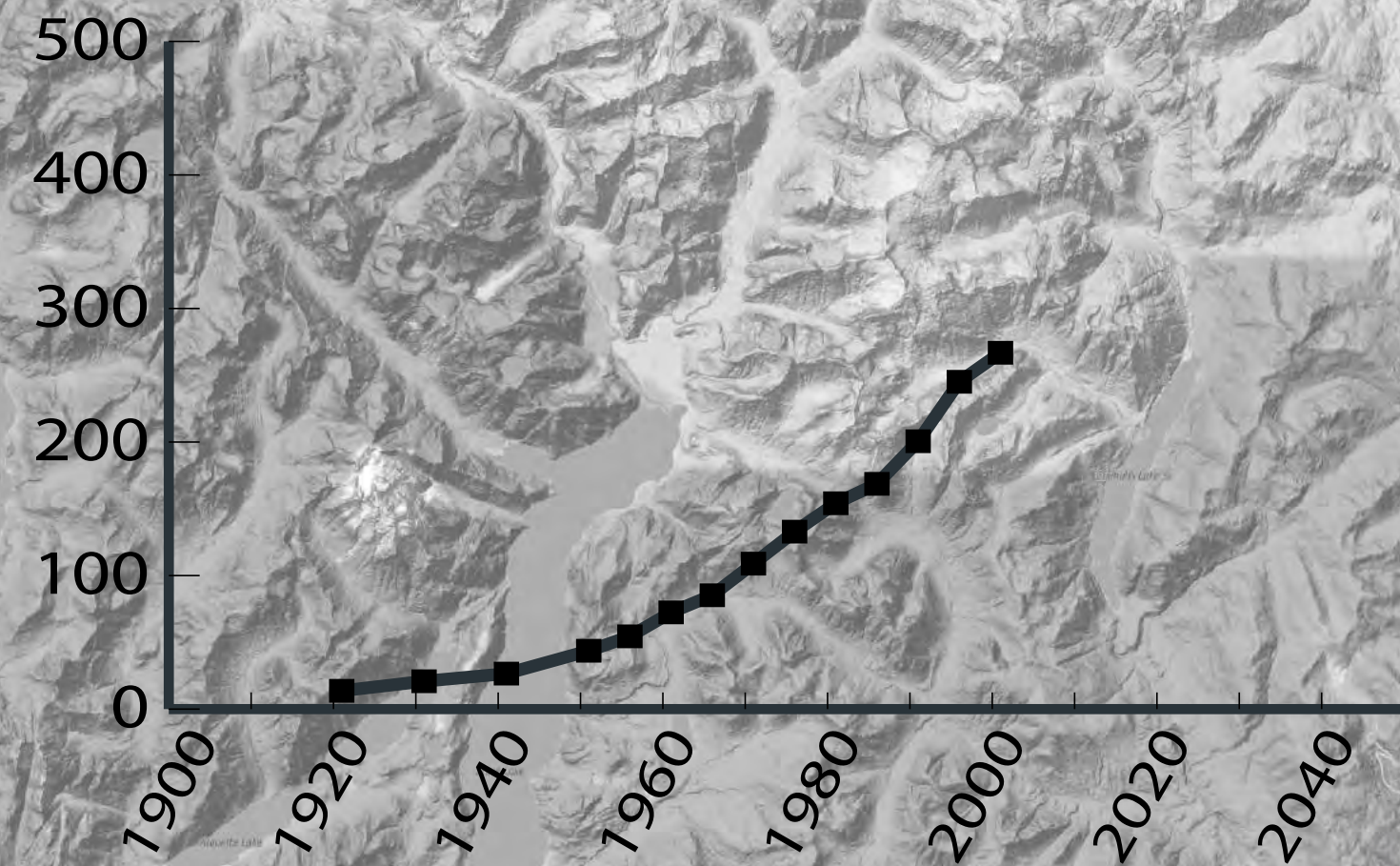


Flood Hazard



Exposed Population

2001

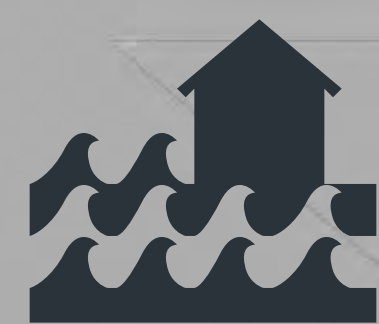
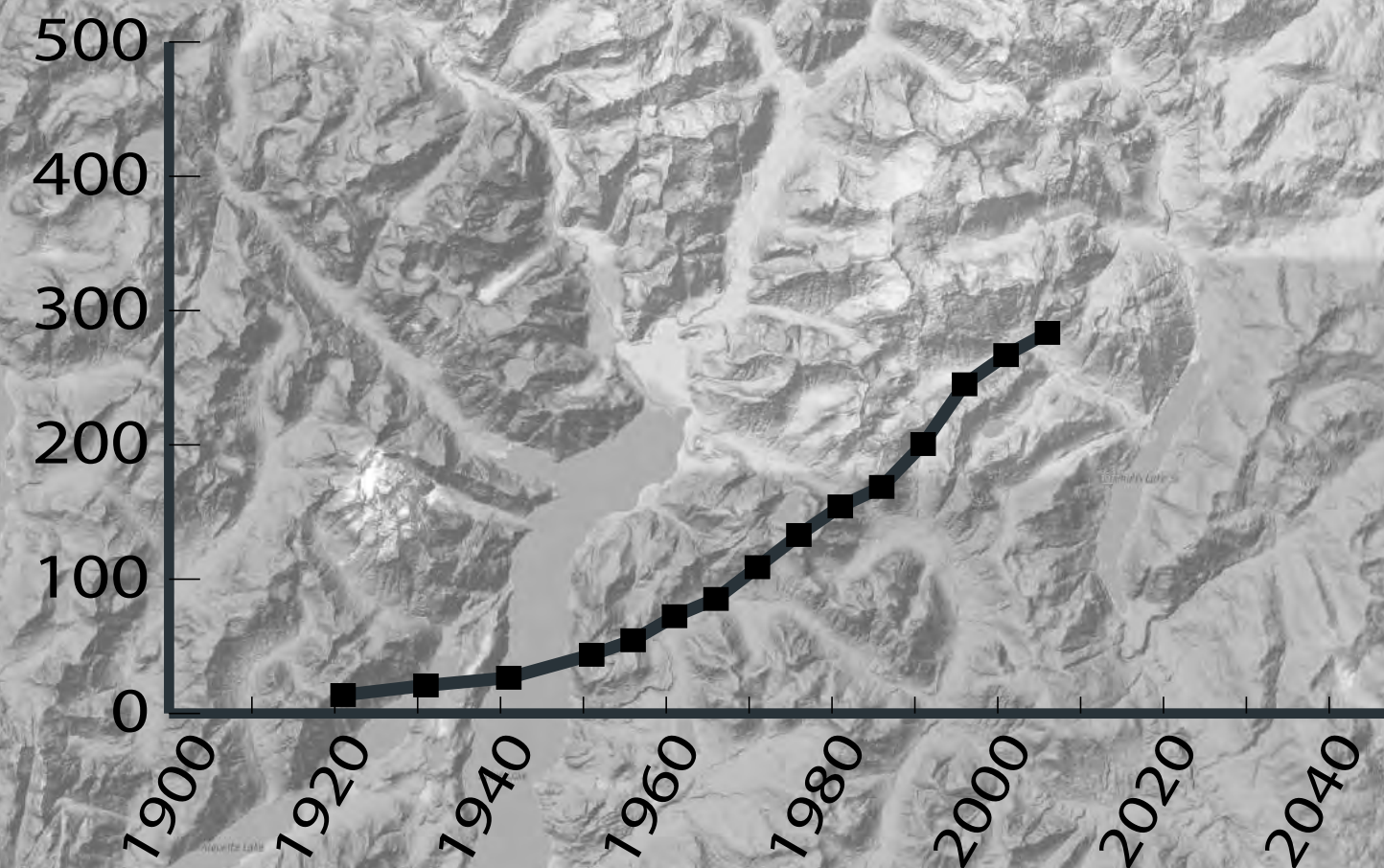


Flood Hazard

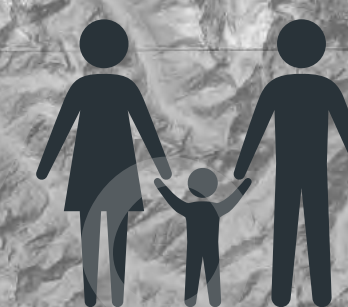


Exposed Population

2006

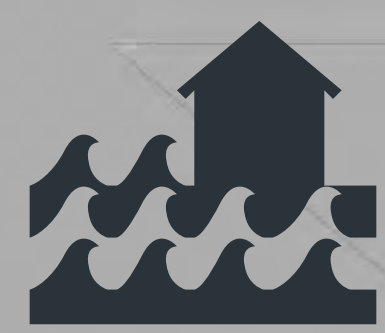
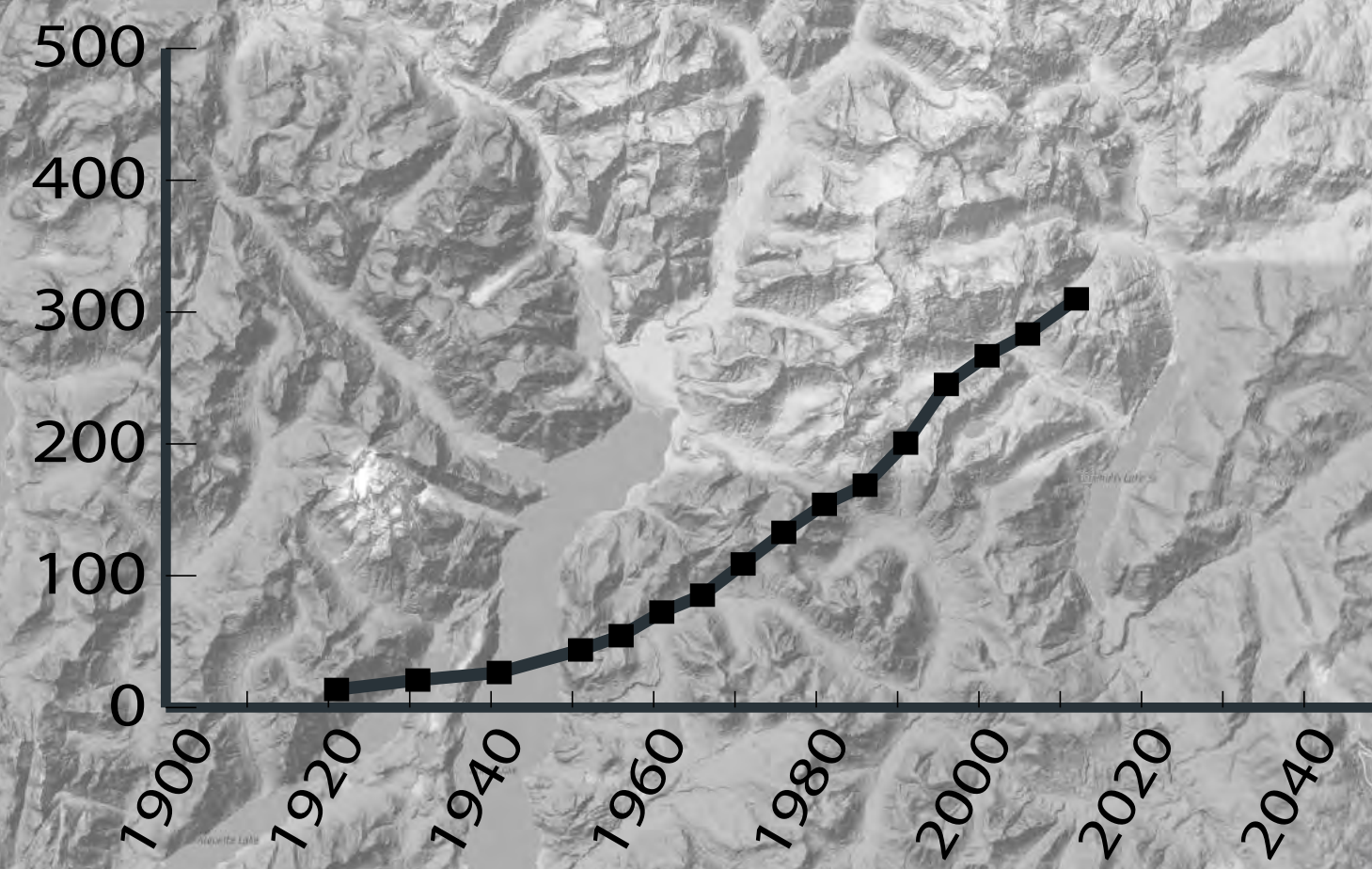


