Western Science

Seismic Microzonation Mapping for Metro Vancouver: 2nd Annual Project Update with Stakeholders

Project Leader: **Dr. Sheri Molnar**, Assistant Professor

Research Associate: Dr. Hadi Ghofrani

Graduate students: J. Assaf, C. Boucher, M. Fyfe, S. Ladak, S. Raj Adhikari, A. Samani, A. Sirohey, A. Yeznabad

Agenda

Provide an annual update on project's progress with partners and stakeholders in the region

- Review Project's Aim and Deliverables (our last update was Nov. 2017)
- Update to the Project Agreement, effective March 2018
- Update on Project Progress: Development of the geodatabase
  - Growth of project team personnel
  - Collection of previous geodata and reports
  - New seismic data collection campaign (July 2018)
- Items for discussion

Metro Vancouver Seismic Microzonation Project

- Emergency Management British Columbia (EMBC), the Institute for Catastrophic Loss Reduction (ICLR), and the University of Western Ontario are working together to **generate comprehensive earthquake hazard maps** for the Metro Vancouver region of British Columbia, Canada.
- This **multi-year project** involves assessment and mapping of:
  - **Earthquake shaking** hazard (amplification, site period, basin effects)
  - **Liquefaction susceptibility** hazard
  - **Landslide susceptibility** or slope instability hazard

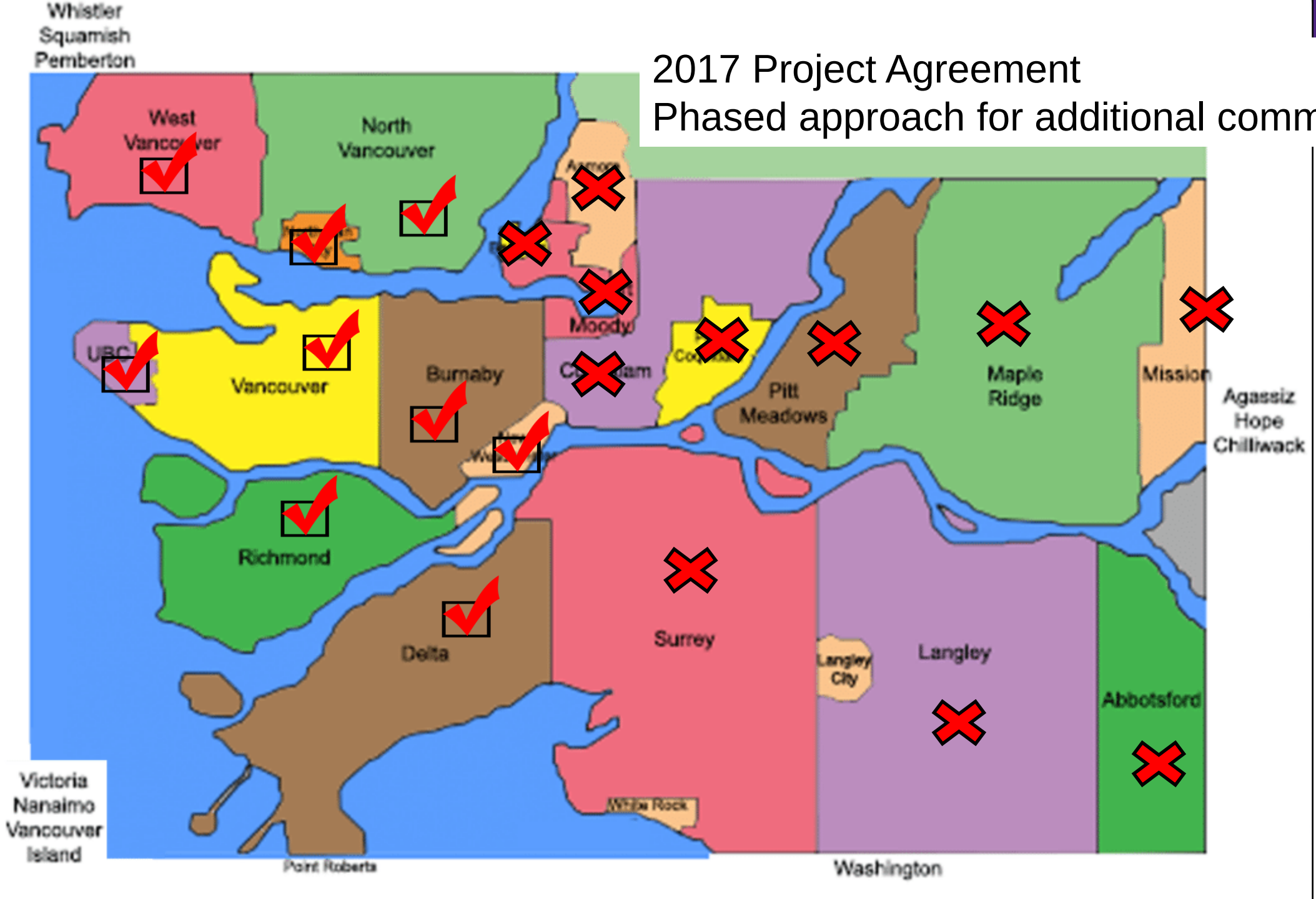
- At a **neighbourhood scale** with an initial focus of the western communities of Metro Vancouver

BRITISH COLUMBIA | Emergency ManagementBC
Disaster Mitigation Branch

Institute for Catastrophic Loss Reduction

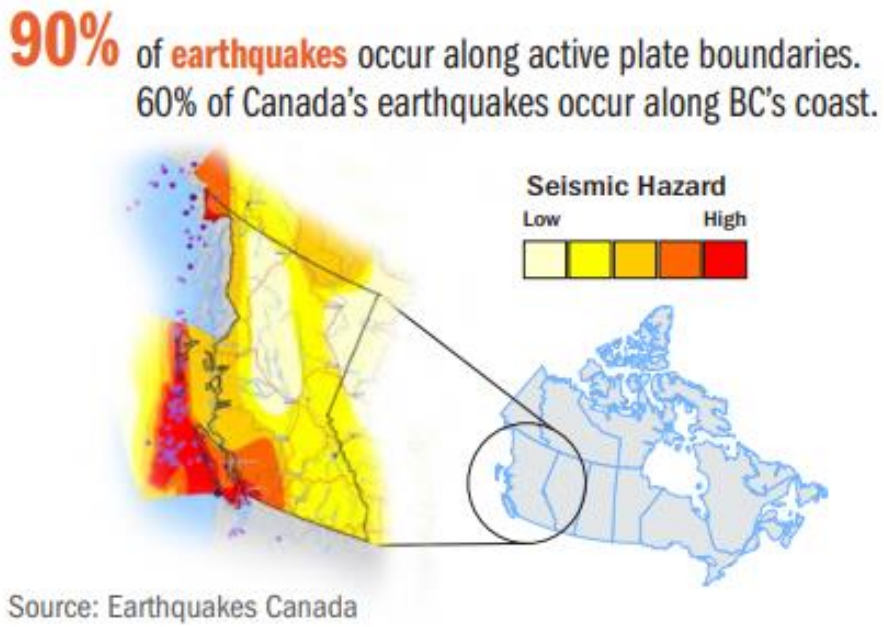
Western

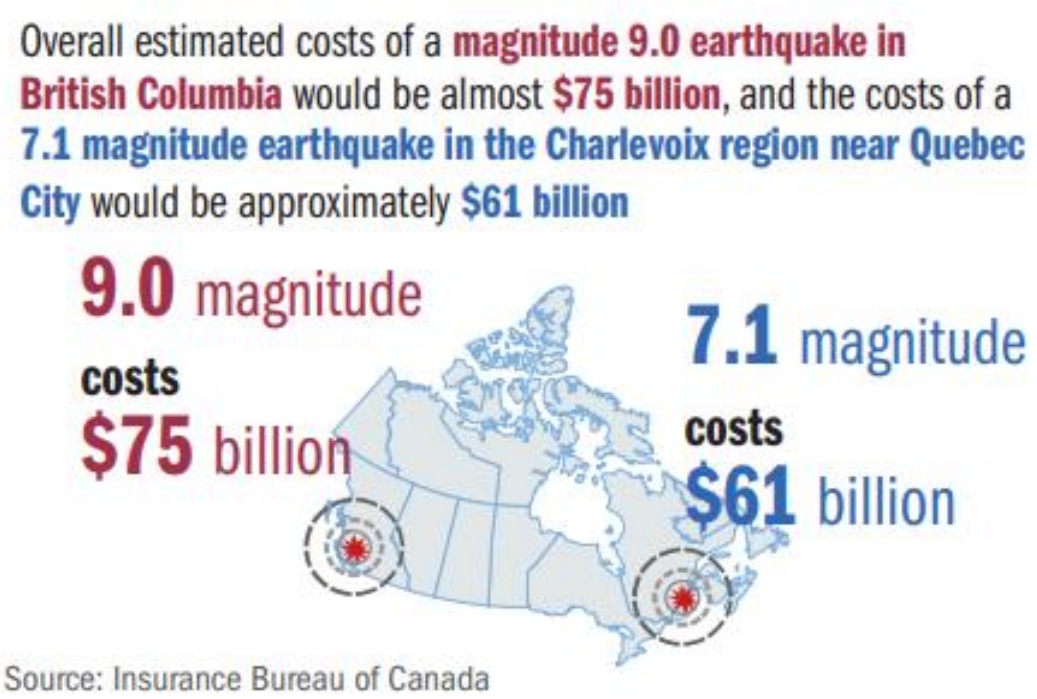
2017 Project Agreement
Phased approach for additional communities



Why does Metro Vancouver need seismic hazard mapping?