Flood Hazard

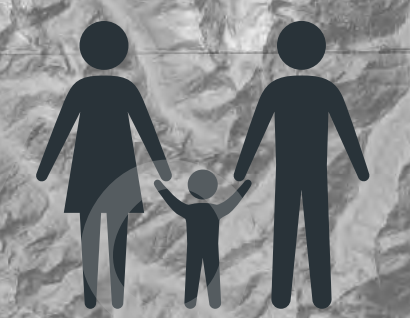


Exposed Population

2012

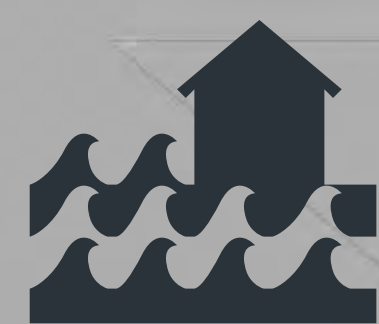
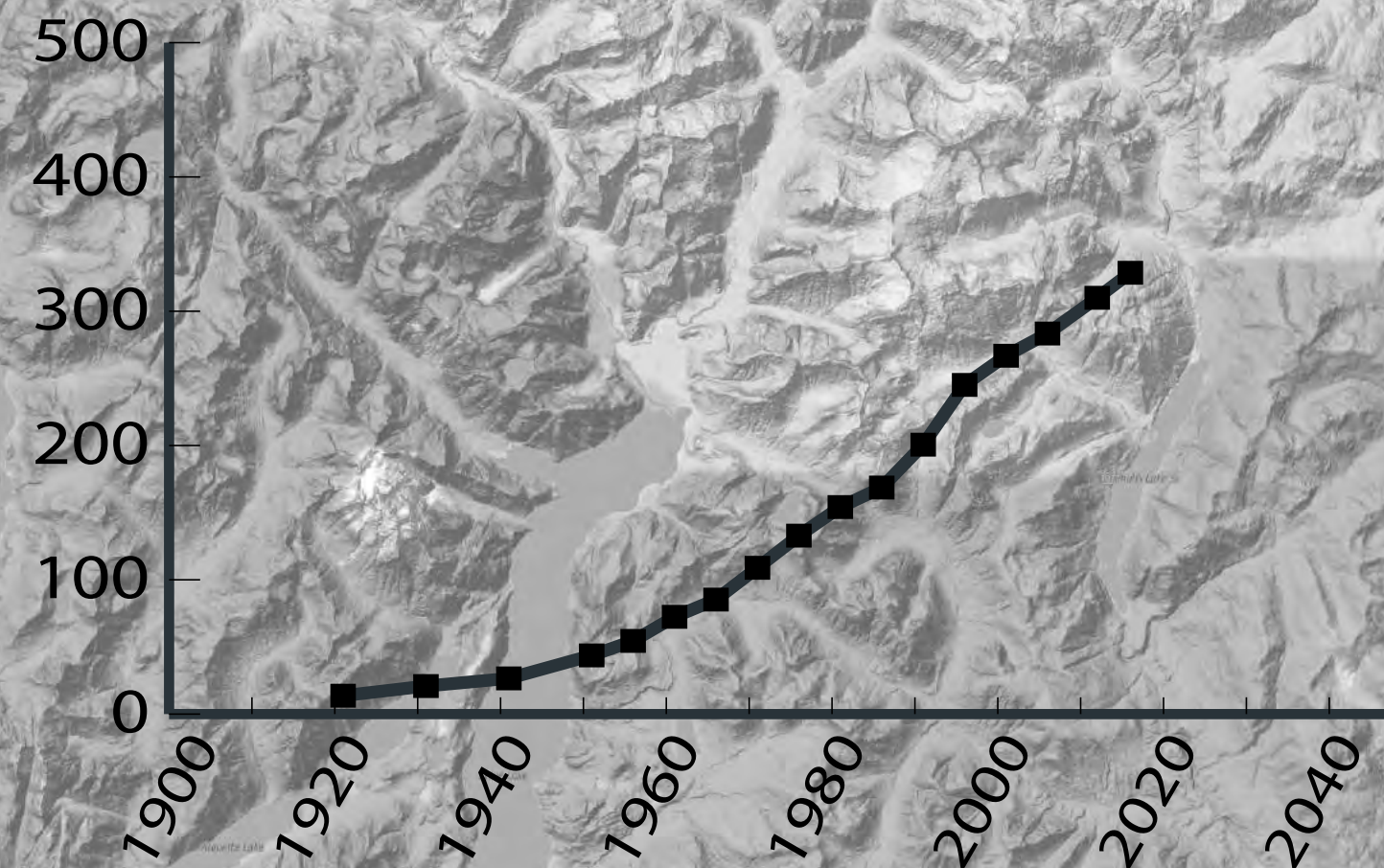


Flood Hazard



Exposed Population

2016

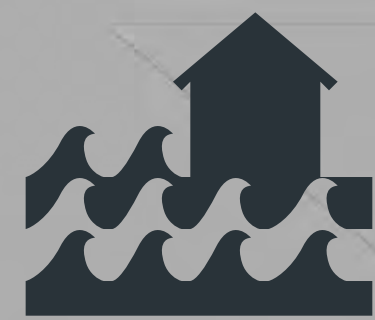


Flood Hazard



Exposed Population

Present Day Dike Assessment



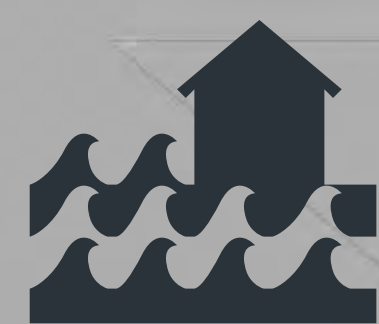
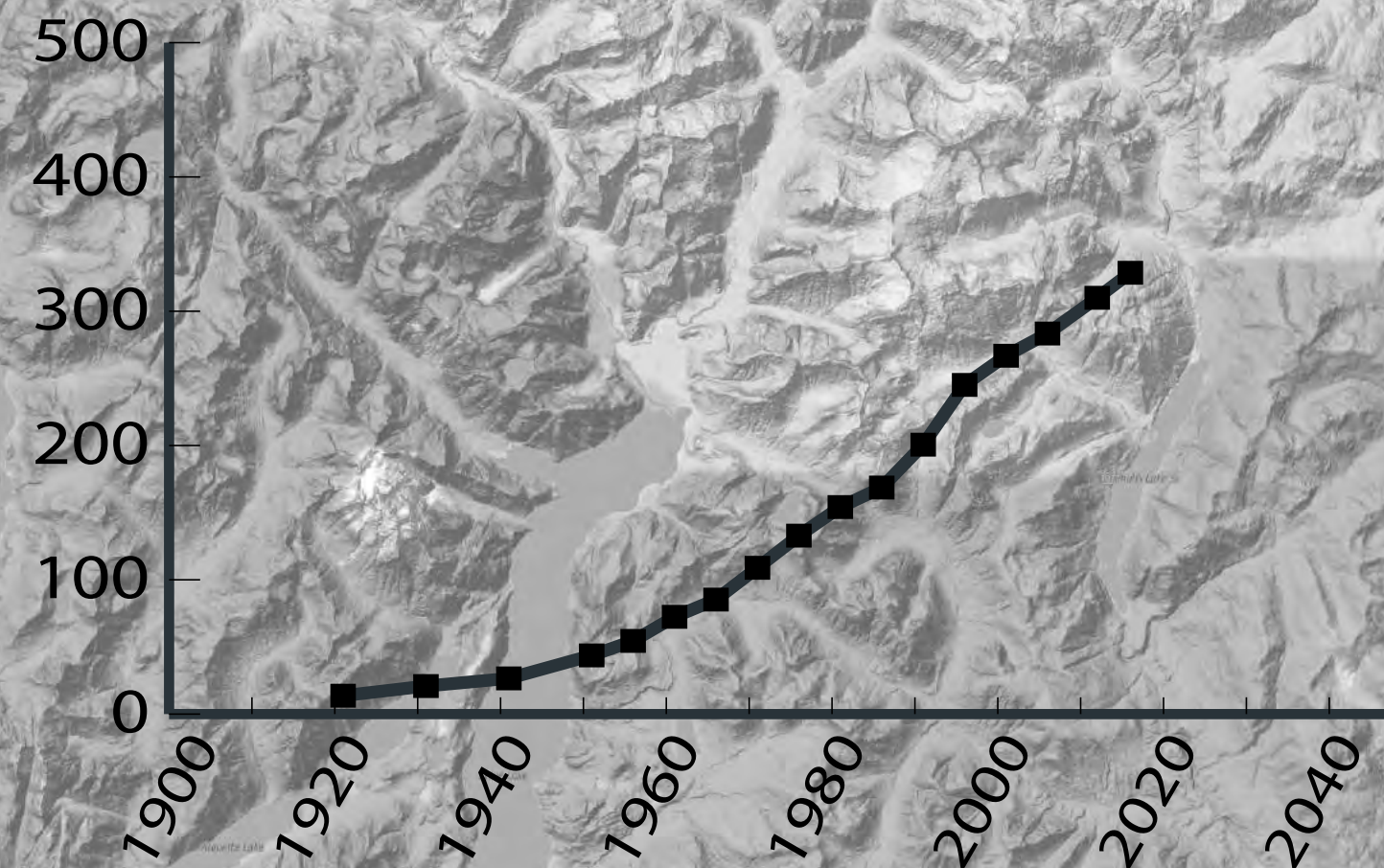
Flood Hazard



Exposed Population

Dike Assessment Data from NHC 2015

2016

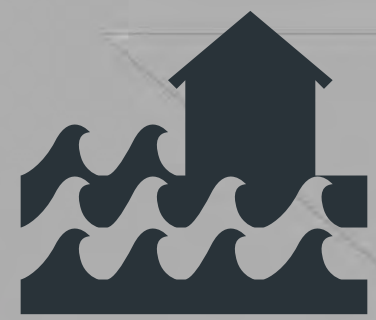


Flood Hazard



Exposed Population

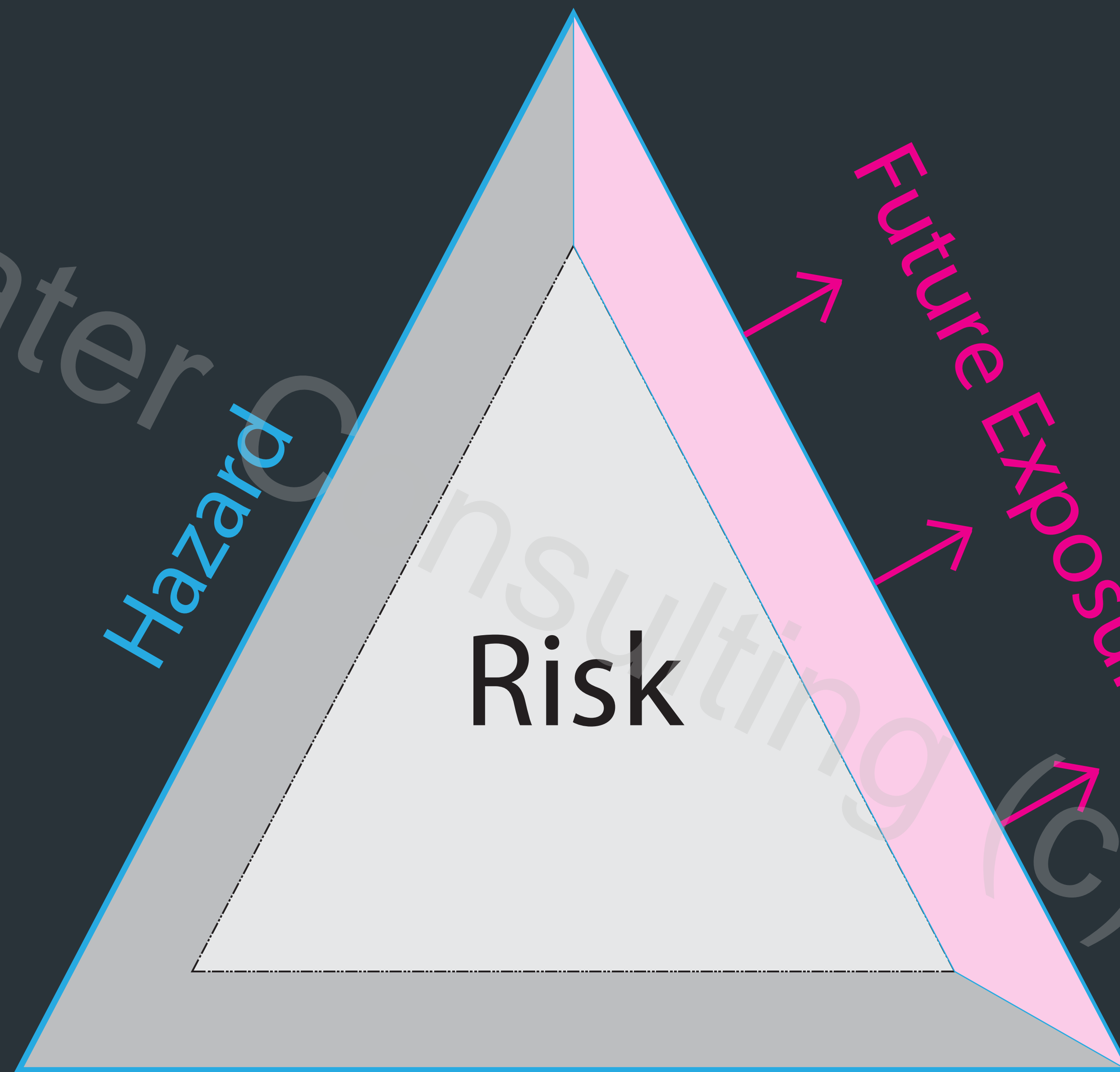
Agricultural Land Reserve



Flood Hazard



Exposed Population



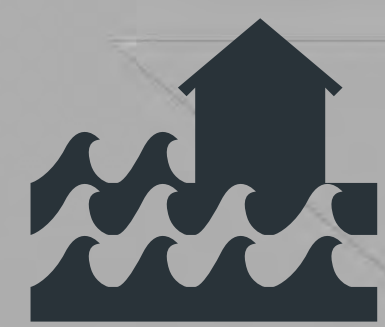
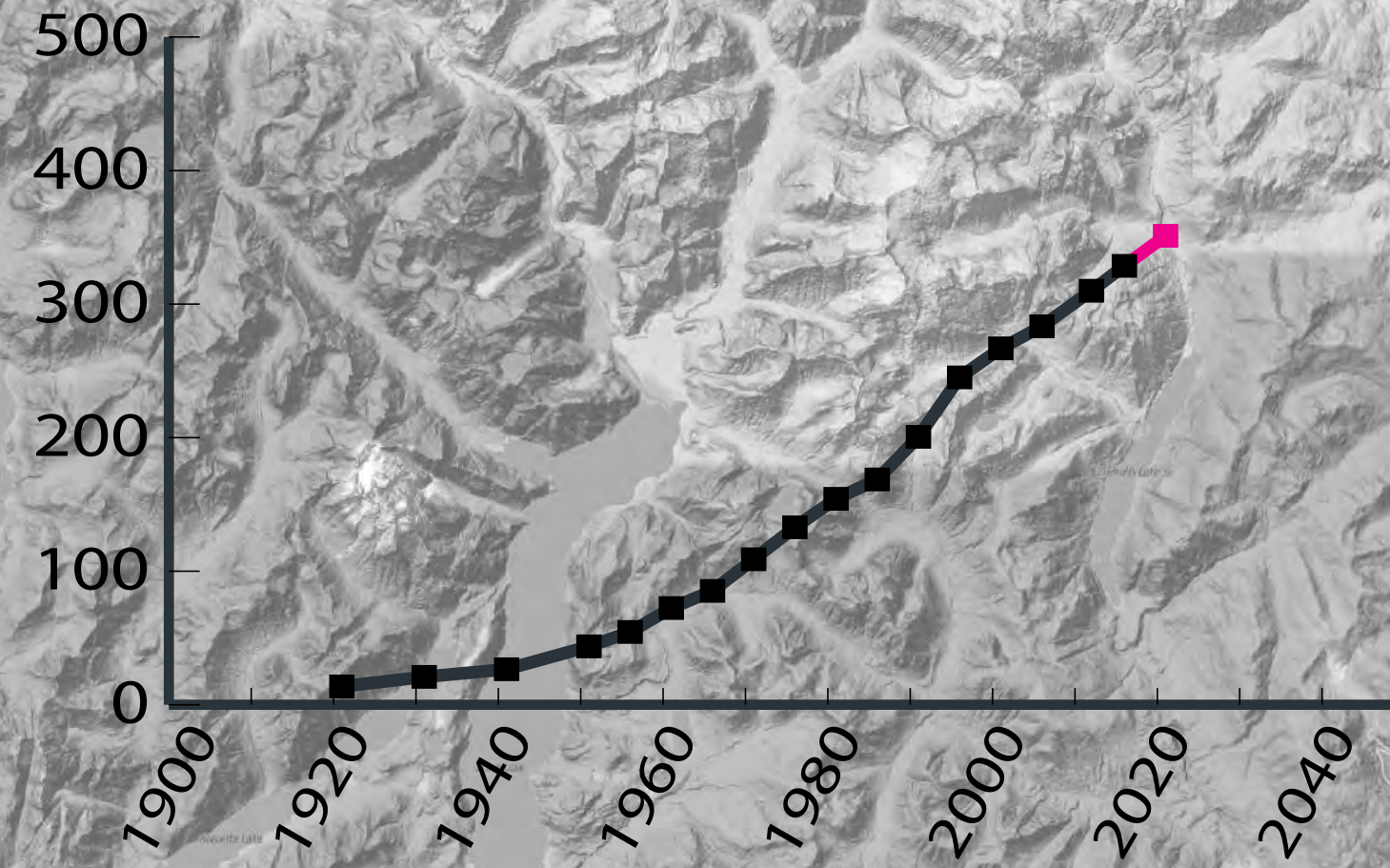
Hazard

Risk

Vulnerability

Future Exposure???