- Highest seismic risk city in Canada



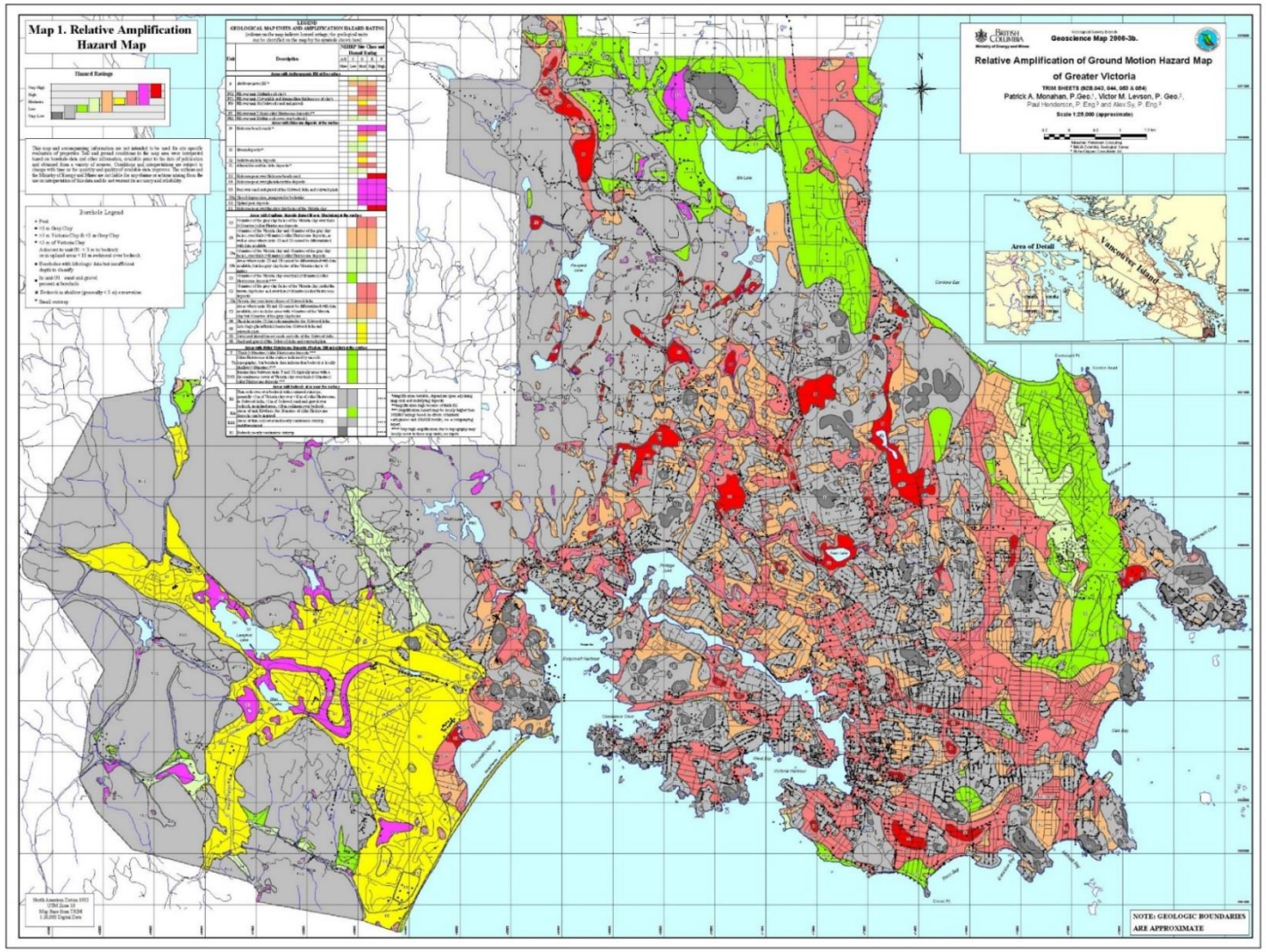


- The largest uncertainty in seismic hazard prediction is local site effects
  - As in, the biggest payoff for estimating earthquake shaking is detailed site assessment
  - Correct ground motions, improved hazard understanding, improved risk (loss) estimates…

What are microzonation maps?

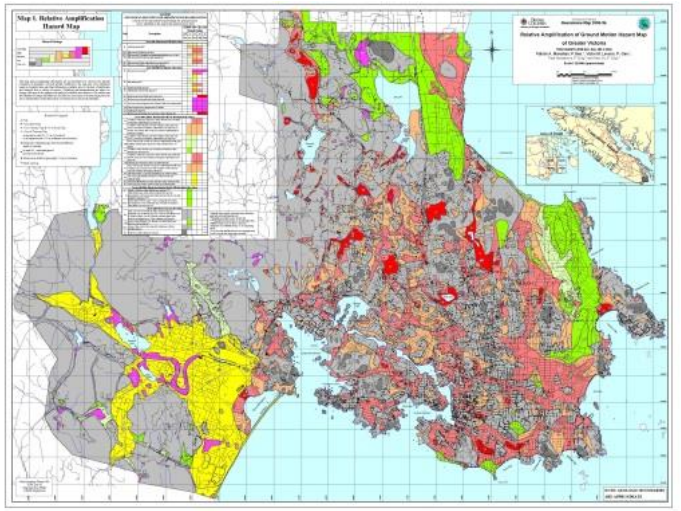
- Effects of earthquake shaking are not uniform due to variation in local site conditions.
- **Seismic microzonation maps** display predicted variation in earthquake shaking effects due to local site conditions.
- The **input data** to produce these maps includes geological, geophysical, geotechnical information combined with numerical modelling.

Low shaking hazard to high shaking hazard

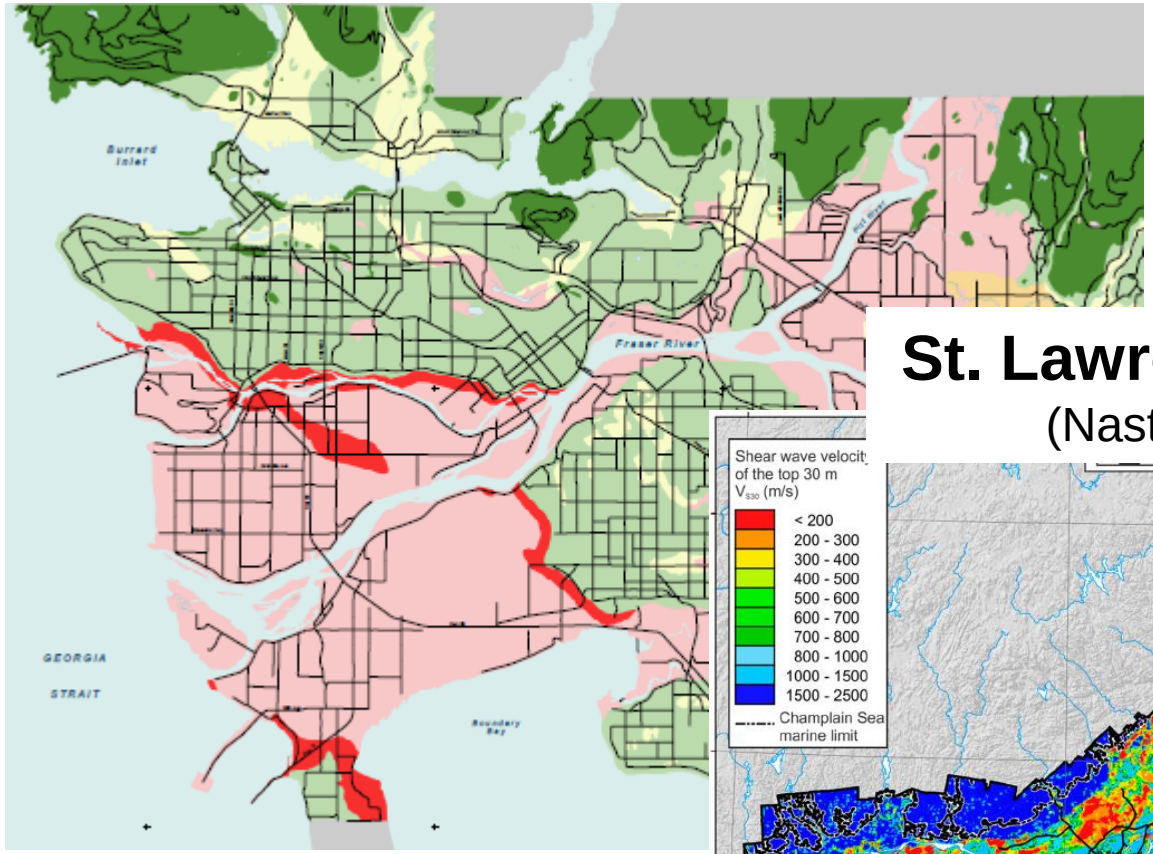


Seismic Microzonation Maps in Canada

Developed for the four highest seismic risk cities

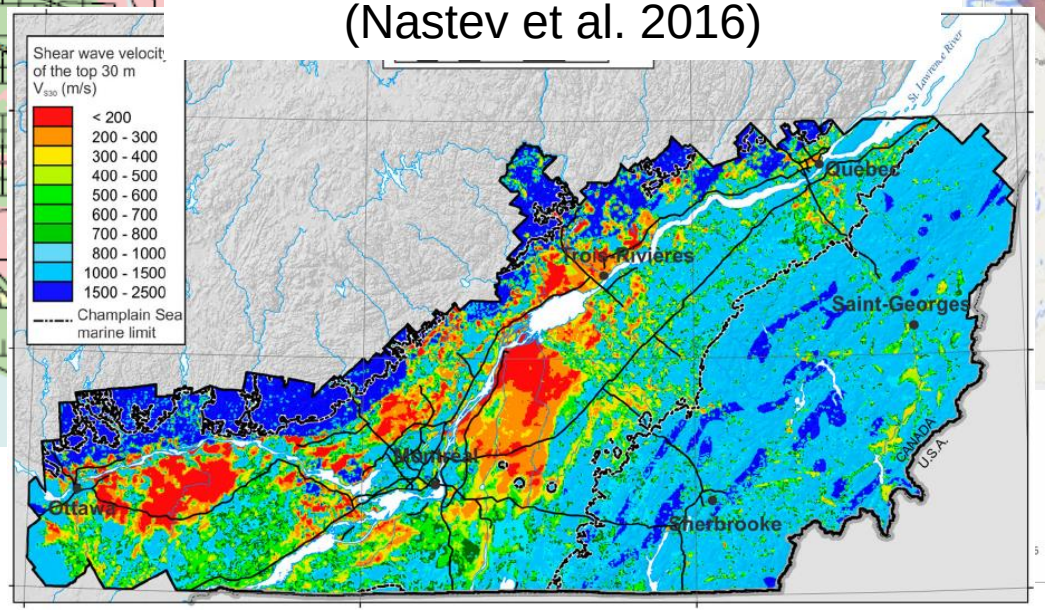


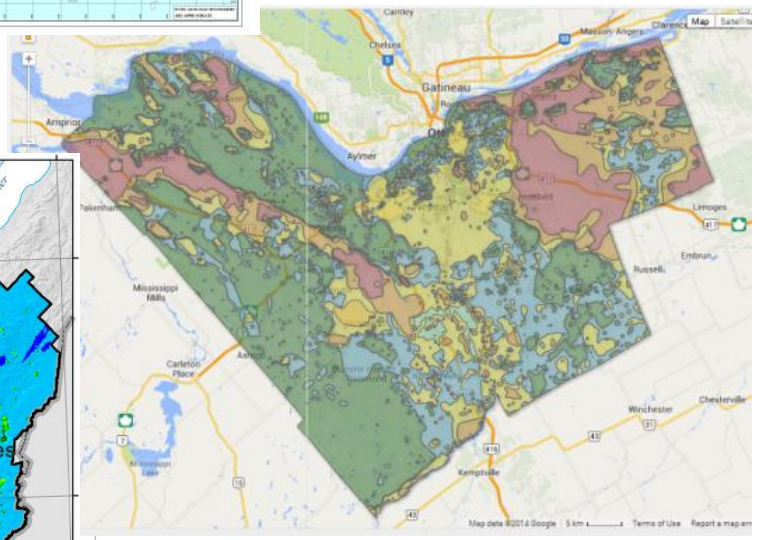
Victoria
(Monahan et al. 2000)



Vancouver
(Taylor et al. 2006)

St. Lawrence Lowlands
(Nastev et al. 2016)





Ottawa
(Motazedian et al. 2011)

Seismic Microzonation Maps in Canada

"*Quality of the zonation maps depends on the quantity and quality of the input data*" (Mihalic et al. 2011)

Table 1. Use of input data depending on the scale of mapping, i.e., the level of zonation (ISSRM, 1999).