2021

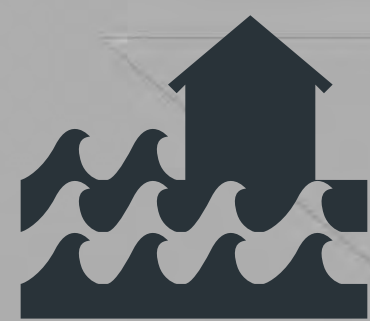
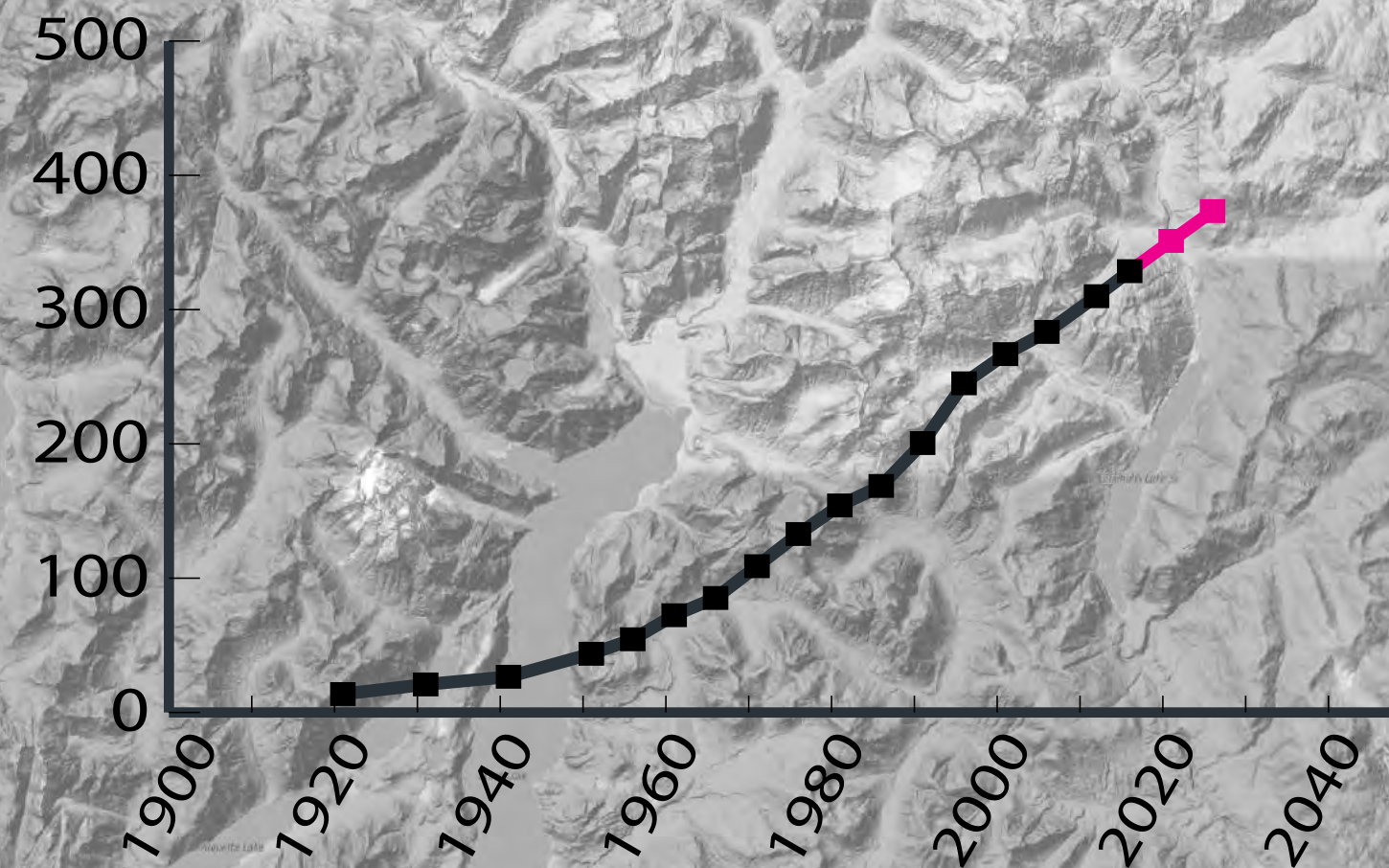


Flood Hazard

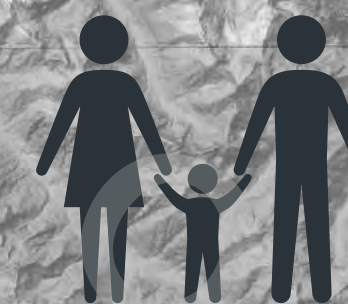


Exposed Population

2026

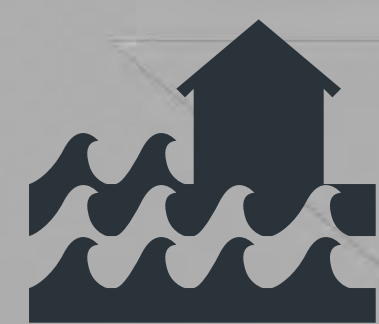
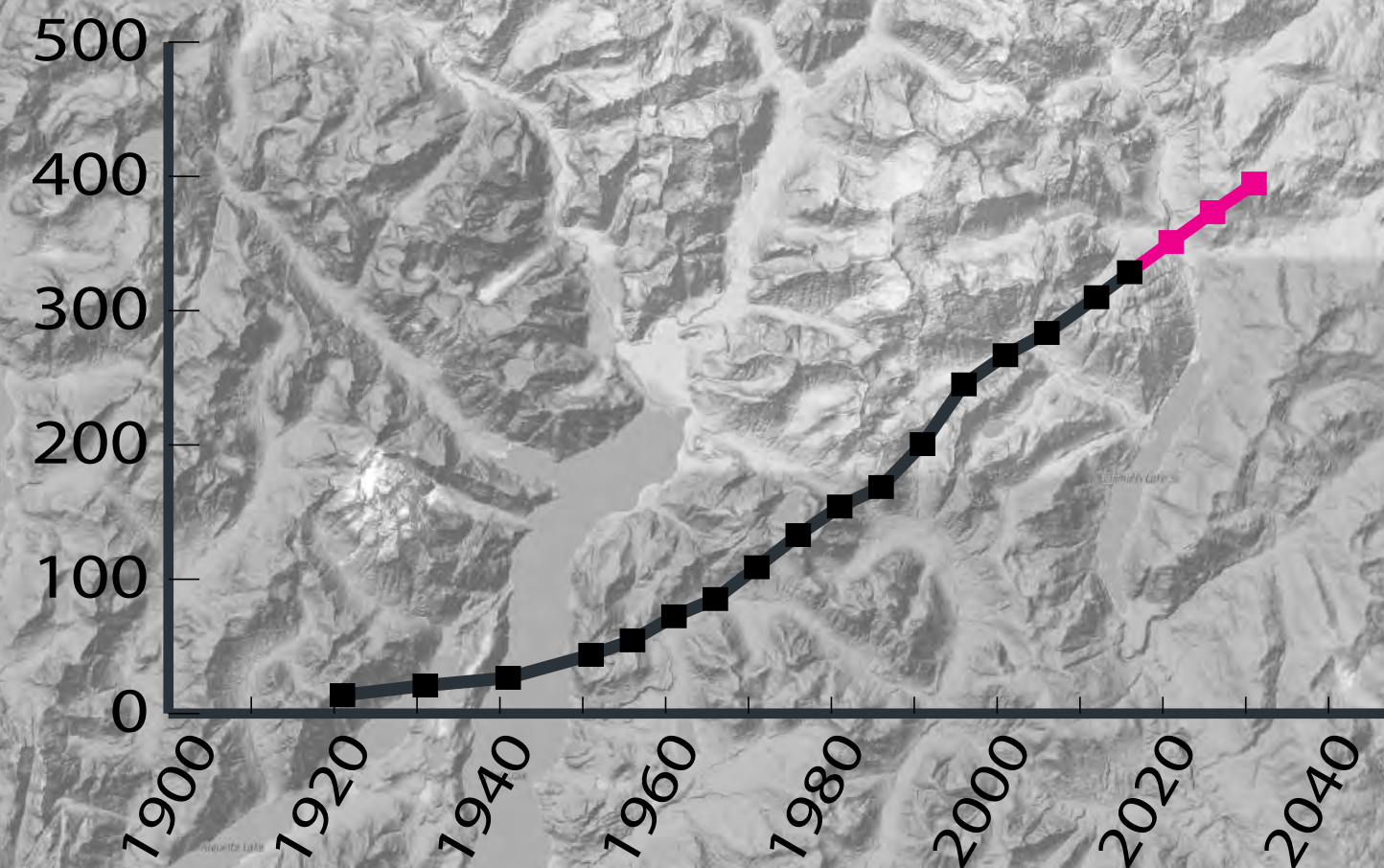


Flood Hazard



Exposed Population

2031

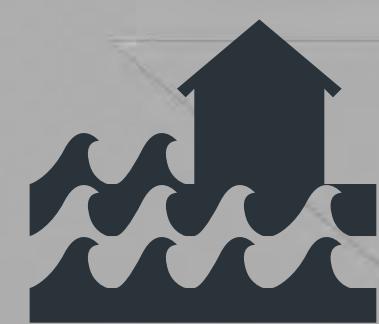
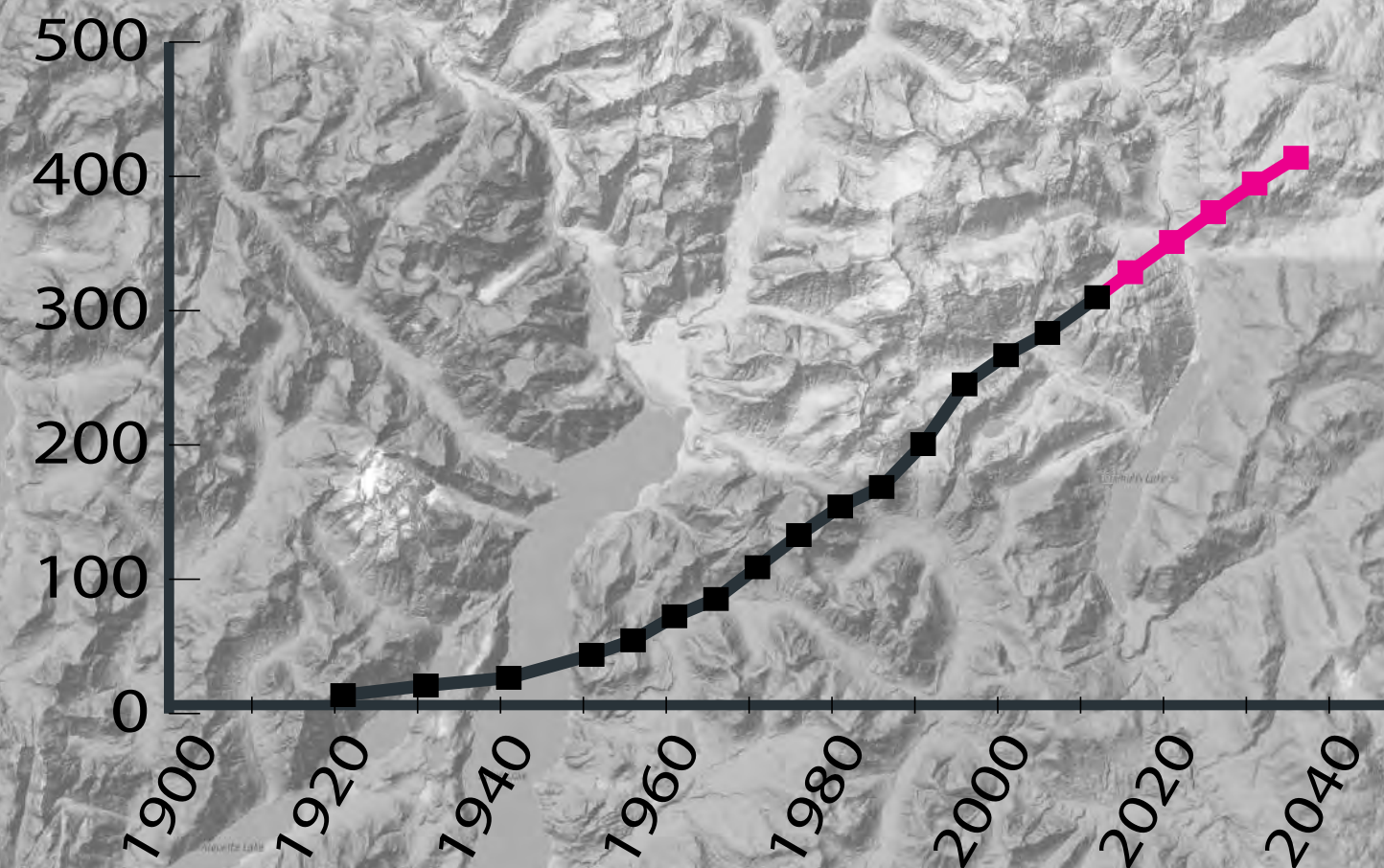


Flood Hazard



Exposed Population

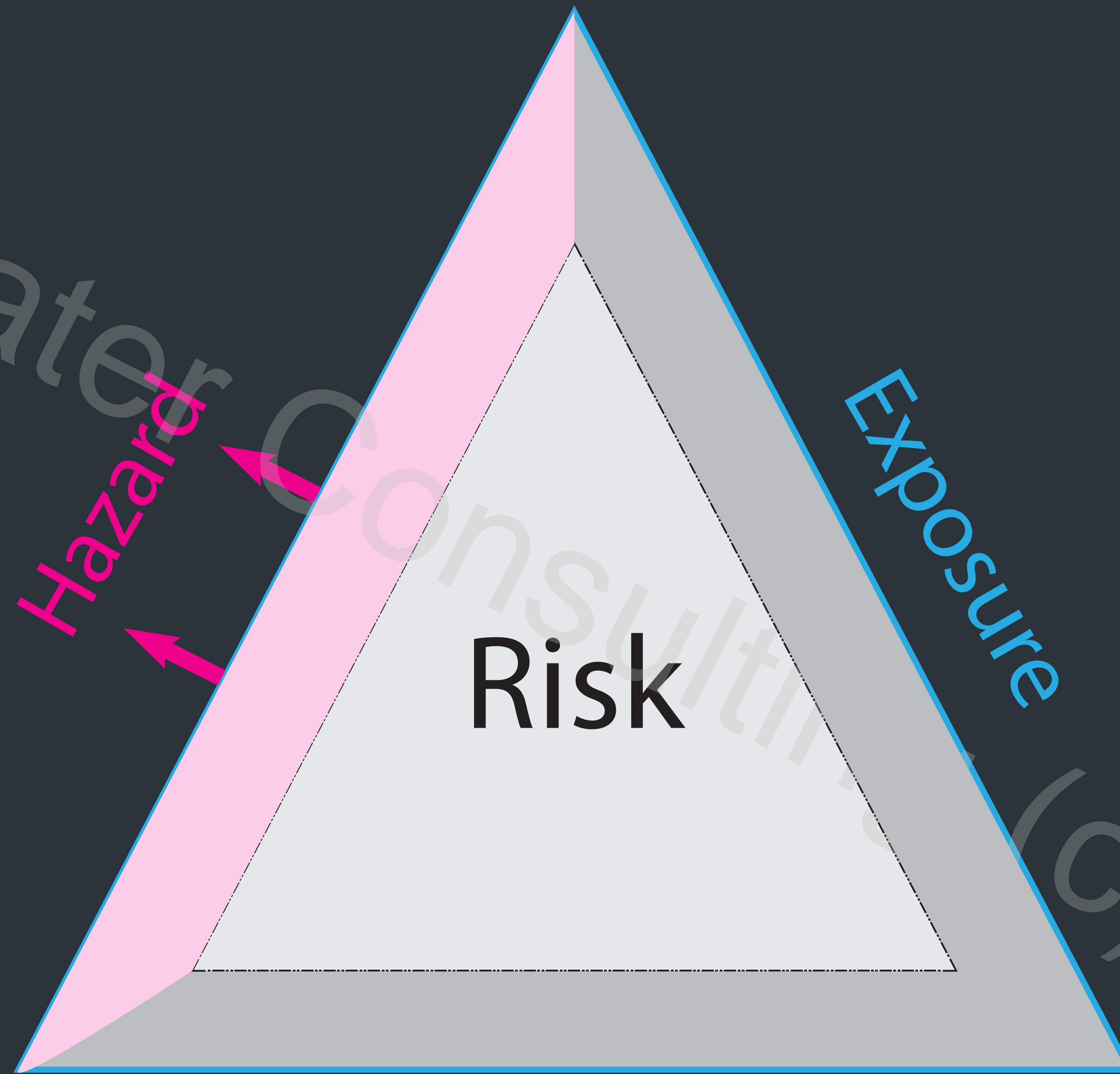
2036



Flood Hazard



Exposed Population



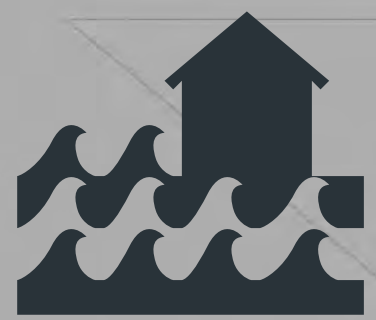
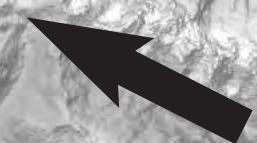
Risk

Hazard

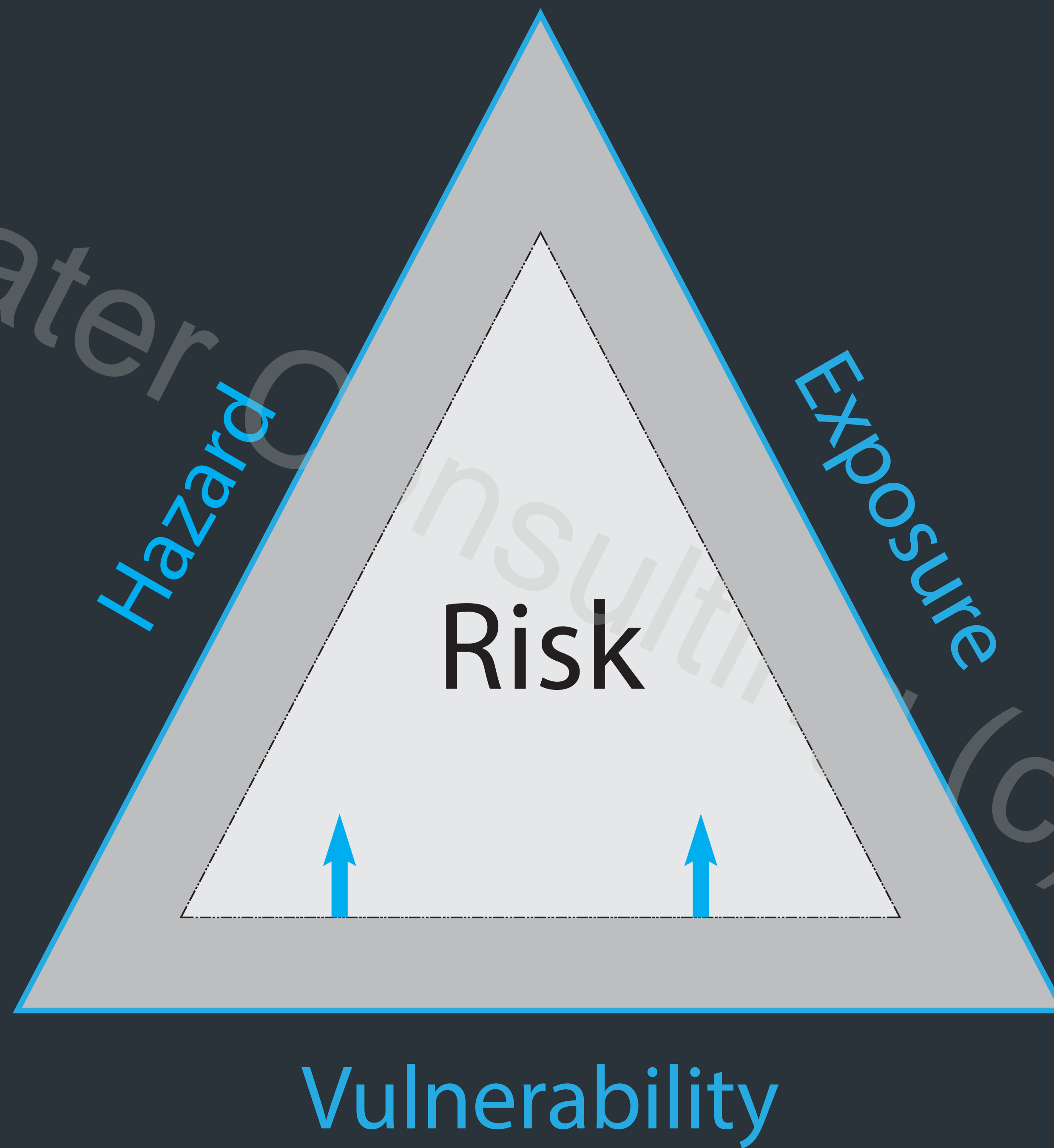
Exposure

Vulnerability

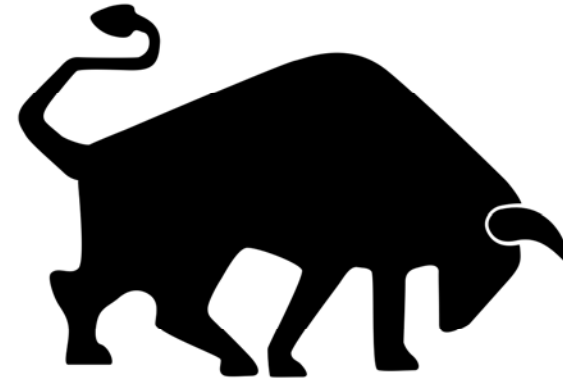
Climate change is affecting our hazard



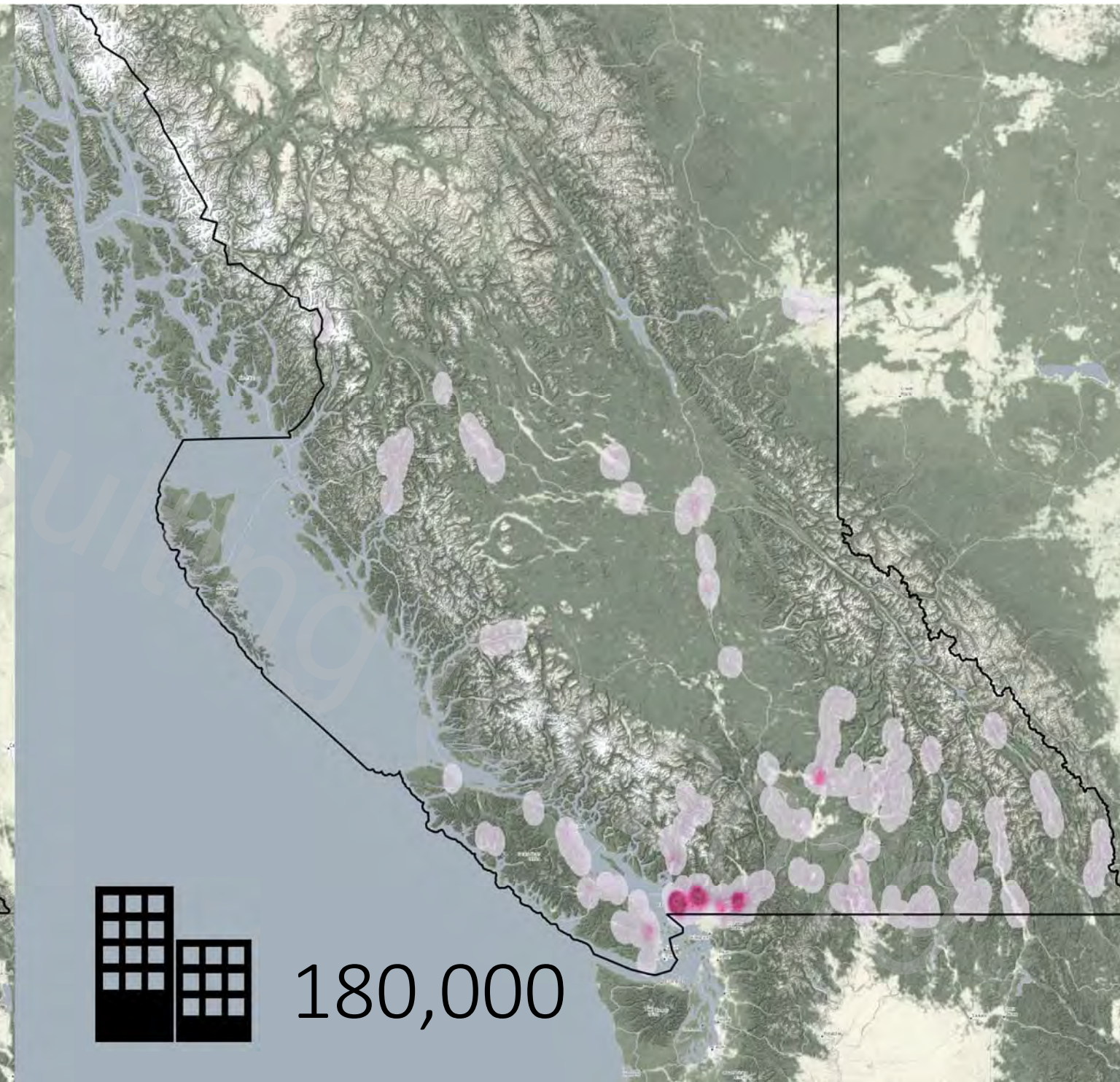
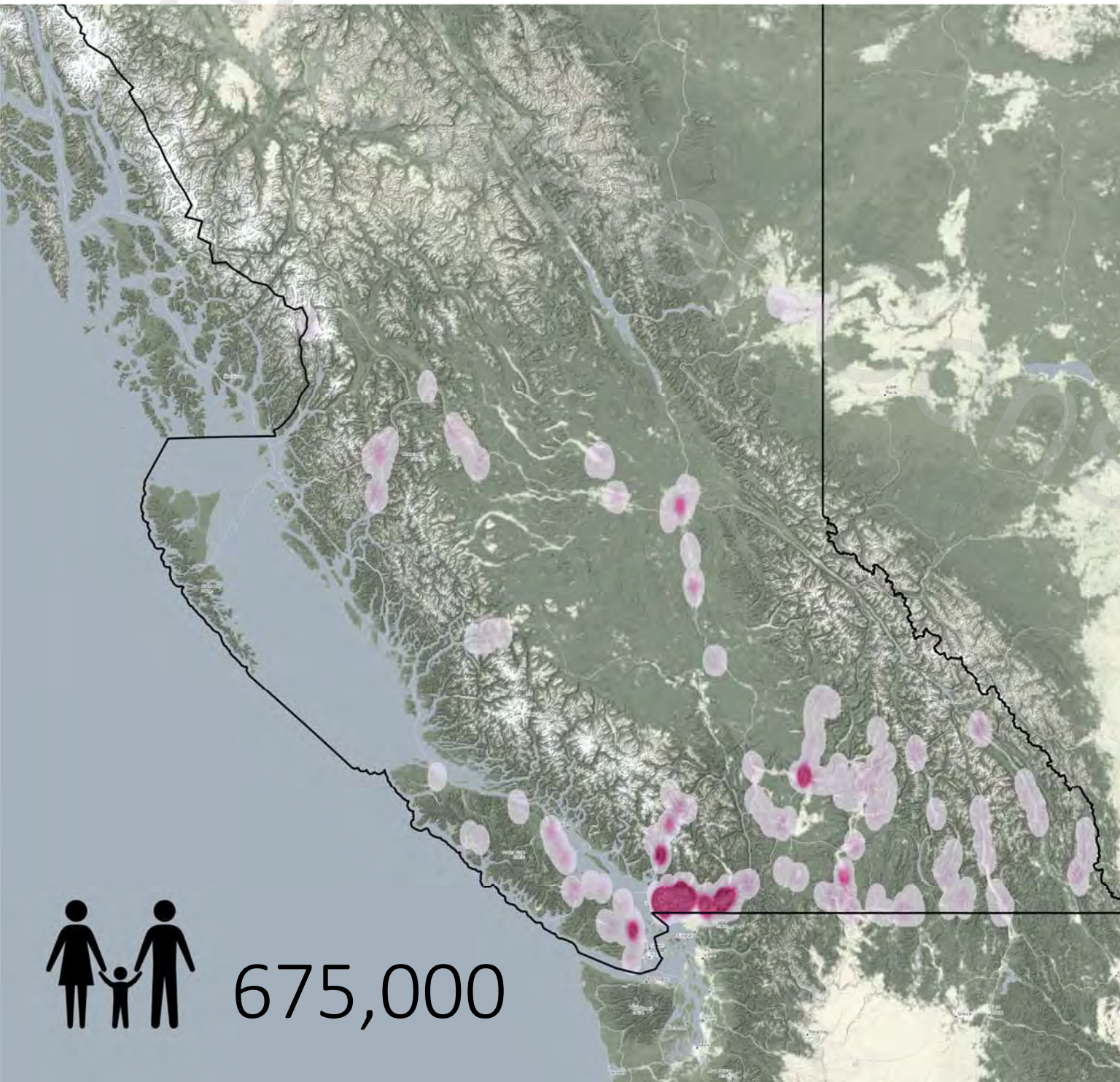
Flood Hazard