~ $100,000's ~ $ millions

	Grade I	Grade II	Grade III
Ground motions	• historical earthquakes and existing information • geological maps • interviews with local residents	• microtremor • simplified geotechnical studies	• geotechnical investigations • ground response analysis
Slope instability	• historical earthquakes and existing information • geological and geomorphologic maps	• air photos and remote sensing • field studies • vegetation and precipitation data	• geotechnical investigations • analysis
Liquefaction	• historical earthquakes and existing information • geological and geomorphologic maps	• air photos and remote sensing • field studies • interviews with local residents	• geotechnical investigations • analysis
Scale of mapping	1:1000000–1:50000	1:100000–1:10000	1:25000–1:5000

Seismic Microzonation Maps in Canada

Vancouver

Goal: Update to Grade III

Geology-based

Limited Vs data outside FRD

Victoria

Grade I-II

Geology-based

Limited Vs data

Montreal

Grade III

26,600 boreholes

3 downhole V_S profiles

29 MASW V_S profiles

7.5-km of hi-res reflection profiling

700 microtremor locations

1D numerical site response analysis

Ottawa

Grade II-III

15 downhole V_S profiles

686 refraction-reflection profiles

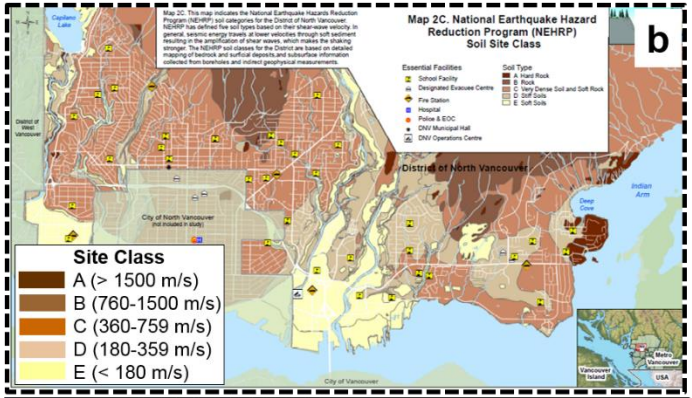
25-km of hi-res reflection profiling

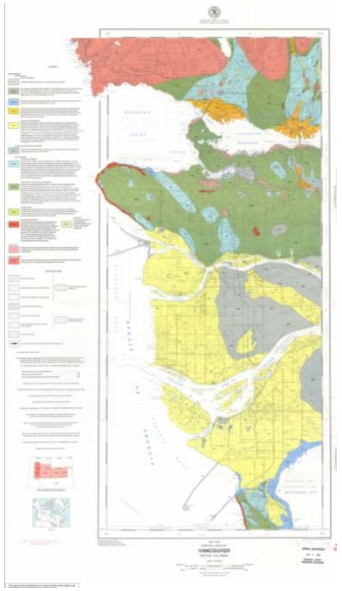
400 microtremor locations

Greater Vancouver amplification hazard (site class) maps

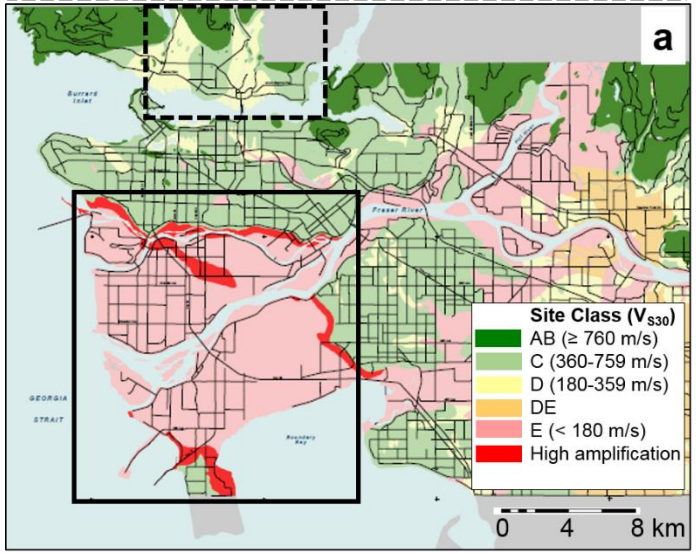
3 Vs profiles
80 SPTs
90 MHVSRs

Wagner et al. (2015)

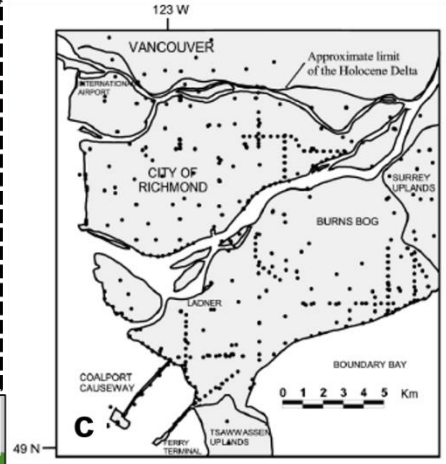




Armstrong (1979)
GSC Map 1486a

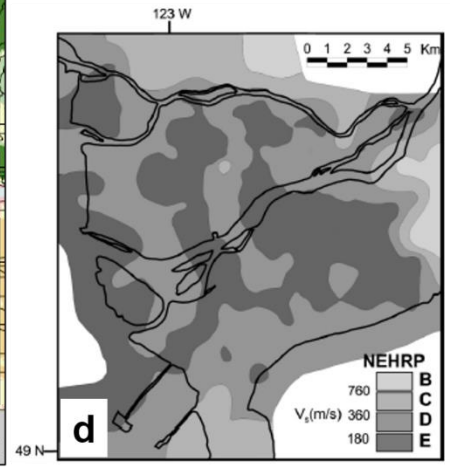


Taylor et al. (2006)



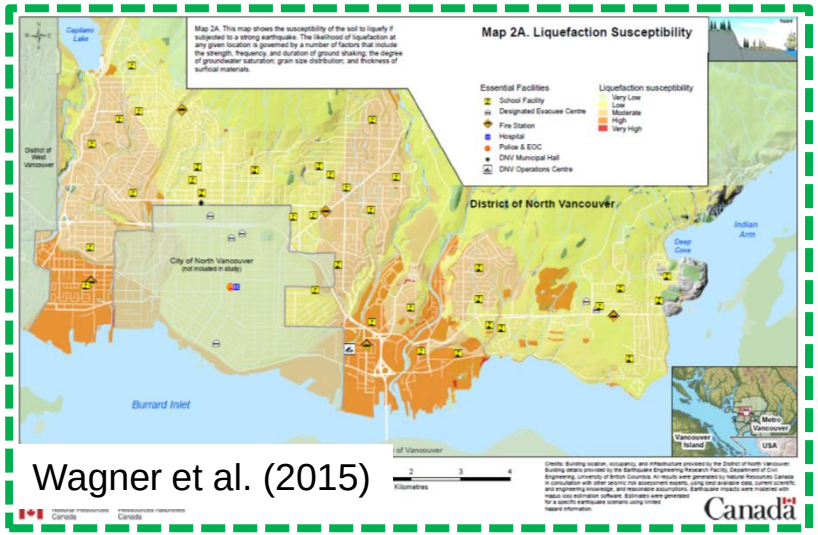
52 DH
88 SCPTs
115 V_S reflection

Hunter et al. (1998)

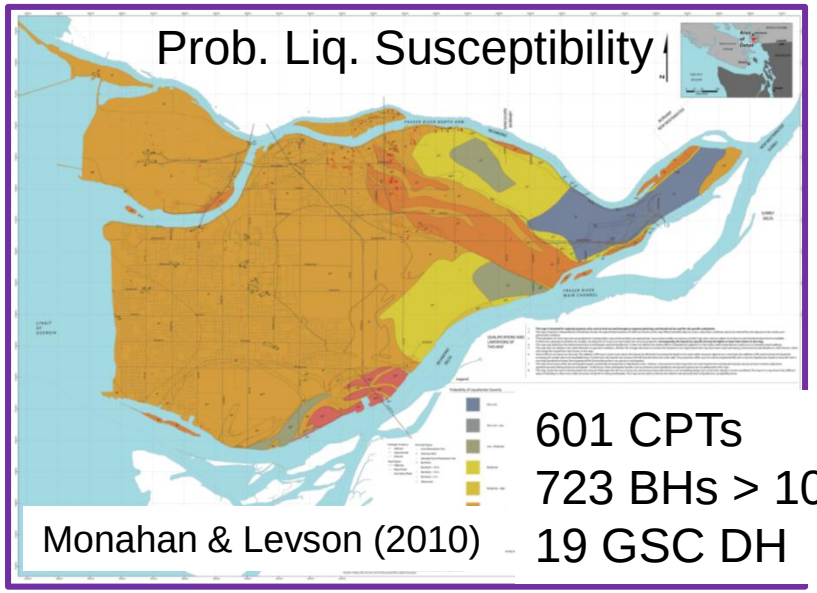


Hunter et al. (2002)

Greater Vancouver liquefaction hazard maps



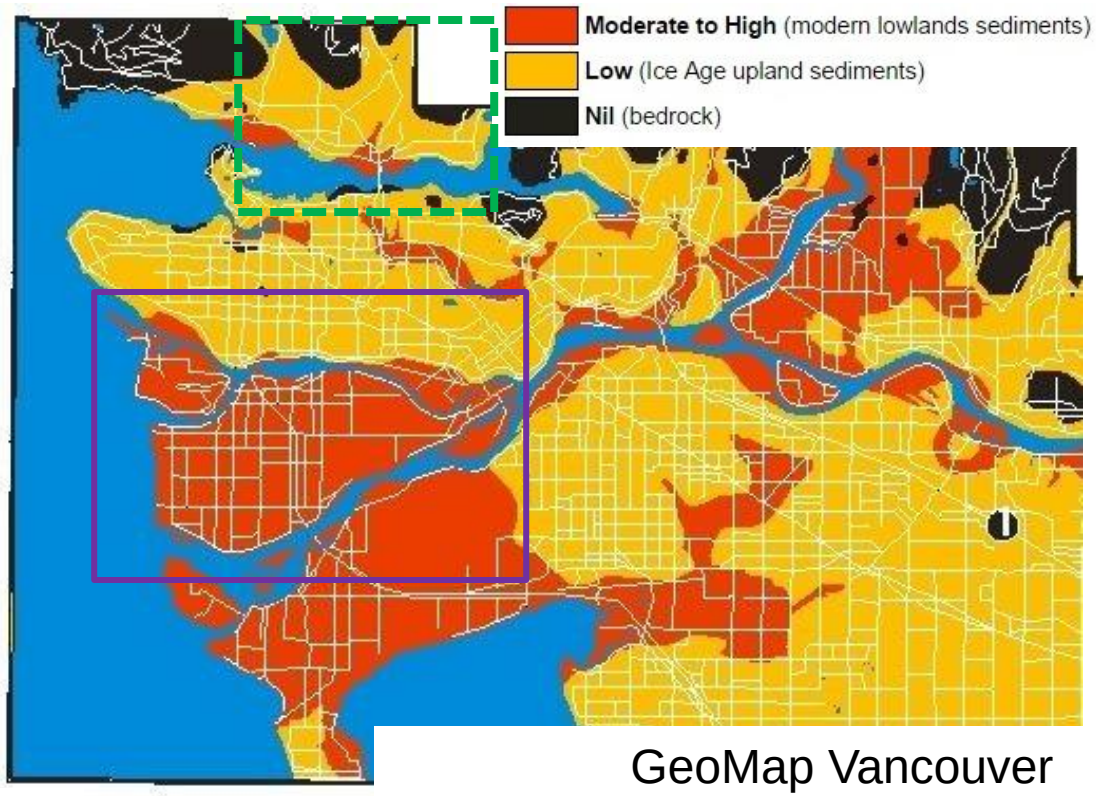
Wagner et al. (2015)



Monahan & Levson (2010)