Let's flip this
problem on
its head



Exposure = Opportunity for Risk Reduction



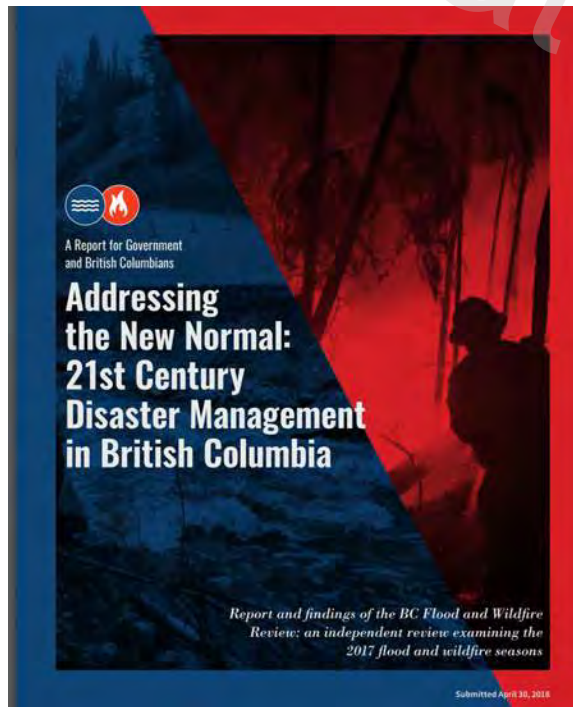
An Evolution in Flood Management

Sayers et al. 2014

A willingness to live with floods	<ul style="list-style-type: none">• Individual and small communities adapt to nature's rhythm.
A desire to use the floodplain	<ul style="list-style-type: none">• Fertile land in the floodplain is drained for food production.• Permanent communities are established on the floodplain.• Local (uncoordinated) levees start to be constructed.
A desire to control flood flows and defend against flooding	<ul style="list-style-type: none">• Large scale structural approaches (levees, dams and other controls) are planned and implemented through organized governance.
A desire to reduce flood damages	<ul style="list-style-type: none">• A recognition that engineering alone has limitations.• Effort is devoted to increasing the resilience of communities should a flood occur.• Effort is devoted to mitigate loss of ecosystem services.
A desire to manage risks efficiently	<ul style="list-style-type: none">• A recognition that budgets are limited and not all problems are equal.• Risk management is seen as a means to target limited resources.
A desire to promote opportunities and manage risks adaptively	<ul style="list-style-type: none">• Adaptive management is seen as effective in managing the severe uncertainties in future climate change, funding and demographics.• Working with natural processes is encouraged to both reduce risks efficiently and achieve gains in ecosystem services.

Big Picture Optimism in BC

A movement towards risk-based planning



Abbott and Chapman
Report, Spring 2018

1 OUTCOME

The substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries

1 GOAL

Prevent new and reduce existing disaster risk through the implementation of integrated and inclusive economic, structural, legal, social, health, cultural, educational, environmental, technological, political and institutional measures that prevent and reduce hazard exposure and vulnerability to disaster, increase preparedness for response and recovery, and thus strengthen resilience

4 PRIORITIES

Understanding disaster risk

Strengthening disaster risk governance to manage disaster risk

Investing in disaster risk reduction for resilience

Enhancing disaster preparedness for effective response, and to "Build Back Better" in recovery, rehabilitation and reconstruction

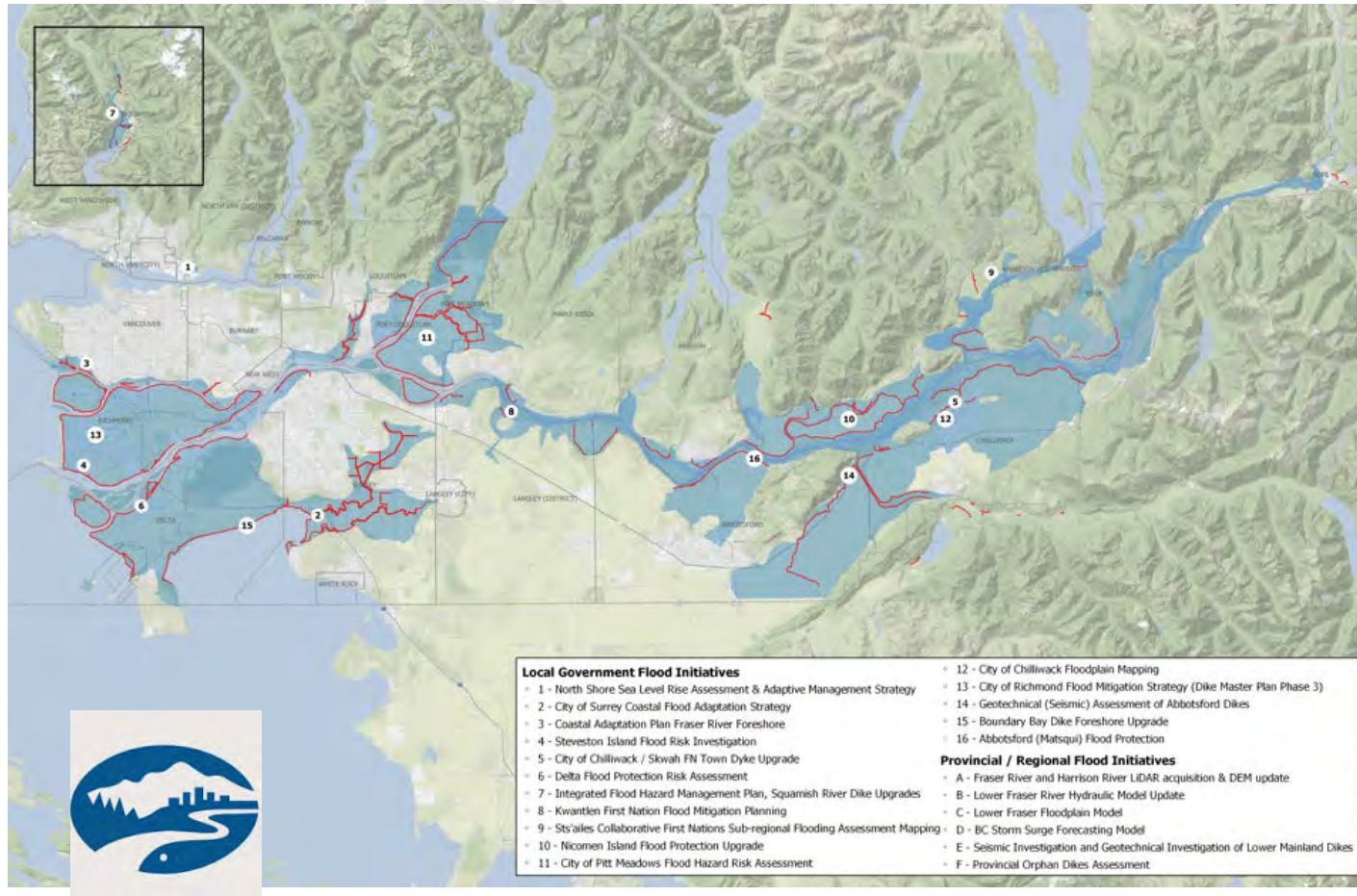
7 TARGETS

- ↓ DISASTER MORTALITY BY 2030
- ↓ NUMBER OF AFFECTED PEOPLE BY 2030
- ↓ ECONOMIC LOSS BY 2030
- ↓ INFRASTRUCTURE DAMAGE BY 2030
- ↑ DRR NATIONAL/LOCAL STRATEGIES BY 2020
- ↑ INTERNATIONAL COOPERATION BY 2030
- ↑ EWS AND DR INFORMATION BY 2030

Province becomes signatory to Sendai, Fall 2018

On the Ground Optimism

Lower Mainland Flood Management Strategy and other initiatives



Map provided by Fraser Basin Council

A willingness to live with floods

- Individual and small communities adapt to nature's rhythm.

A desire to use the floodplain

- Fertile land in the floodplain is drained for food production.
- Permanent communities are established on the floodplain.
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A desire to promote opportunities and manage risks adaptively

- Adaptive management is seen as effective in managing the severe uncertainties in future climate change, funding and demographics.
- Working with natural processes is encouraged to both reduce risks efficiently and achieve gains in ecosystem services.

BC in 2019:

We're on the cusp of big things

A fair amount of activity stuck in the anthropocene....

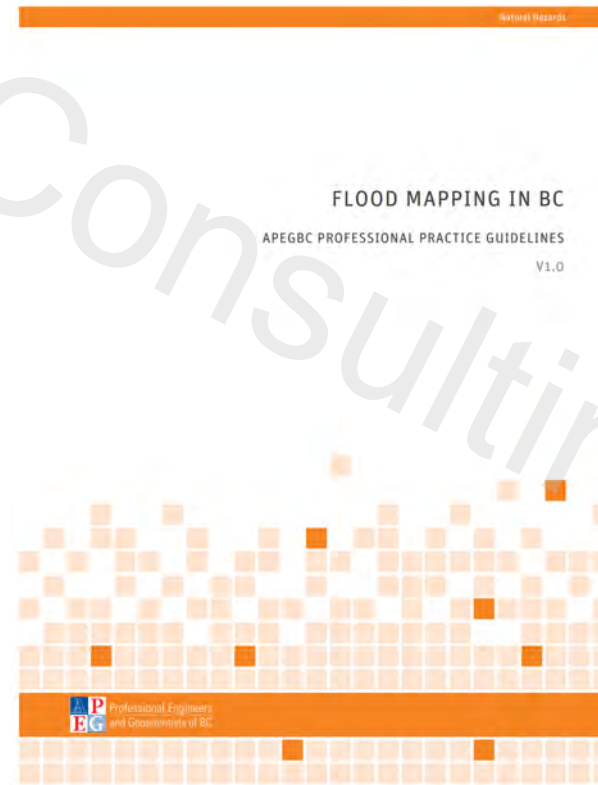
But, strong signals from senior government and local governments that we need to evolve

And yet...we have many obstacles

\$ ≠ Capacity



From river to map...requires
data and expertise
(and in my opinion,
bathymetry)



FEATURE
A CASE FOR DEVELOPING A CANADIAN STANDARD
FOR FLOOD MANAGEMENT COMPETENCY

PLAIDOYER EN FAVEUR DE L'ÉLABORATION D'UNE
NORME CANADIENNE POUR LES COMPÉTENCES
EN MATIÈRE DE GESTION DES INONDATIONS

Dakota X. Davis', Pablo Pina-Poujof', Tamsin Lyle'
Southern Alberta Institute of Technology,
Ebbwater Consulting

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Southern Alberta Institute of Technology,
Ebbwater Consulting

Flood Impacts

Flooding is the most frequent and costly natural hazard in Canada, with impacts spread across social, economic, and environmental sectors. In Calgary alone, flooding has led the city to declare a Local State of Emergency twice in 8 years (2005 and 2013) (City of Calgary, 2018). Between property damages and financial losses, Southern Alberta's 2013 floods cost \$6 billion (Teufel, et al., 2017). Approximately 80,000 people were evacuated and five lives were lost (Teufel, et al., 2017). In Toronto, flooding in the same year cost the municipal government over \$65 million (Hemstra & Thistlethwaite, 2017). Between 2000 and 2018, 10 Alberta floods have been classified as catastrophic (see Table 1.1).

Impacts des inondations

Les inondations constituent le risque naturel le plus fréquent et le plus coûteux au Canada, qui se répète sur les secteurs sociaux, économiques et environnementaux. À Calgary seulement, les inondations ont amené la ville à déclarer l'état d'urgence local deux fois en l'espace de huit ans (2005 et 2013) (Ville de Calgary, 2018). Entre les dommages matériels et les pertes financières, les inondations survenues dans le sud de l'Alberta en 2013 ont coûté six milliards de dollars (Teufel, et al., 2017). Environ 80 000 personnes ont dû être évacuées et on déplore cinq décès (Teufel, et al., 2017). À Toronto, une inondation survenue au cours de la même année a coûté à l'administration municipale plus de 65 millions de

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- Risk management is seen as a means to target limited resources.