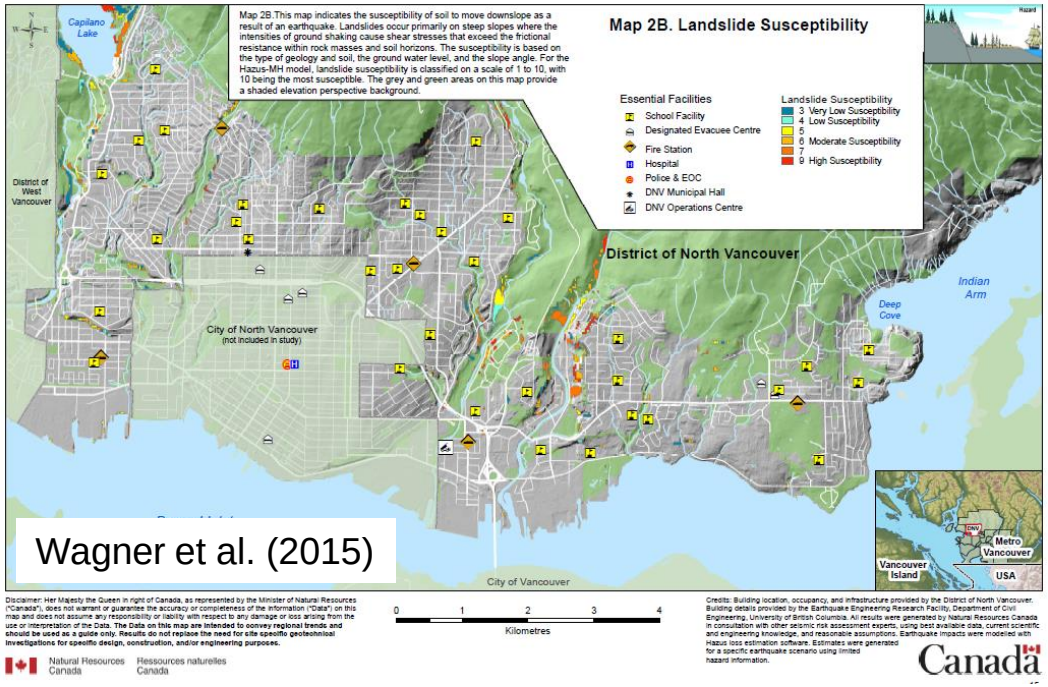
601 CPTs
723 BHs > 10 m
19 GSC DH

Liquefaction susceptibility



GeoMap Vancouver
Turner, Clague, Groulx, Journeay (1998)

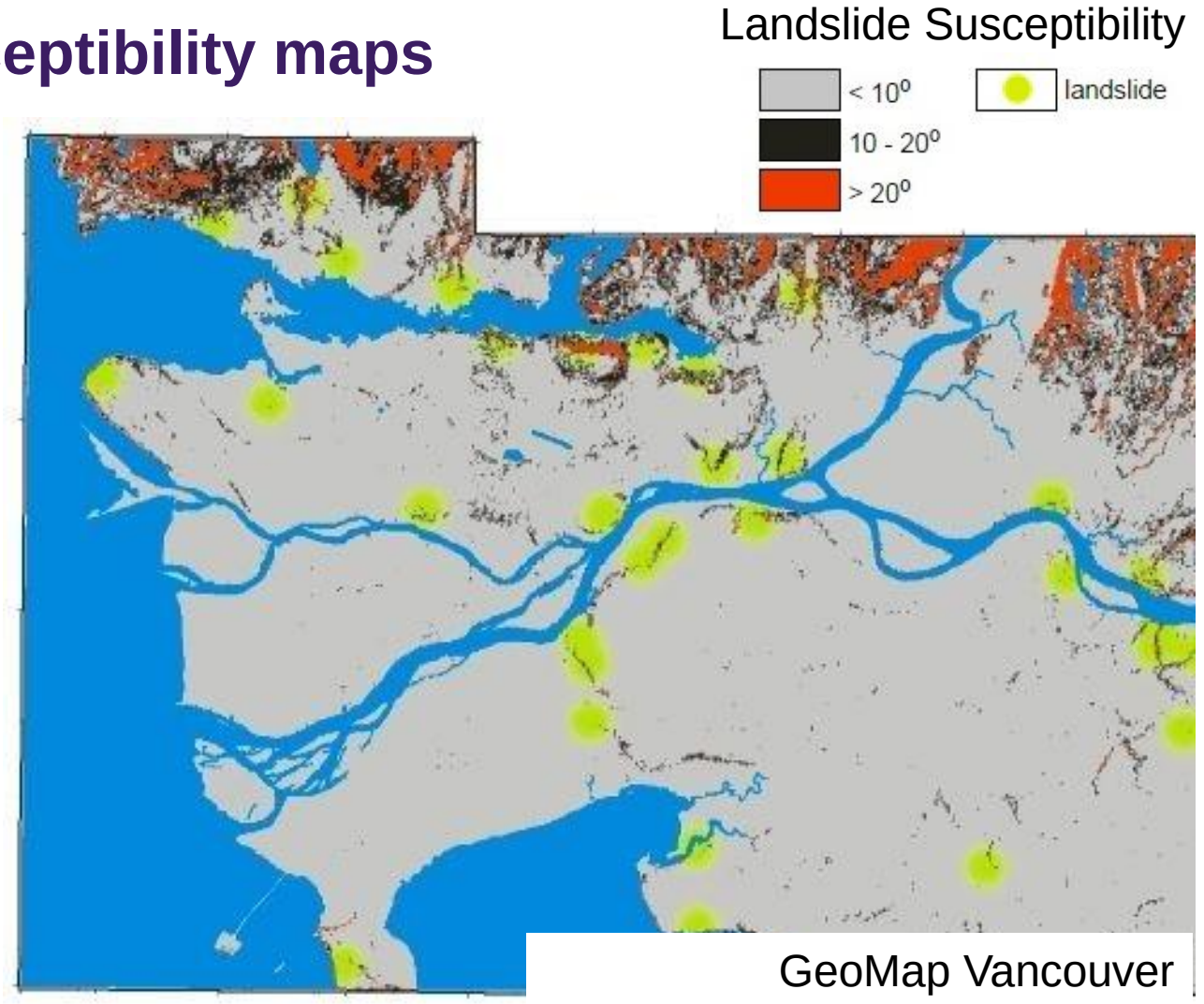
Greater Vancouver landslide susceptibility maps



Wagner et al. (2015)

Higher susceptibility if:

- steeper slope,
- saturated (wet) ground,
- geology.



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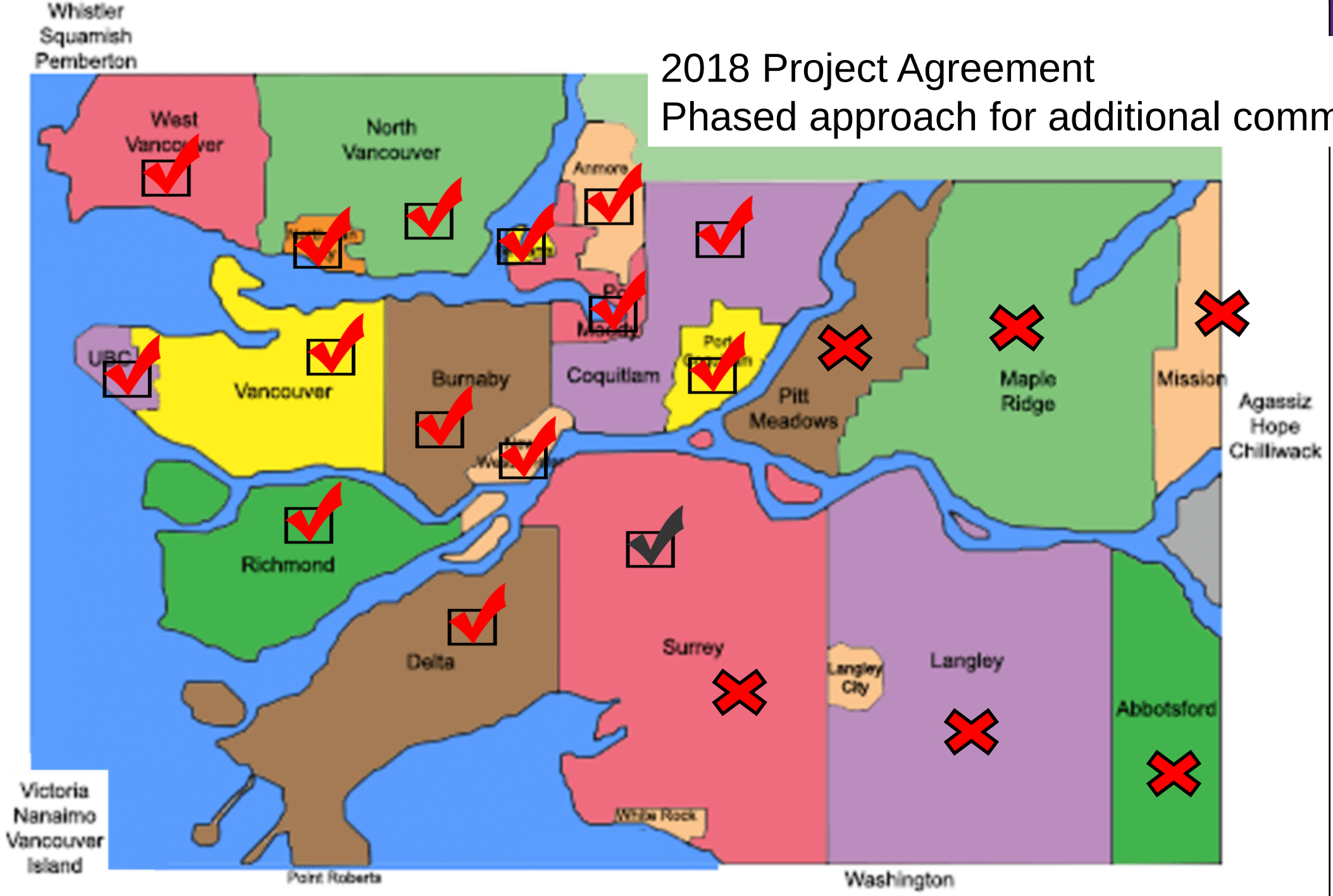
Project Amendment, March 2018

Additional funding supplied from EMBC Disaster Mitigation Branch for:

1. Hazard mapping of an additional community area

2018 Project Agreement
Phased approach for additional communities



Project Amendment, March 2018

Additional funding supplied from EMBC Disaster Mitigation Branch for:

1. Hazard mapping of an additional community area
2. EGBC led Peer Review of project methodologies and analyses
3. EGBC Professional Practice Guidelines for Seismic Microzonation Mapping in BC

- One year extension, project completion: March 31 2023

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Growth in Project Team Personnel in 2018

Amplification hazard mapping

- Jamal Assaf (PhD, Geotech. Eng.), Sameer Ladak (MSc)
- Sujan Raj Adhikari (PhD), Chris Boucher (MSc), Meredith Fyfe (MSc), Aamna Sirohey (MSc)

Liquefaction potential mapping

- Alireza Javankbaht Samani (PhD)

Slope stability mapping

- Ali Fallah Yeznabad (PhD, Geotech. Eng.)

3D Basin modelling

- Dr. Hadi Ghofrani (Research Associate)

Summer field support

- Alex Bilson Darko (MSc)

GEODATABASE

Initial Request for Geo Data,

Nov. 2017

How can you help?

To properly assess these hazards, knowledge of subsurface geology and its parameters are required which can be achieved by the collection and analysis of geophysical and geotechnical information.

If you or your organization (municipal engineering department, engineering firm, etc.) has any of the following geophysical or geotechnical information, please contact Dr. Sheri Molnar (smolnar8@uwo.ca). Preference is for information at depths greater than 10 metres and in digital file format. We will accommodate any confidentiality concerns.

- Stratigraphy or lithology at depths greater than 10 metres
- Groundwater level or monitoring
- Historical water channel (stream) maps and/or pre-construction aerial photos
- Compression-wave or shear-wave velocity measurements
- Standard penetration (blowcounts) or cone penetration (tip resistance, sleeve friction, etc.) measurements
- Soil mechanics laboratory testing including gradation, Atterberg limits, shear strength tests, etc.

Procurement of available datasets (up to March 2018)

Internal or public (online) datasets

- Topography (DEM), Surficial geology maps, Land use map, Terrain class map
- Previous site classification maps for BC (2001) and Metro Vancouver (2005)
- Seismic logging at ~500 Fraser River delta locations (Hunter et al. 1998, GSC Open File)
- ~20 online geotechnical reports downloaded

Assembled previous seismic data collections

- (Strong motion) Earthquake recordings from BCSIMS and NRCAN (BC Hydro, before 2004)
- UBC EERF ambient vibration dataset: ~600 MHVSR measurements, few V_s profiles

Agencies that provided data following initial data request (after Nov. 2017)

- **City of Coquitlam** provided their borehole database
- **City of Delta** sent 5 geotechnical reports
- **NRCAN** (Vancouver) provided geodata and Vs_{30} values from DNV seismic risk study

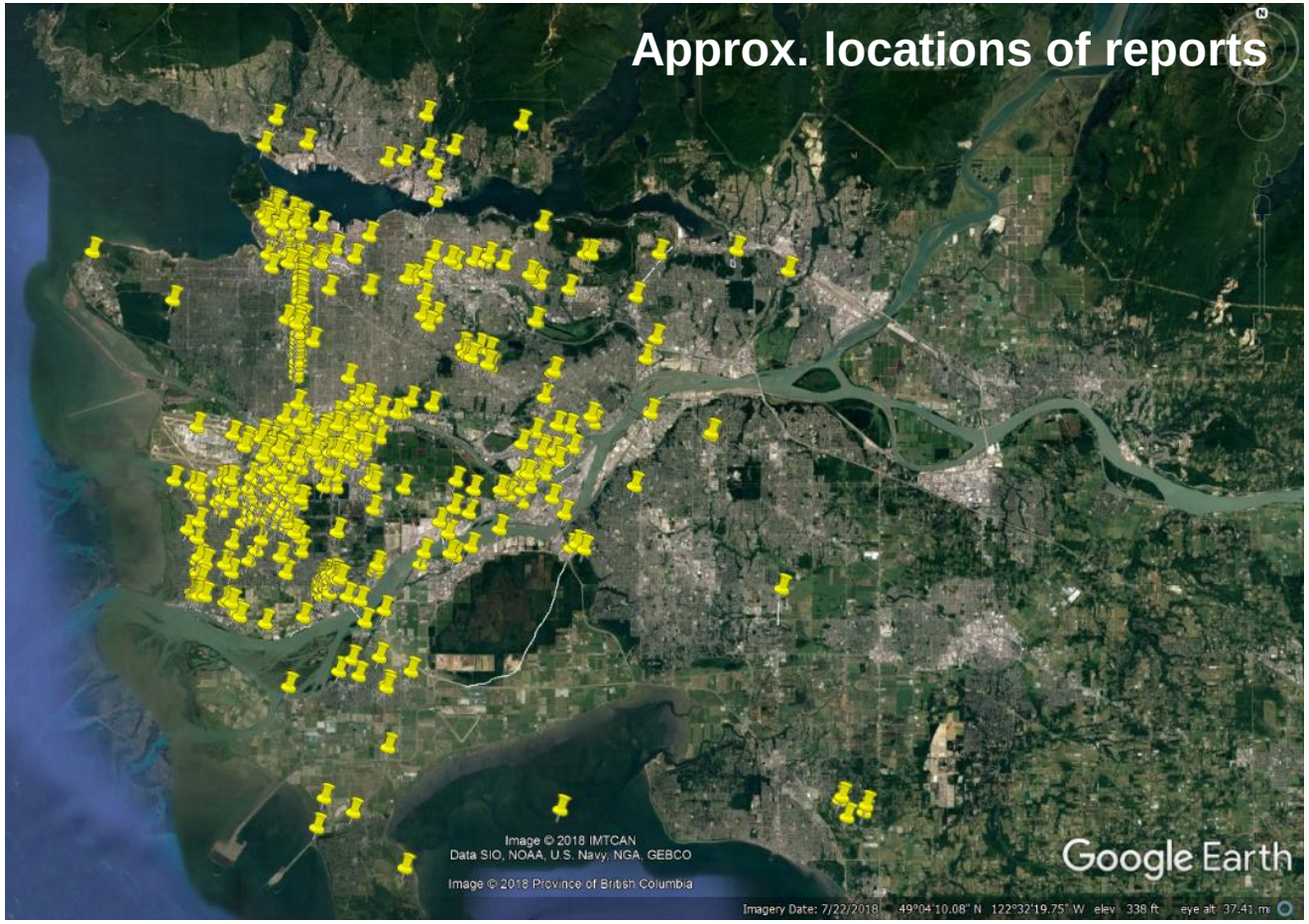
Procurement of available datasets (July 2018)

- Met with several agencies in July 2018 to obtain data access.
- A Western data sharing agreement was developed and shared with agencies upon request.

Organization (Meeting date)	Outcomes
Fortis BC (July 4, 18)	36 reports copied
UBC (July 9)	Shared seismic data for two sites.
Translink (July 17)	20 reports copied
GeoPacific (July 19)	100 reports copied
Pat Monahan (July 25-26)	Estimate ~500 files. (150 CPT data files, 320 digital reports, 100 reports copied)
City of Surrey	157 reports downloaded
Cities of Vancouver and Surrey, Port of Vancouver	Data sharing agreements signed.
ConeTec, Golder Assoc.	Discussion of data sharing mechanisms.

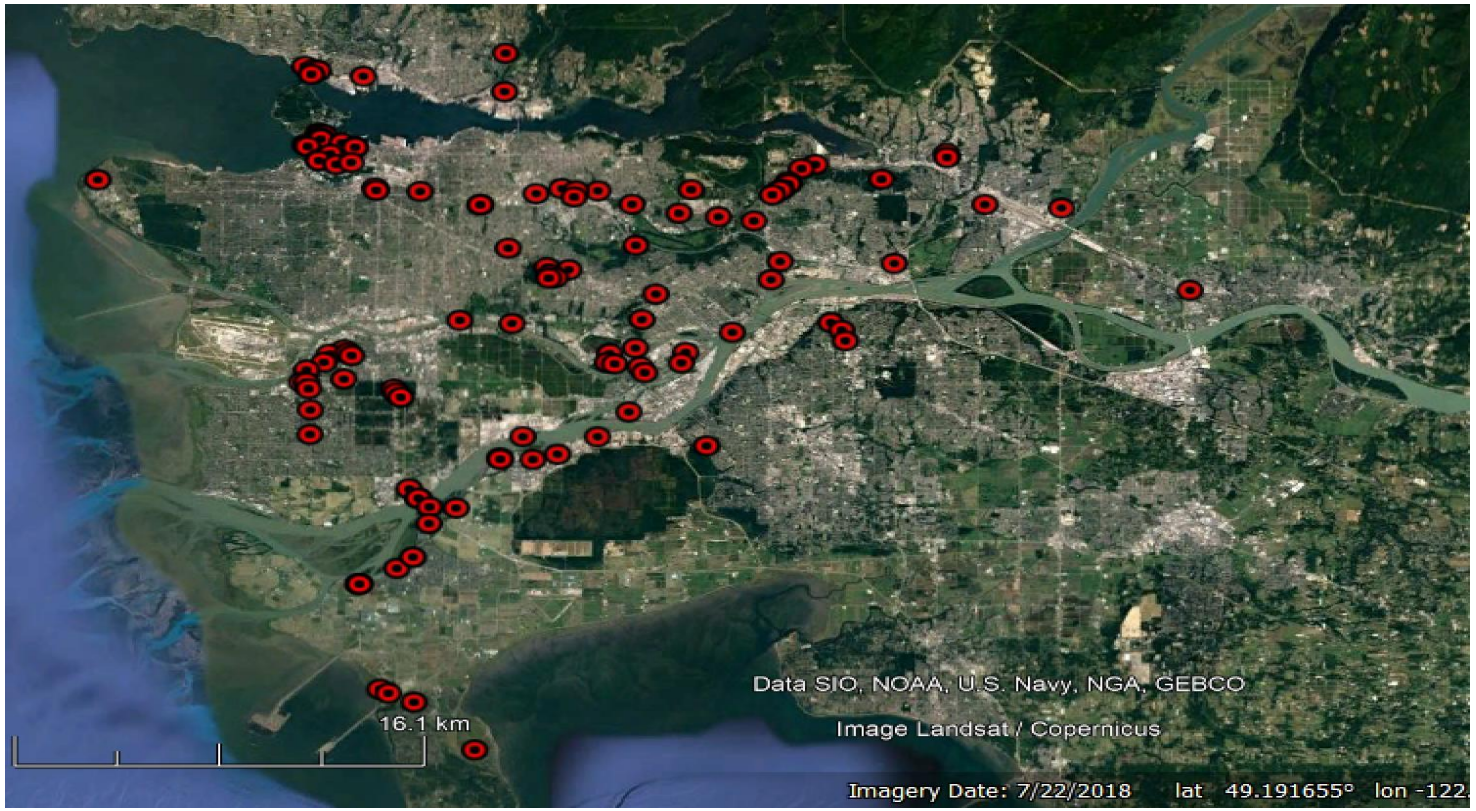
Procurement of available datasets (April – August 2018)

- Met with several agencies in July 2018 to obtain data access.
- A Western data sharing agreement was developed and shared with agencies upon request.
- **911 reports from 41 agencies obtained from 6 sources.**



Geodatabase development (Sept. – Nov. 2018)

- Met with several agencies in July 2018 to obtain data access.
- **911 reports from 41 agencies obtained from 6 sources.**
- We are tabulating data from the accumulated geo-files for our project analyses
- Undergraduate students hired to help compile this information.
- **Effort is ongoing in obtaining previous geodata from agencies and municipalities, by 2022**
- **Contact smolnar8@uwo.ca**