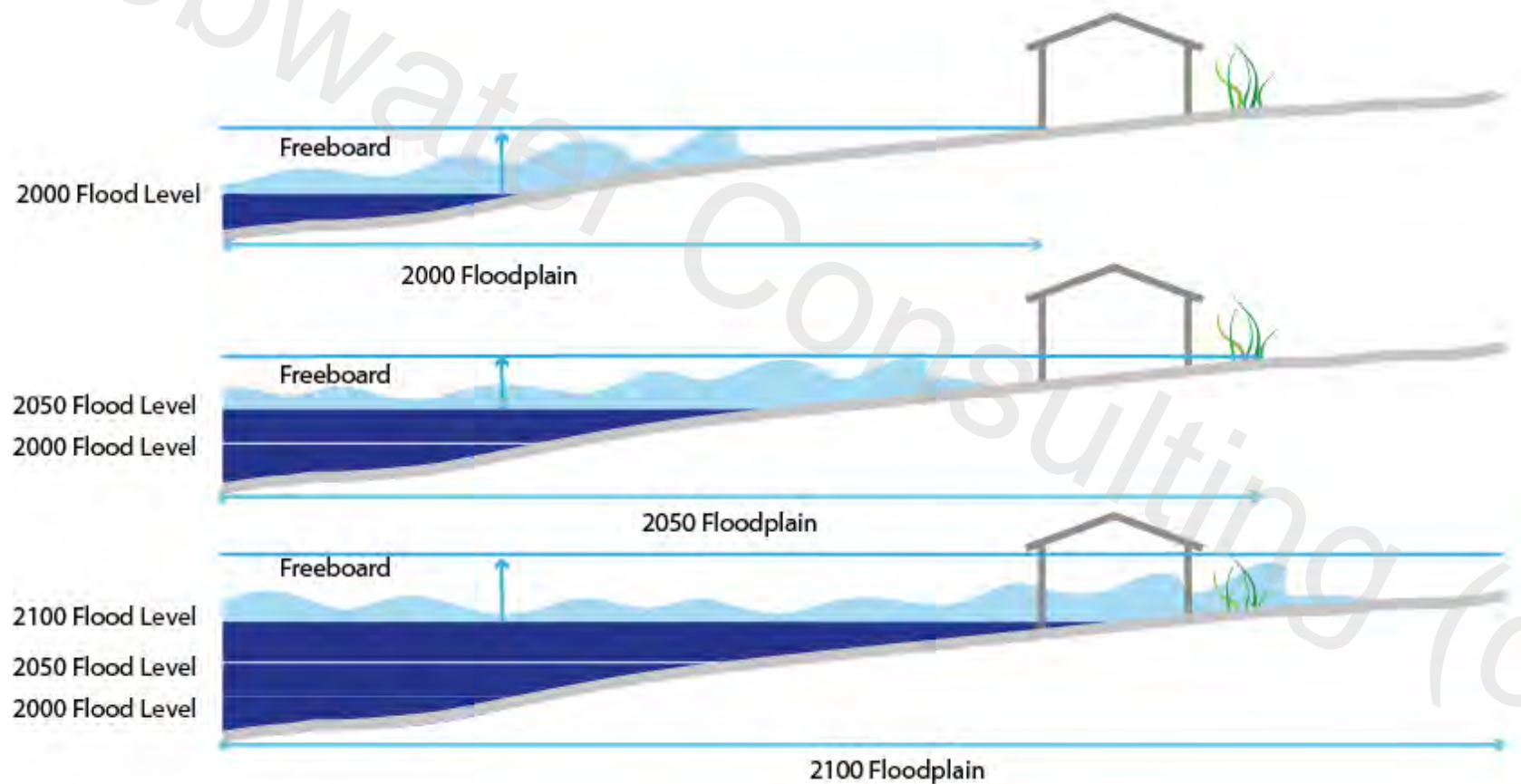
A desire to promote opportunities and manage risks adaptively

- Adaptive management is seen as effective in managing the severe uncertainties in future climate change, funding and demographics.
- Working with natural processes is encouraged to both reduce risks efficiently and achieve gains in ecosystem services.

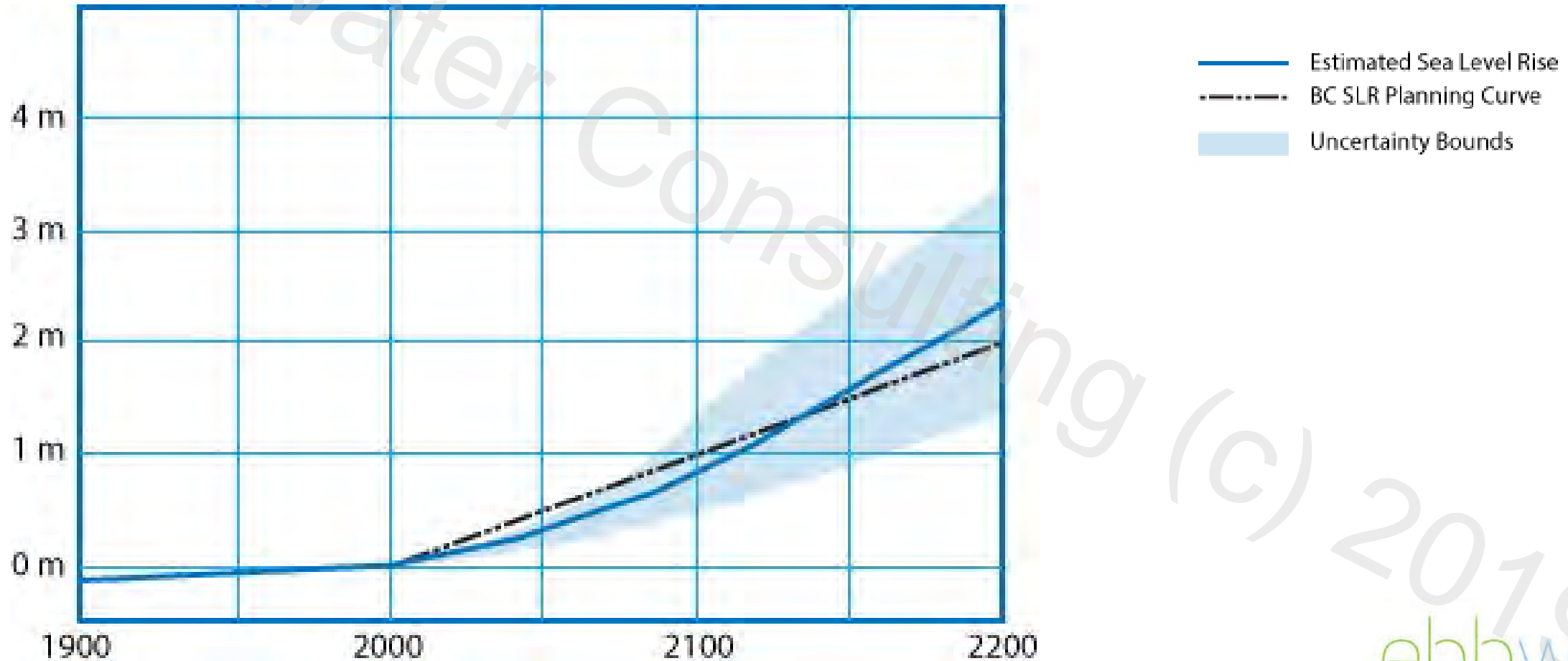
BC in 2019:
Also home to
internationally
recognized approaches
to flood and climate
adaptation

*And an engineer who
will shamelessly plug a
project she thoroughly
enjoyed working on*

Climate change: forcing a paradigm shift



An uncertain and messy third dimension

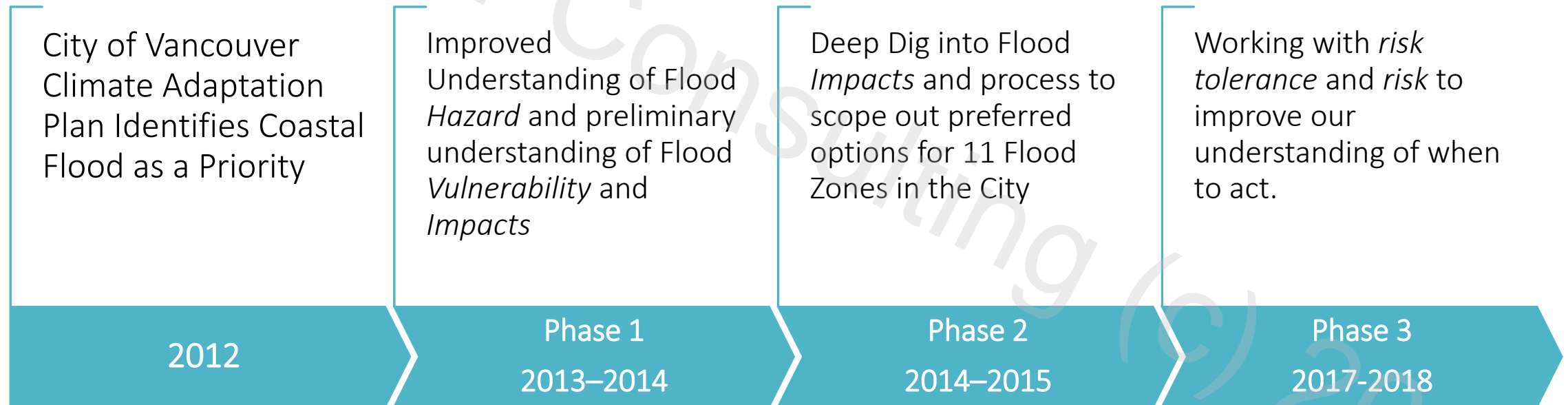


Which in Vancouver, has big implications



Flood hazard extents from City of Vancouver CFRA Phase 1 (NHC 2014)

Vancouver has been working at this for a while...



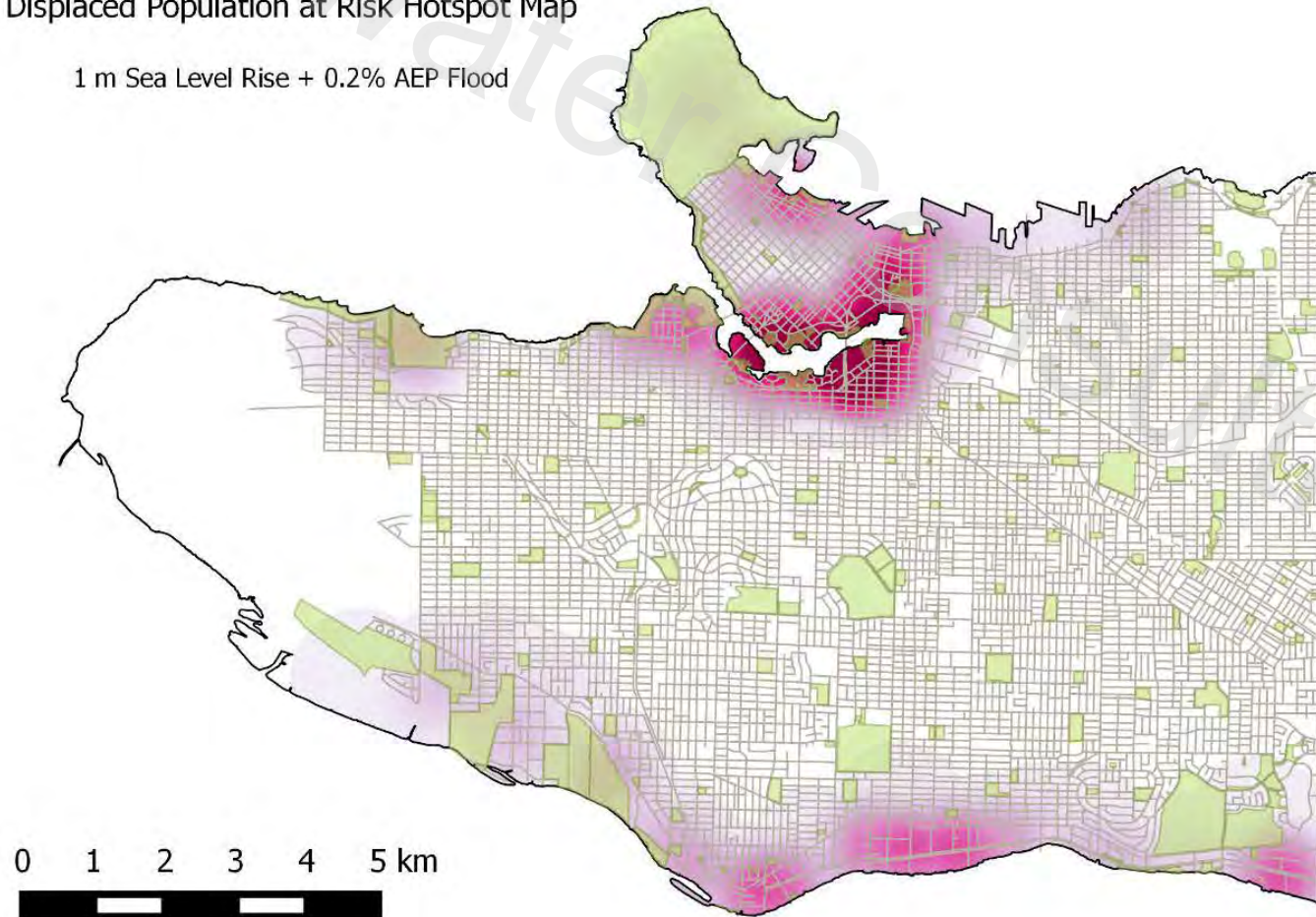
The What?