SUMMER 2018 FIELD CAMPAIGN

Summer 2018 Field Campaign – Training and Planning

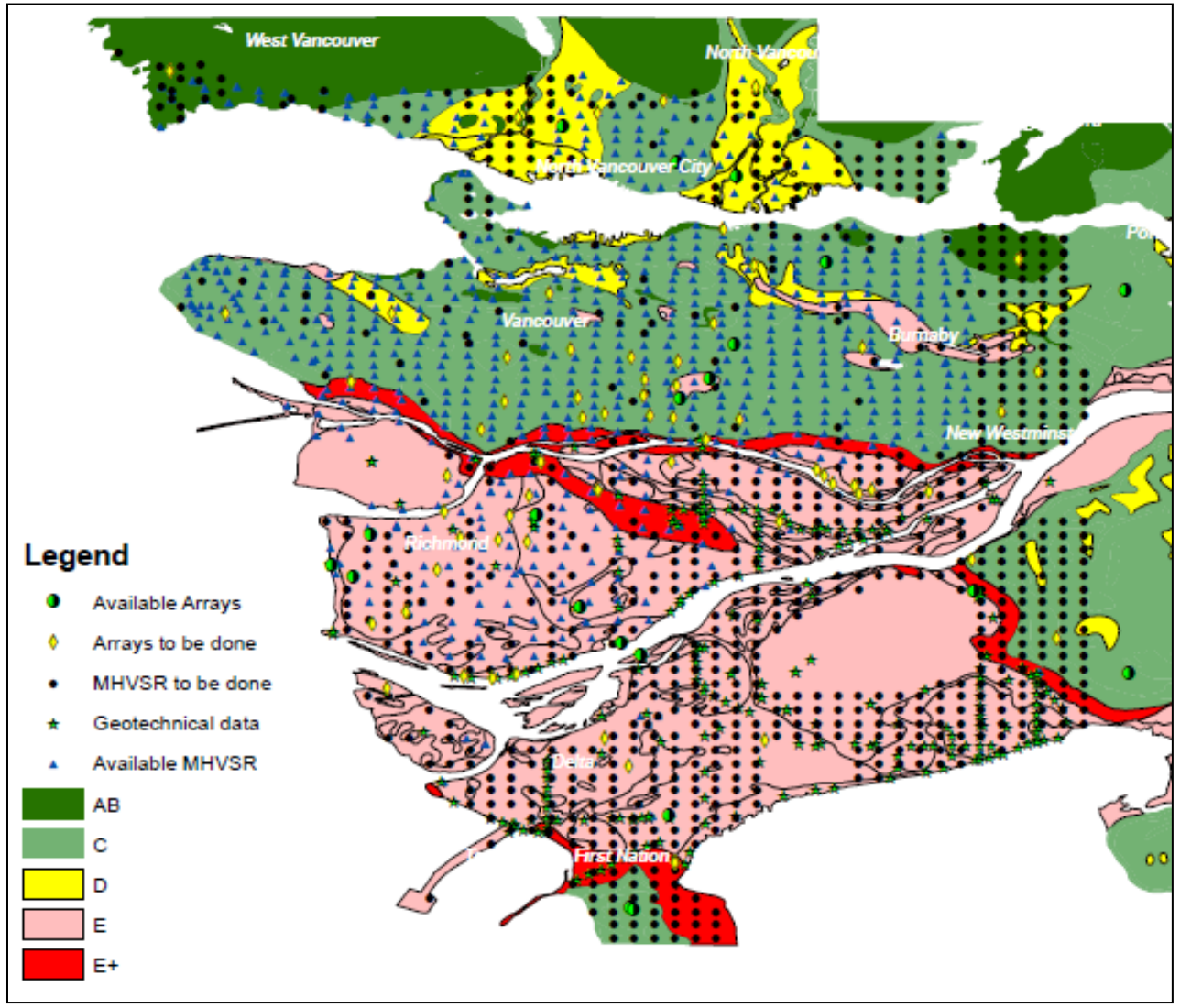
- 9 student field crew established
- May 22 - June 1 2018:

Two week training course on non-invasive methods with graduate students held at Western. Provide familiarity with equipment, processing procedures and software.

- June 18-29 2018:

Project field campaign planning at Western. Planned field testing locations.

- ♦ **Seismic array tests**
- **MHVSR tests**



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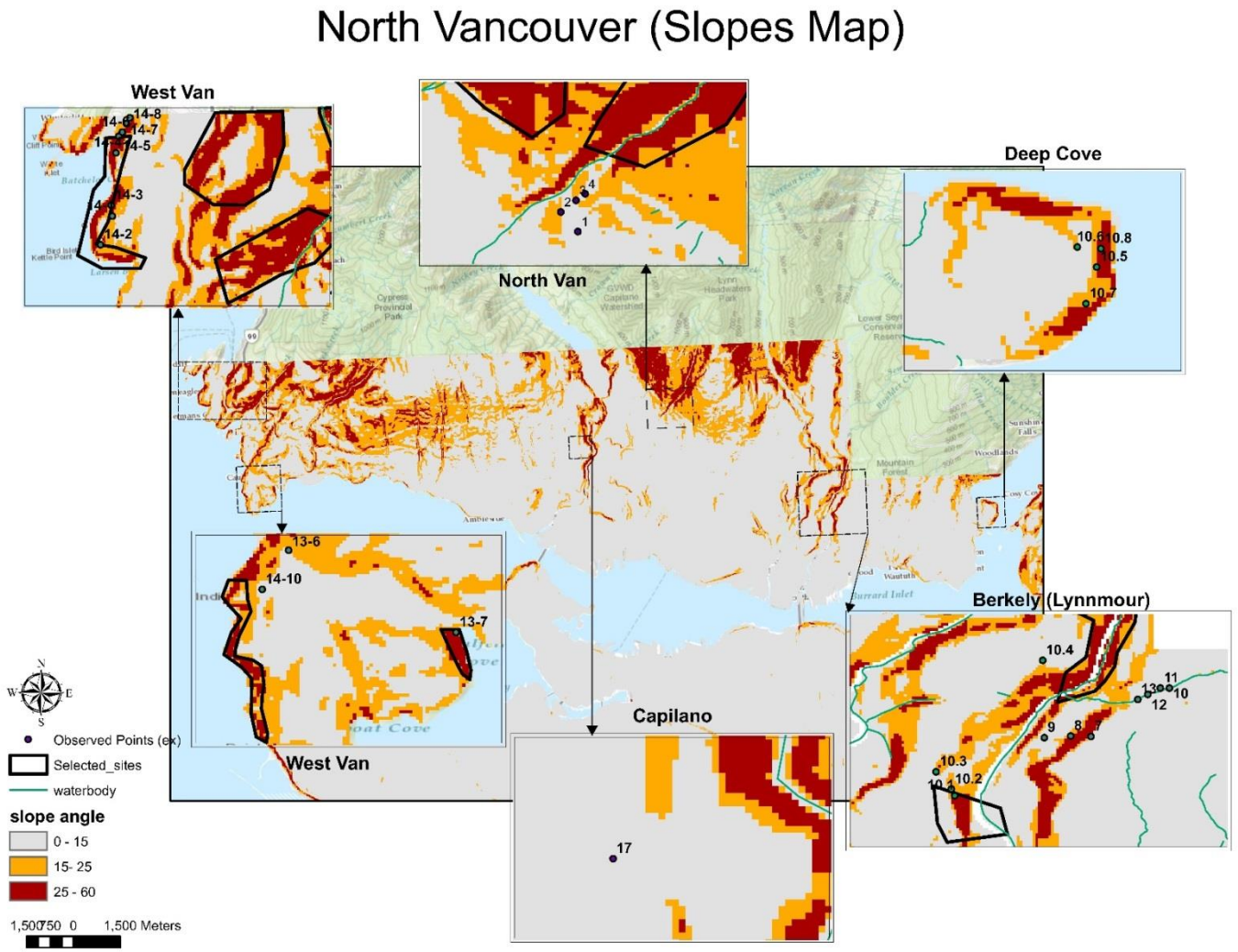
And planned **Slope stability surveys.**



Non-invasive seismic testing

Two main methods:

1. **MHVSR**

A single seismometer placed on ground for ~15 mins (deeper delta site for 30-45 mins.)

2. **Arrays**

Non-invasive seismic testing

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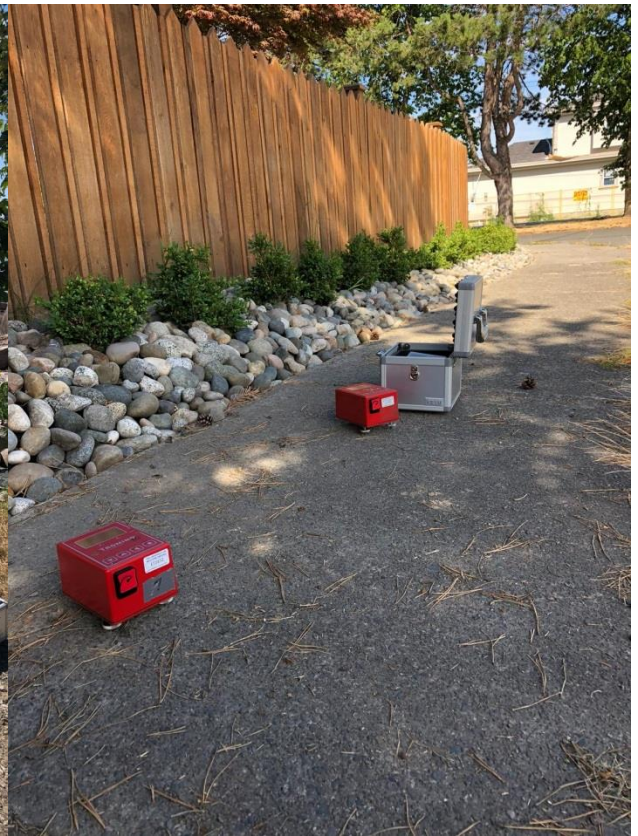

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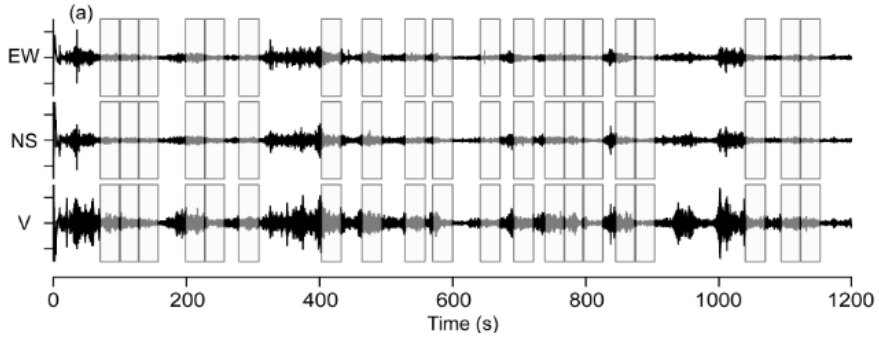
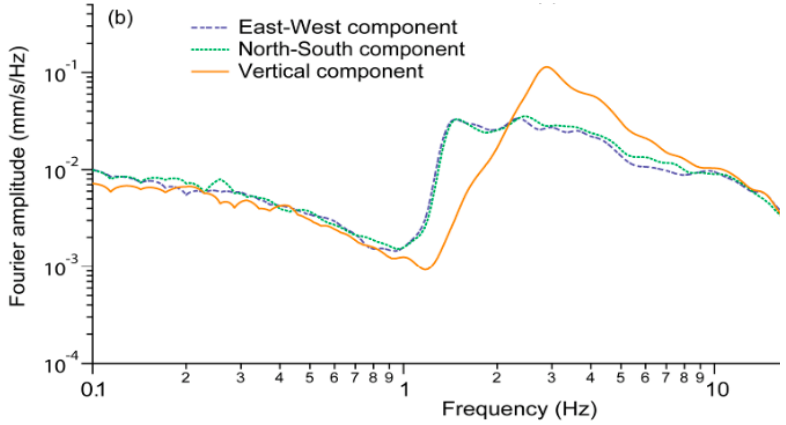
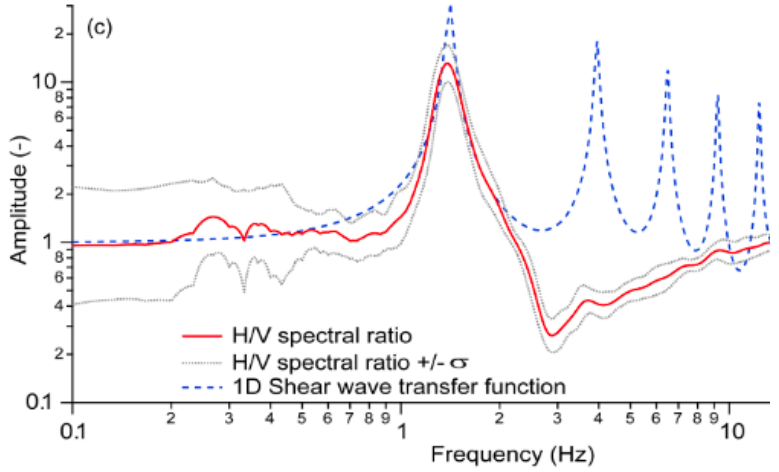
Calculate horizontal-to-vertical spectral ratio of microtremor recordings (MHVSR)







Non-invasive seismic testing

Two main methods:

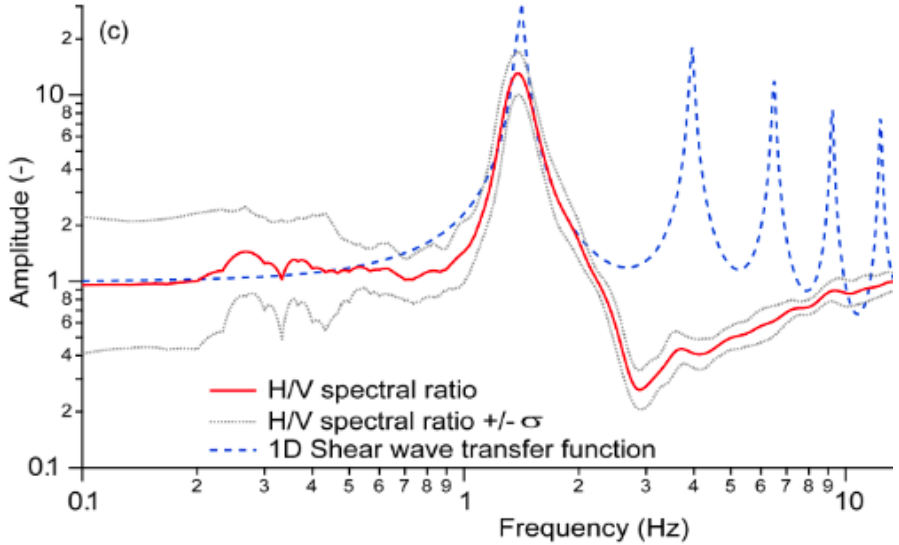
1. **MHVSR**

A single seismometer placed on ground for ~15 mins (deeper delta site for 30-45 mins.)

Calculate horizontal-to-vertical spectral ratio of microtremor recordings (MHVSR)

This MHVSR amplification function is a measure of ground stiffness and depth to impedance contrast or resonator (glacial till or bedrock). [Peak frequency = Vs_{av} / 4h]

2. **Arrays**

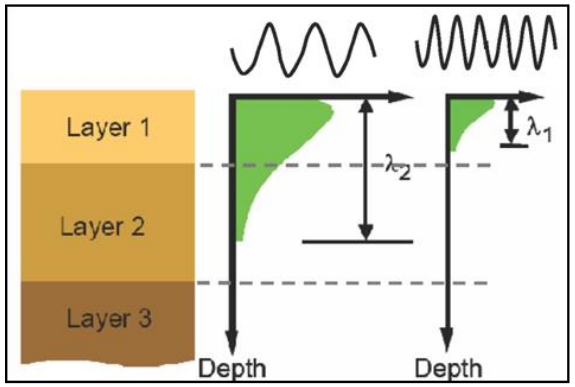


Non-invasive seismic testing

Two main methods:

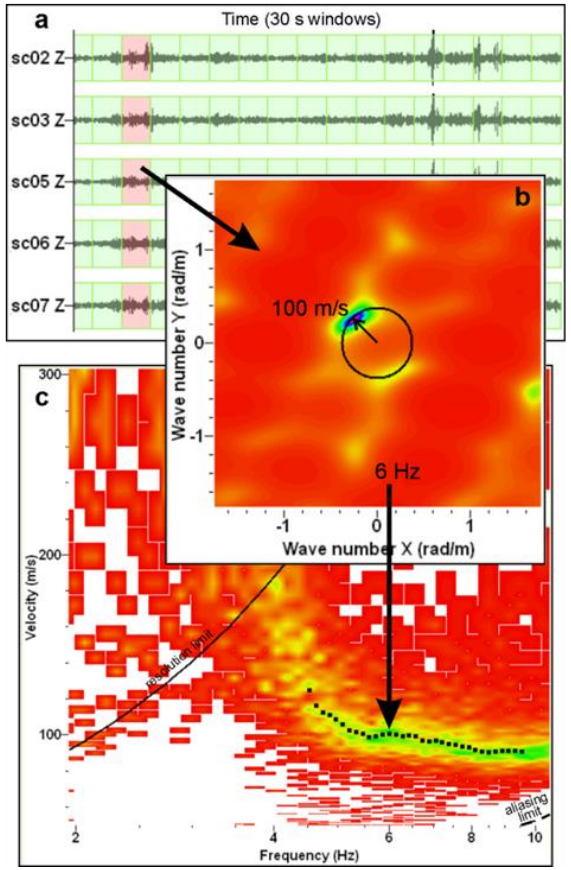
1. MHVSR
2. **Arrays**

1. Record ambient vibrations with seismic array

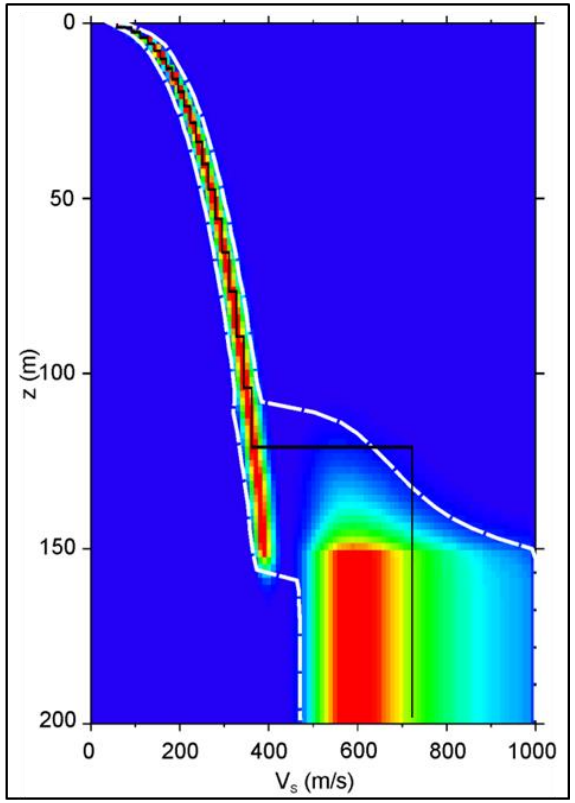


Vary array size to resolve different wavelength ranges (depth)