Making decisions about how to
act

People: 'At Risk' Population Displaced

Displaced Population at Risk Hotspot Map

1 m Sea Level Rise + 0.2% AEP Flood



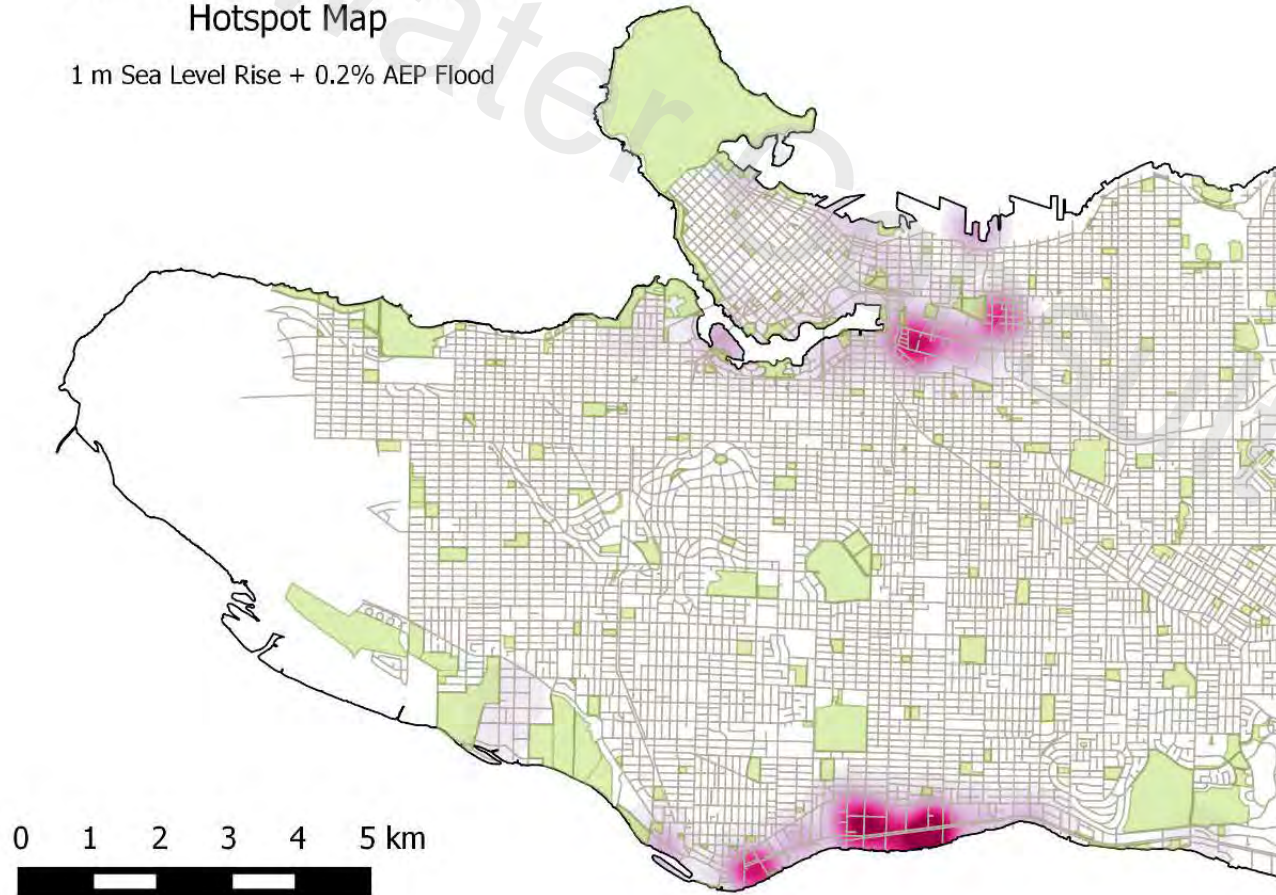
Measure: Social Vulnerability Indexed Affected Population

Summary: Quantitative assessment of at-risk population displacement during flood events. This is a function of People Displaced (separate measure based on hazard and population from 2011 census tract) and a Social Vulnerability Index by census tract as developed by Western University.

Environment: Contaminants

Potential Contaminant Sources Hotspot Map

1 m Sea Level Rise + 0.2% AEP Flood



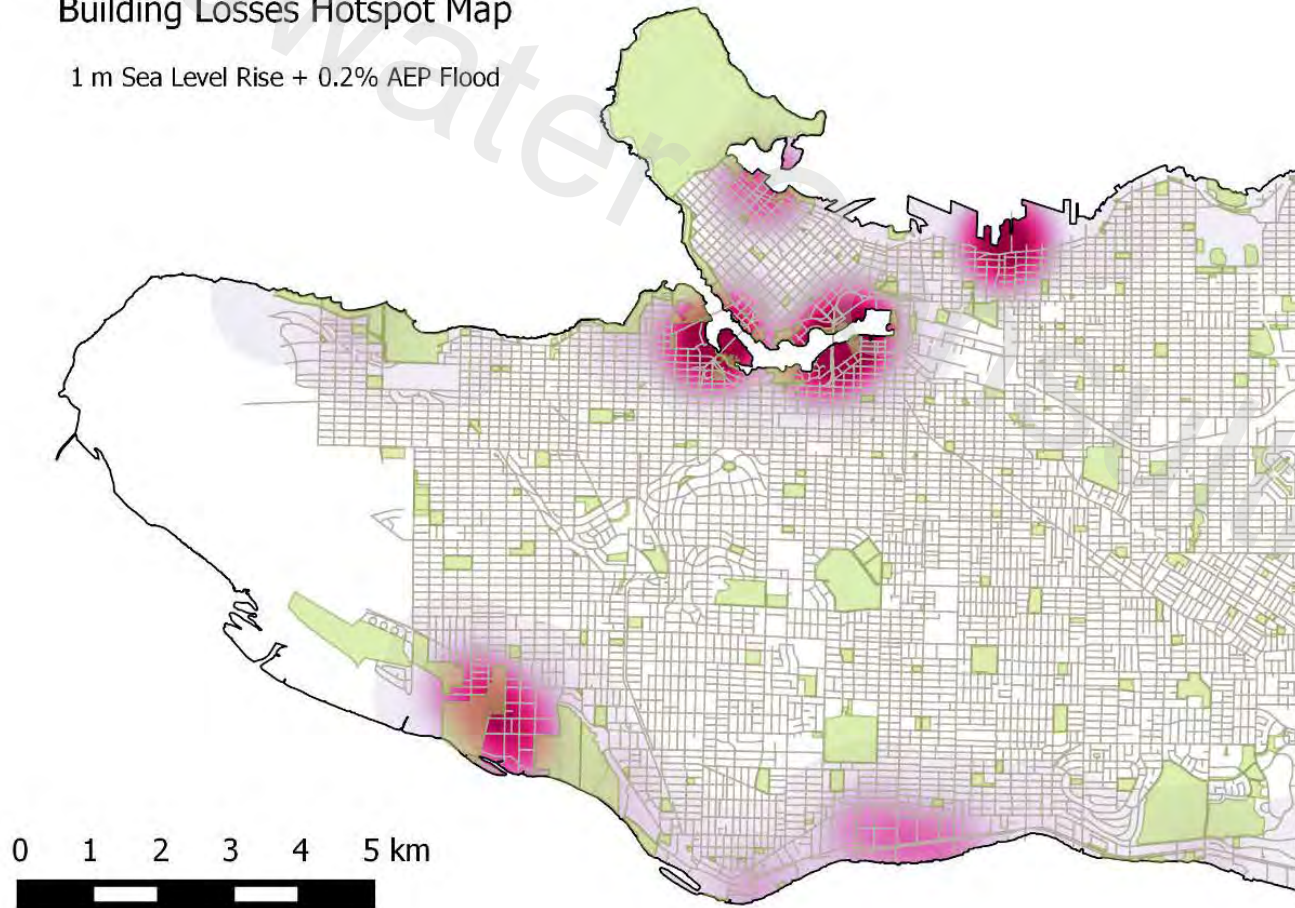
Measure: Risk of contaminant release.

Summary: Quantitative assessment of the number of businesses that might be a contamination source within the floodplain. City of Vancouver Business Licenses were assessed using GIS.

Economy: Building Losses

Building Losses Hotspot Map

1 m Sea Level Rise + 0.2% AEP Flood



Measure: Millions of Dollars

Summary: Quantitative assessment of the dollar cost of building damage based on Hazus modelling

Decisions based on varied values

PEOPLE	
People Displaced	# of people displaced from flood events
People Displaced	# people displaced permanently
'at risk' people impacted	Social Vulnerability Index (SVI) weighted displacement
Park and Recreational Amenity Value	Value-weighted area affected per event
Loss of critical services	# of pieces of infrastructure impacted
Aesthetics	-2 to 2
ENVIRONMENT	
Risk of Contaminant Release	# of sites with potential contaminants
Environmental Benefits	-2 to +2
ECONOMY	
Damage to Infrastructure	Value-weighted km of roads impacted
Damage to buildings	\$M
Business disruption	# of employees working in impacted businesses
Loss of Inventory	\$M
Emergency Response costs	Estimated cost per event
IMPLEMENTATION	
Capital Costs	\$M
Maintenance costs	\$M
Adaptability	1 to 4
Ease Of Implementation	1 to 5

Example measures for City of Vancouver, 2015. Developed with Compass Resource Management.

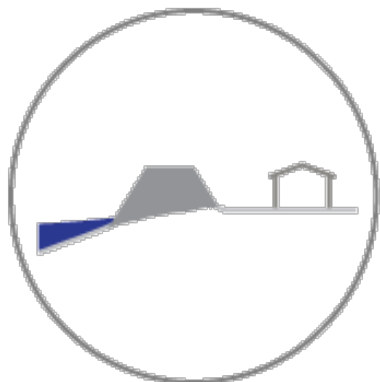
To get to preferred options by neighbourhood

Impacts from Flood Event (Per Event – 1 m SLR + 0.2% AEP Flood Event)

Measure	Scale	BASELINE	PROTECT Park Dike	PROTECT Road Dike	ADAPT Multiple Tools	RETREAT
PEOPLE						
People displaced temporarily	# of people displaced	461	0	231	124	0
"At risk" people impacted	Social Vulnerability Index (SVI) weighted displacement	231	0	185	62	0
Park and recreational amenity value	Area affected per event (km ²)	0.6	0.04	0.34	0.6	0.6
Loss of critical services	# of pieces of infrastructure impacted	8	6	7	0	0
ENVIRONMENT						
Risk of contaminant release	# of sites with potential contaminants	0	0	0	0	0
ECONOMY						
Damage to infrastructure	Value-weighted km of roads impacted	4.9	0.0	0.5	1.3	0
Damage to buildings	\$M	4	1.1	1.3	1	0
Loss of inventory	\$M	10	5.4	6.7	3	0
Business disruption	# of employees working in impacted businesses	124	107	121	33	0
Emergency response costs	\$M	0.3	0	0.2	0.1	0

Complementary Design with Co-Benefits

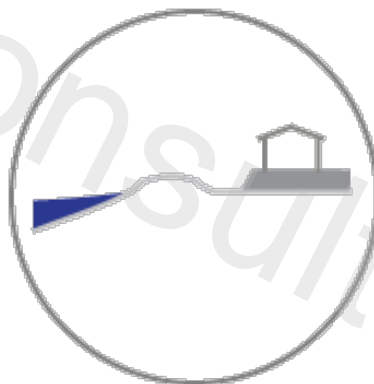
Cornerstone Idea



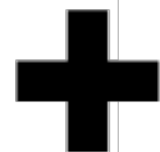
e.g. a dike



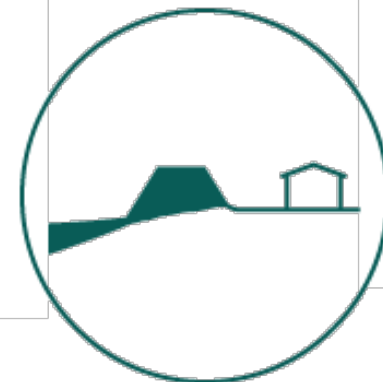
Brick Idea



complemented with
property-level-protection



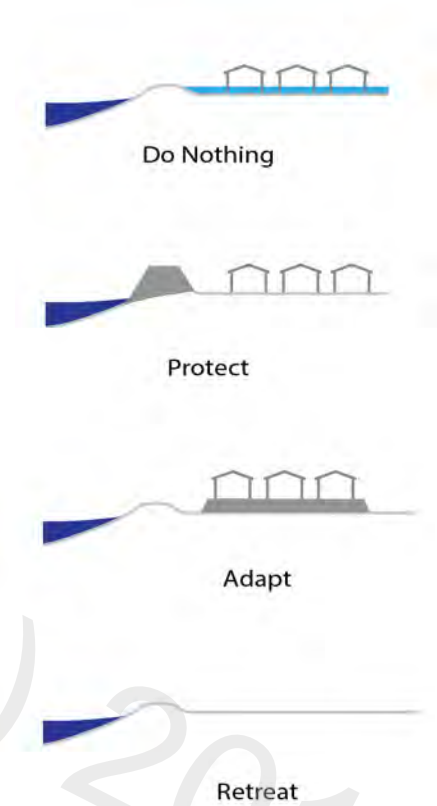
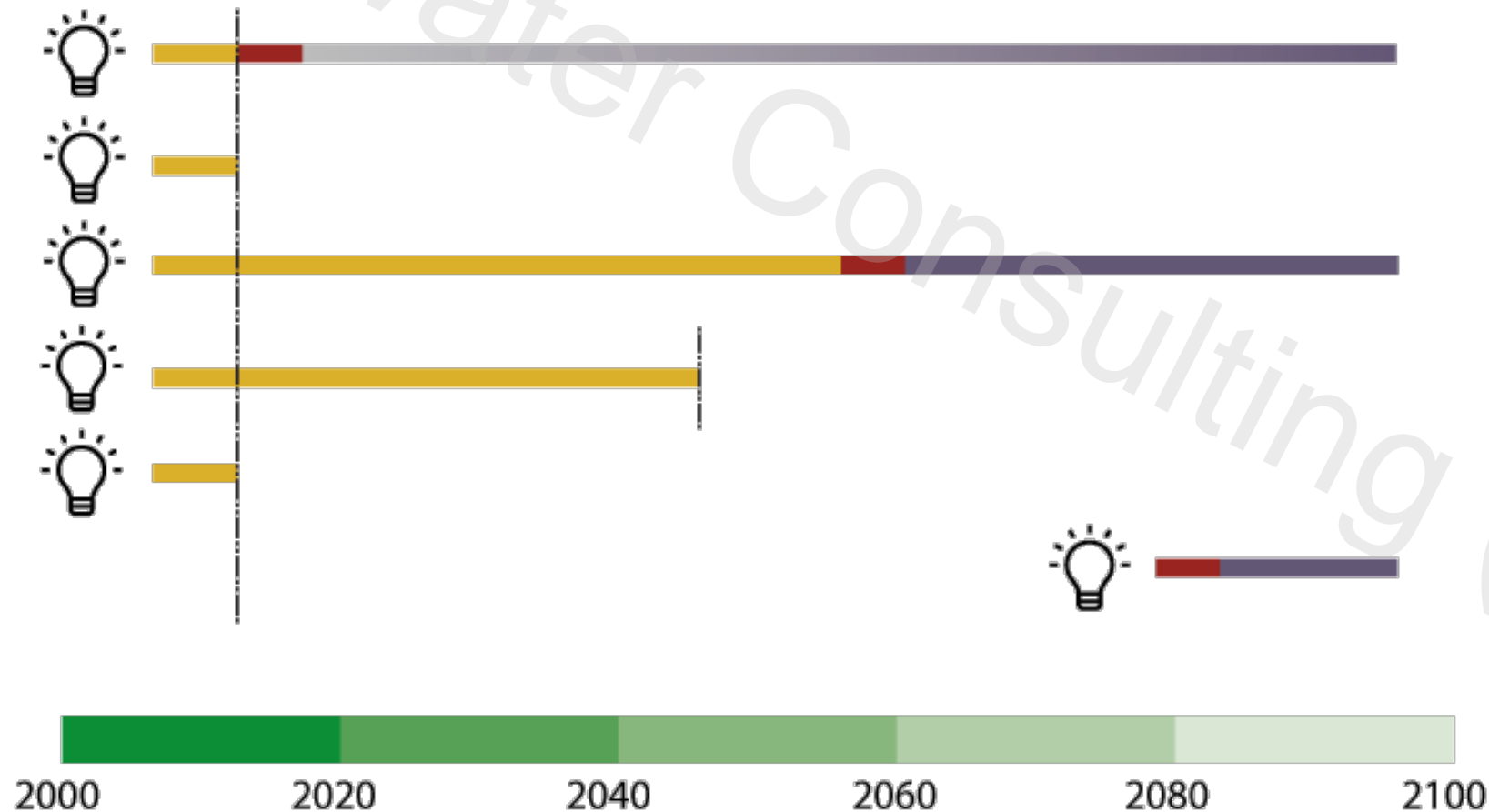
Brick Idea



improved with habitat
enhancement and a bike path

Phase 2 Results

Preserve Options, Ideally Adaptive Ones. Act thoughtfully.