2. Extract dispersion curve

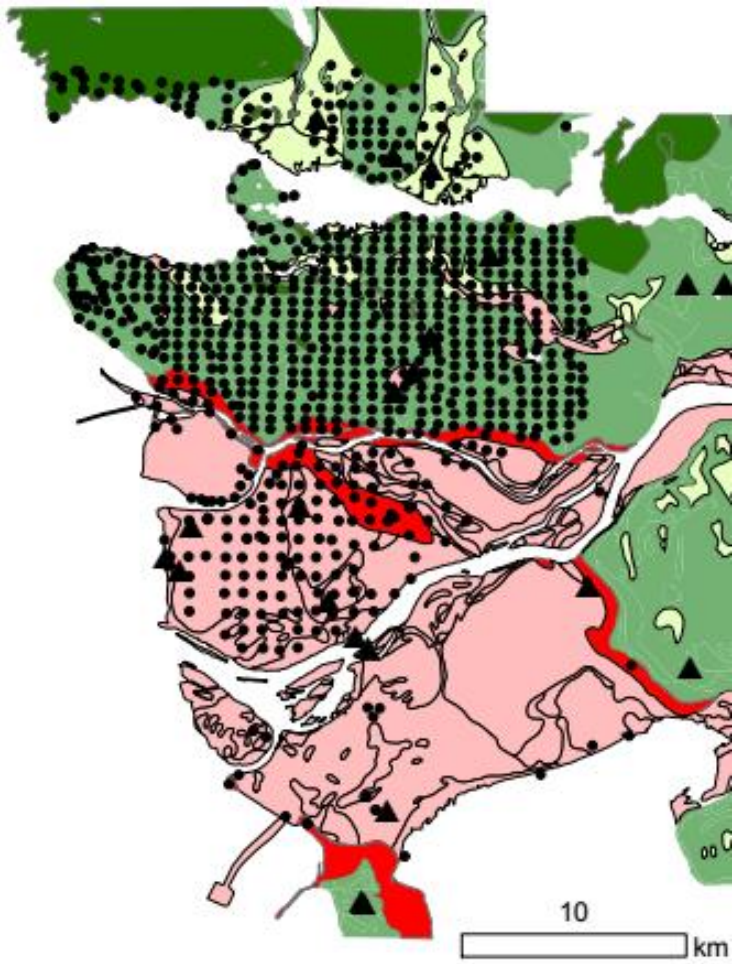


3. Invert for shear-wave velocity depth profiles

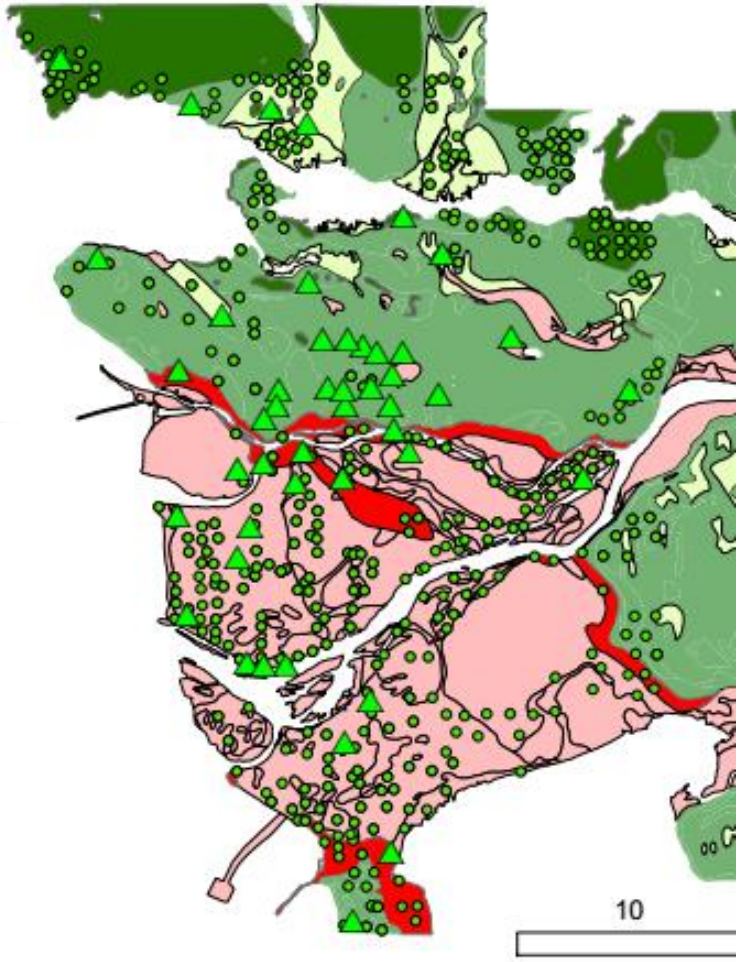


Non-invasive seismic testing

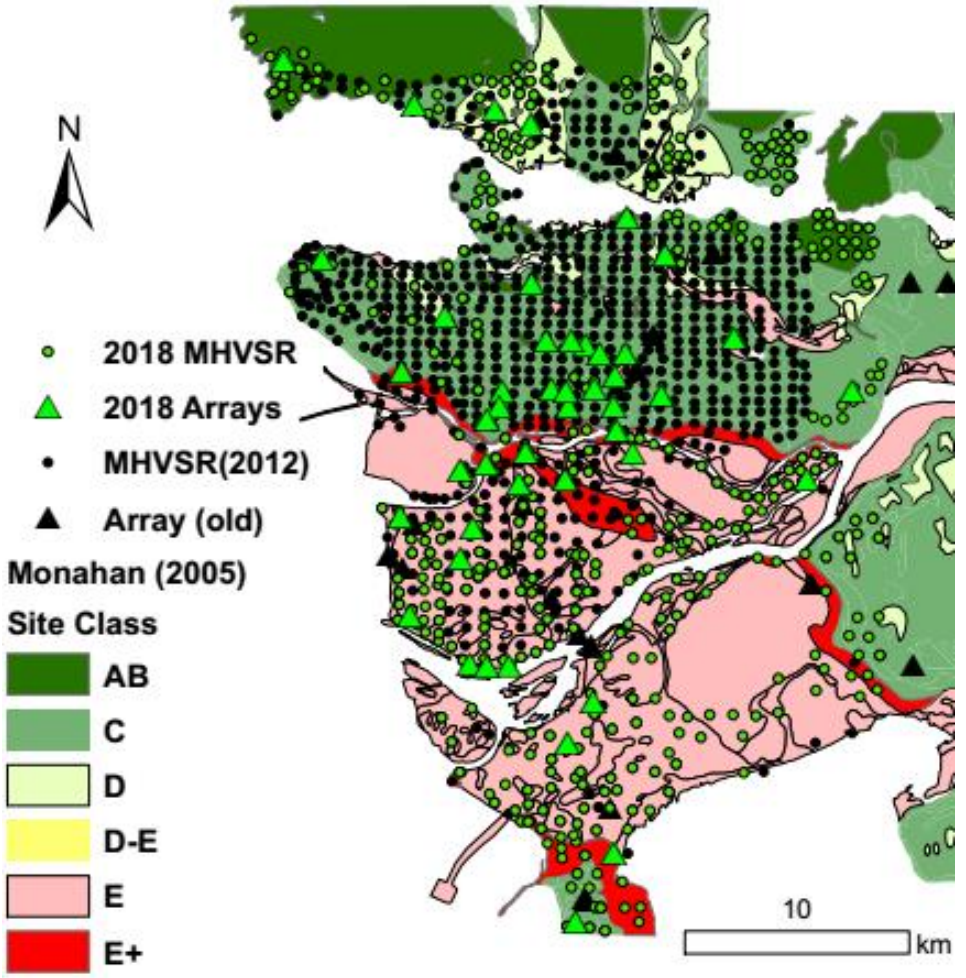
2009 – 2012 by UBC
- ~600 MHVSR sites
- ~10 Array sites



July 2018
- 401 MHVSR sites
- 44 Array sites

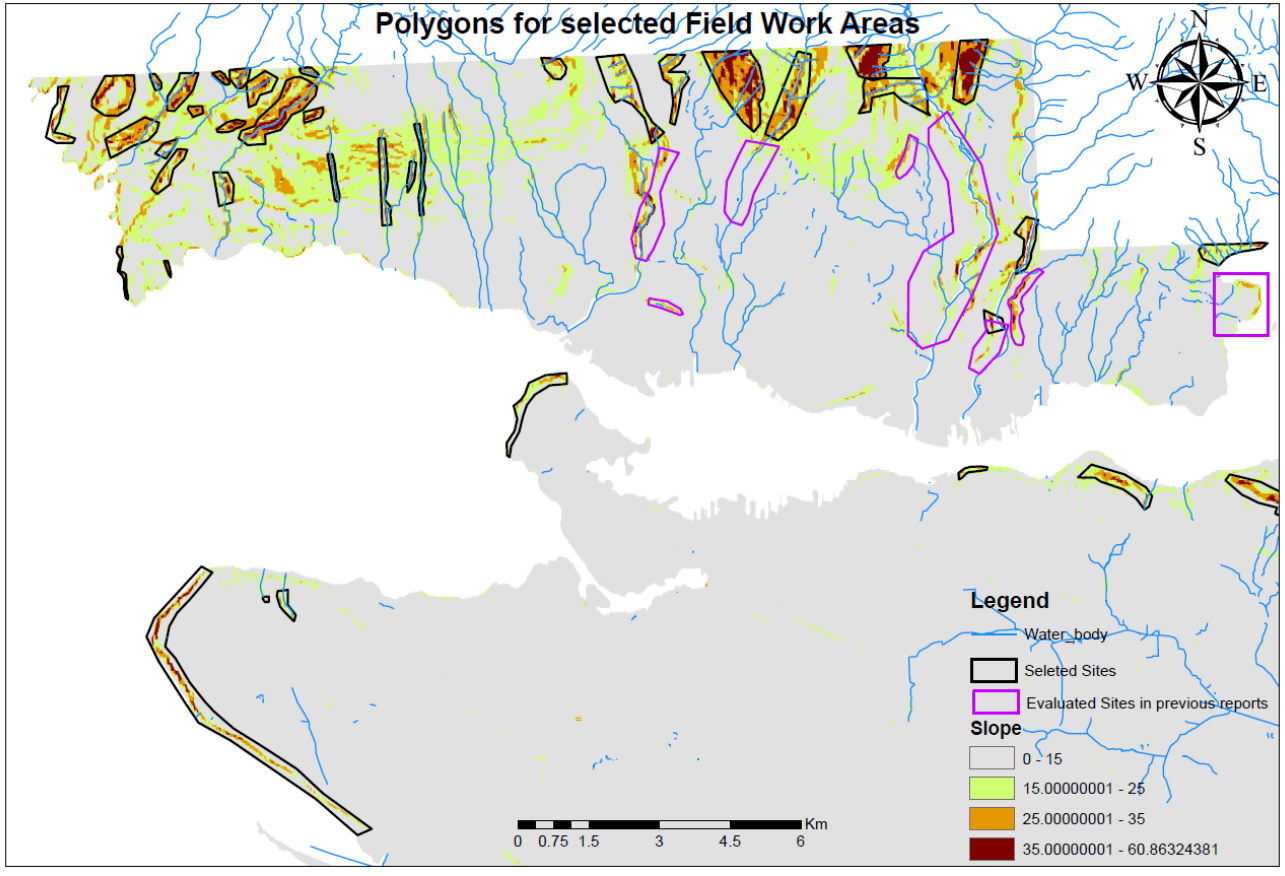


Cumulative dataset
- 1009 MHVSR sites
- ~54 Array sites



Slope stability field surveys

- Conducted **observational surveys of steep slope areas** in Tsawwassen, North Delta, Vancouver, Burnaby, North Vancouver, and West Vancouver.
- Notes on the slope geology and morphology, presence of structural elements, retaining walls, seepage and runoff, vegetation, and fill were made; supplemented with pictures taken in the field.
- Field day with Dr. John Clague (SFU, retired) observing geological and slope hazards in region.



Next steps – Continue to build geodatabase (2018 - 2021)

- Iterative “data collection, processing, review” pattern

In consultation with
EGBC
Peer Review Committee

ENGINEERS & GEOSCIENTISTS BRITISH COLUMBIA

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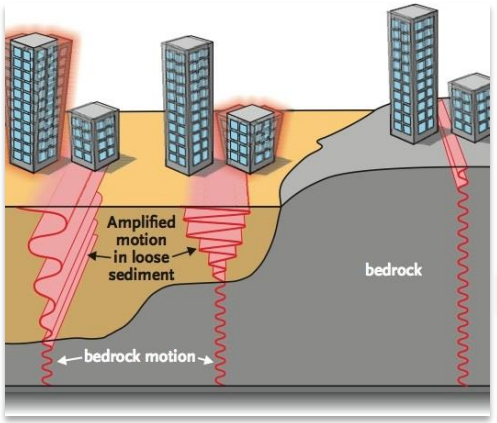
Items for discussion

smolnar8@uwo.ca

- Comments on project and progress thus far
- Annual engagement with stakeholders
  - Is this working for you? What we can do better?
  - Next year will start presenting analyses and values
- Professional Seismic Microzonation Mapping Guidelines
  - Foresee representation from all or key stakeholders:
    - Engineering seismologists, Engineers, Building official, and …
    - **Emergency Manager(s), Planner(s), Insurer(s), Consultant(s) ???**
  - Will need to consider policies for geodatabase management and growth
  - Will need to consider policies for professional map use
  - What is your professional practice with these maps?

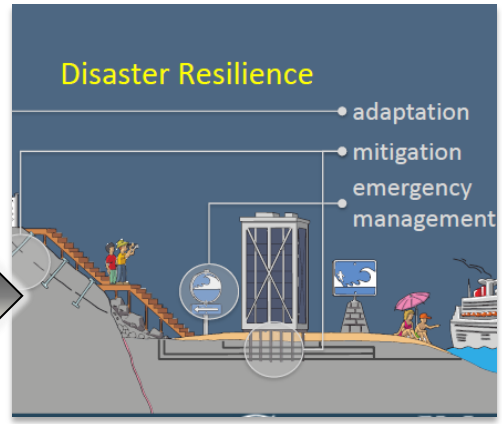
Western Science

Shaking Hazards | Liquefaction Hazards | Landslide Hazards



Hazard Maps

In progress



Informs

Mitigation

- Subsurface geological conditions
- Site period and shear-wave velocity data
- Extensive borehole & water well data
- Numerical modelling

- BC Earthquake Response Plans ☑
- National Building Code of Canada ☑
- BC Integrated Risk Assessments ☑
- Disaster Risk Reduction ?

Used to support mitigation and adaptation planning at local and regional scales

- Land use planning
- Emergency response planning
- Catastrophe modelling
- Insurance
- Prioritize seismic retrofits

?

?

?

Use of Map Data & Map Communication

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- **WHO** will use this information and **HOW** will it be used?
- Maps as communication tools
  - Data format / display preferences
  - Level of interaction by users
  - Availability to the public
- Consultation with stakeholders
  - Stakeholder input is essential to determine effective ways to convey & display information for practical use
  - Discussion, surveys, workshops, etc.
- Collaborative approach to produce useful map products

Summary

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- On track with project plan and deliverables
- Personnel for project team assembled
- First successful seismic field campaign, three more to go
  - 401 MHVSR sites, 44 Array sites in 30 days
- Collection of previous geodata reports and files is ongoing through 2021
  - Lots of shallow borehole data, **need more geophysics (velocity, density) and geotechnical (soil strength, dynamic behaviour) reports**
  - A time intensive process but necessary
  - VGS and VIGG visits (Nov 8, 9) to inform practicing geotechnical engineers
- Current focus is lots of data processing!, prep. for next summer field tests
- Seeking input for stakeholder engagement and professional map use

Thank you !