Some questions are still unanswered: When to take action?

We know that we need to adapt, but we struggle with when.

Too early will mean wasted resources, distrust or perceptions of fiscal irresponsibility, or abrupt, potentially wrenching, changes in our communities.

Too late and we risk being unprepared and suffering unduly from climate extremes.

Finding the sweet spot on the timeline is a key component of adaptation planning.

The When?

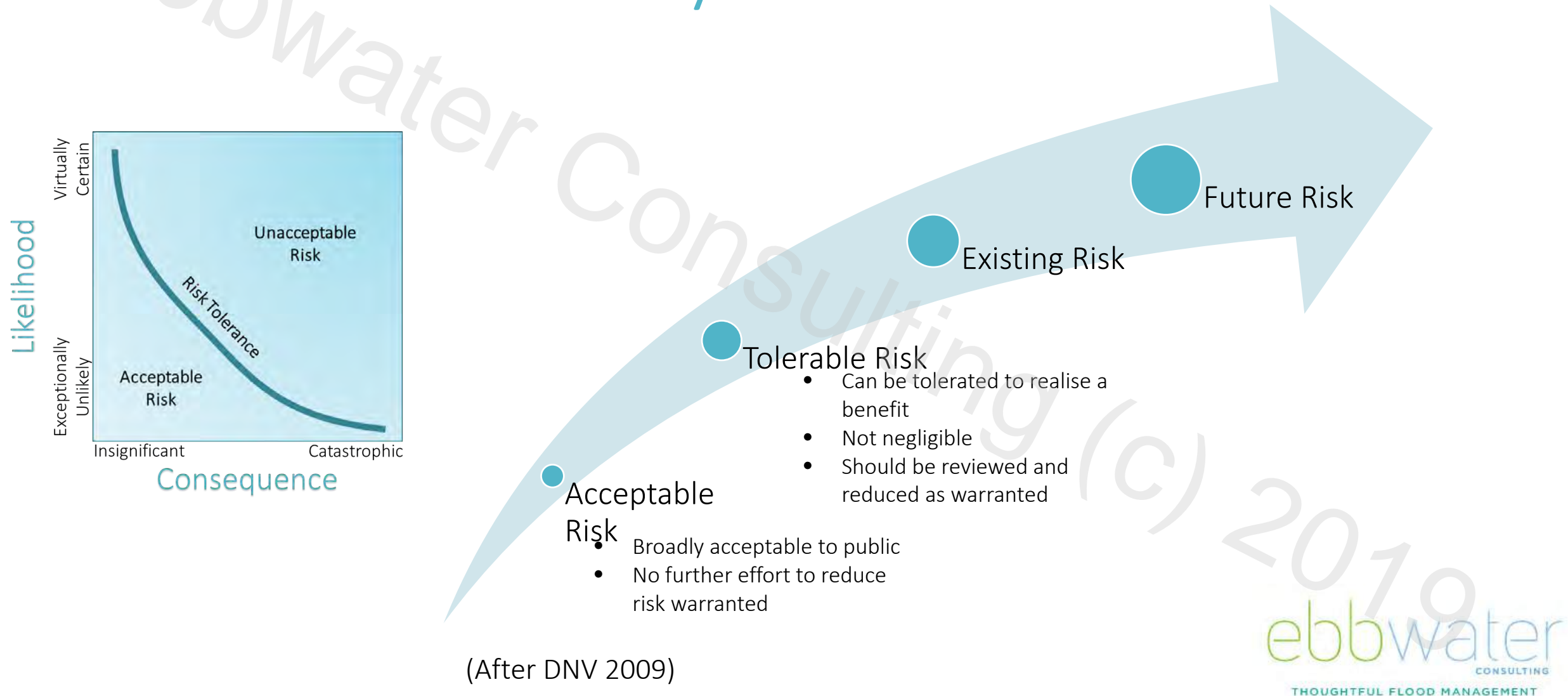
Making decisions about how soon to act.

Phase 3 Objective

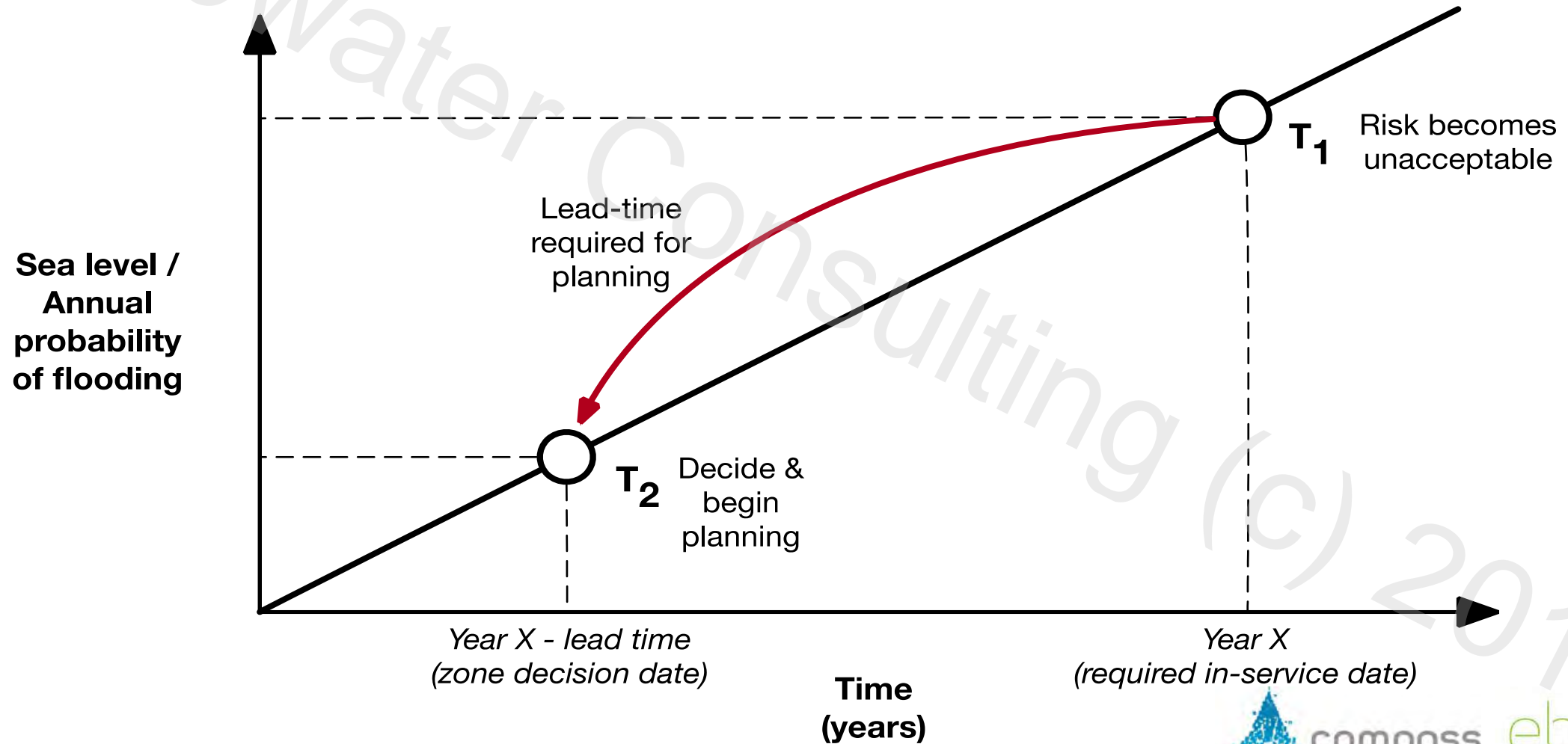
To develop a transparent, repeatable and adaptive process to support decision-making related to the prioritization and timing for implementation of mitigative measures for sea level rise that is:

- *Risk-based (i.e. considers both the local hazard and local consequences of flooding).*
- *Scientifically robust and based on best available information for the City on flood hazard, flood impacts and flood risk.*
- *Mindful of other strategic planning processes being undertaken at the City.*
- *Responsive to new planning and/or development directions and new sea level rise science.*

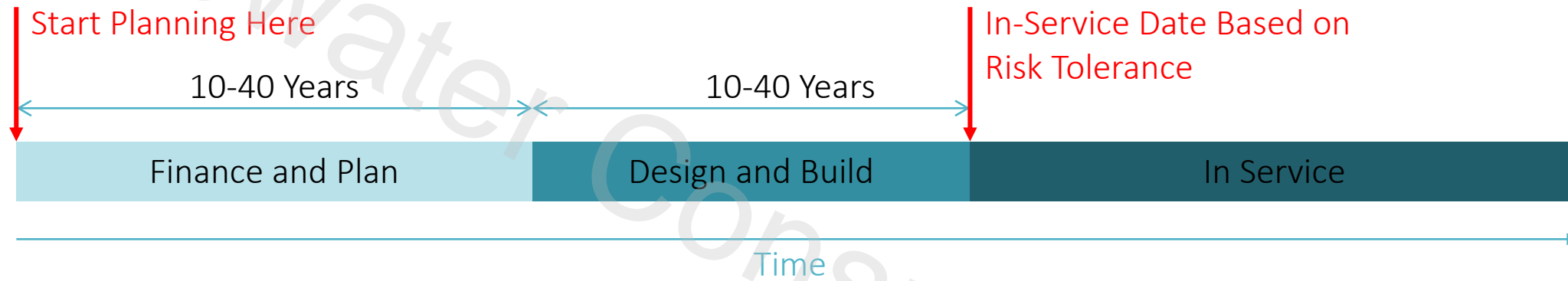
Understanding risk is the start...risk tolerance is the key



Because it tells you when you need to be ready



But we also need time to implement actions



Adapt



35 + Years for Redevelopment Cycle

Protect



25 + Years for Financing/Engineering/Etc.

Retreat



35 + Years for Redevelopment Cycle

We need to prioritise

But be mindful of other opportunities and changes

- Planning processes and redevelopment
- Funding programs
- Political lens
- Flood events
- Changing rates of sea level rise

In-Service Date
Calculation

- A Asset Identification
- B Probability of Inundation Curve
- C Risk Tolerance Refinement
- D Calculation of In-Service Dates
- E Zone In-Service Timing

Implementation
Timeline
Calculation

- A Review Preferred Options
- B Calculate Longest Implementation

Drop-Dead
Date
Calculation

$$\begin{array}{c} \text{Drop-Dead Date} \\ = \\ \text{In-Service Date} \\ - \\ \text{Implementation Timeline} \end{array}$$

Prioritize

Across All Zones

And so – a proposed
framework

What?

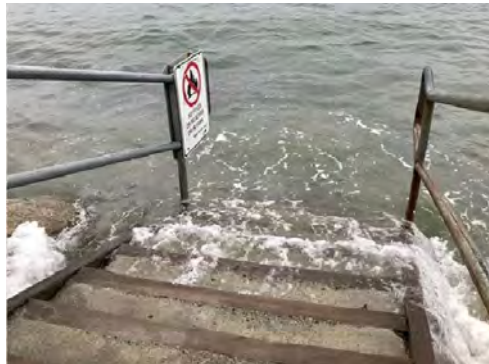
1. We are surprisingly risk intolerant; maybe this will change as we see more water on the ground
2. We are reliant on our present-day lens to make decisions about a changing future; this is never going to be perfect.
3. These are never going to be easy conversations.



604now.com image. 2018 King Tides Initiative

So What?

1. The longer we can [justifiably] put off adaptation decisions, the better our understanding of risk-tolerance to climate change will be.
 - The Vancouver sea level rise framework is not a bad place to start ☺
 - Also a strange statement for an ardent climate adaptation activist.
2. Being scared of the conversation isn't helpful, being armed with lots of different tools is.



Acknowledgements

Clients and Funders



Research Team



Ontario: Where do you see yourselves?

A willingness to live with floods	<ul style="list-style-type: none">• Individual and small communities adapt to nature's rhythm.
A desire to use the floodplain	<ul style="list-style-type: none">• Fertile land in the floodplain is drained for food production.• Permanent communities are established on the floodplain.• Local (uncoordinated) levees start to be constructed.
A desire to control flood flows and defend against flooding	<ul style="list-style-type: none">• Large scale structural approaches (levees, dams and other controls) are planned and implemented through organized governance.
A desire to reduce flood damages	<ul style="list-style-type: none">• A recognition that engineering alone has limitations.• Effort is devoted to increasing the resilience of communities should a flood occur.• Effort is devoted to mitigate loss of ecosystem services.
A desire to manage risks efficiently	<ul style="list-style-type: none">• A recognition that budgets are limited and not all problems are equal.• Risk management is seen as a means to target limited resources.
A desire to promote opportunities and manage risks adaptively	<ul style="list-style-type: none">• Adaptive management is seen as effective in managing the severe uncertainties in future climate change, funding and demographics.• Working with natural processes is encouraged to both reduce risks efficiently and achieve gains in ecosystem services.

Where do we go from here?

Recent Events

+

Climate Change

+

Loose Direction from Senior Governments

=

Opportunity for Change!

Acknowledgements



Natural Resources
Canada

Ressources naturelles
Canada

Canada

Contact

Tamsin Lyle | tamsin@ebbwater.ca |  [@ebbwater](https://twitter.com/ebbwater)



An Evolution in Flood Management:

An optimistic view from the left coast



CWRA | March 2019 | Toronto, Ontario
Tamsin Lyle, P.Eng | Principal Engineer | Ebbwater Consulting Inc.