Topics

1. Natural and Technological Hazards in BC & the PNW
2. Critical Infrastructure and the Disaster Cycle
3. Modelling Critical Infrastructure Interdependencies
4. Development of a BC Provincial CI Inventory for NRCan:
   - *"Gather, compile and deliver a geospatial inventory of British Columbia's ten CI sectors in Esri File Geodatabase format"*

1. NATURAL AND TECHNOLOGICAL HAZARDS IN BRITISH COLUMBIA & THE PNW

Hazards & Disasters in Canada

- Natural Hazards
  - Increasing frequency / size of hazards?
  - Increasing consequences of hazards
    - Environmental
    - Social
    - Life Safety
    - Economic
- National Disaster Mitigation Program (NDMP)
  - CDN $200 million
  - Focus: mitigate flood risk
- British Columbia Activities:
  - Provincial:
    - Emergency Management BC
    - Data BC, Geo BC
  - Federal:
    - Public Safety Canada
    - Natural Resources Canada (NRCan)
      - Seismic, Flood, Interface fire
      - Establish baseline Critical Infrastructure (CI) datasets to support risk identification and mitigation

Motivation: Mitigation / Planning for Natural and Technological Disasters

Event	Hazard Type	Year	Loss of Life
Halifax, NS	Explosion	1917	1,950+
St. Francis Dam, USA	Dam Failure	1920	450+
North Sea, Holland & UK	Storm surge	1953	2,200
Malpasset Dam, France	Dam Failure	1959	450+
Bhopal, India	Chemical	1984	15,000
Indian Ocean	Tsunami	2004	283,000+
State of Victoria, Australia	Interface Fires	2009	141
Great Tohoku, Japan	Tsunami	2011	15,900+
Lac Mégantic, QC	Rail accident	2013	57
Haiyan, Philippines	Typhoon	2013	~6,166
Oso, Washington State	Mudslide	2014	41
Badakhshan, Afghanistan	Mudslide	2014	~500 to 2,000

Hazards in British Columbia

Accidents
- Air crashes
- Marine
- Motor

Atmospheric
- Snow s
- Blizzard
- Ice stor
- Hailsto
- Lightni
- Hurrica
- Tornad
- Heat w

Dam failu

Disease a
- Human
- Animal diseases
- Plant diseases
- Pest infestations

Fire - urban and rural
Fire - wildfire and interface

and debris

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transport r

ls

- Flooding
- Ice jams
- Storm surges

Explosions and emissions
- Gas and gas leaks (pipeline)
- Gas and gas leaks (gas wells)
- Mine
- Other explosions

2003 Okanagan Mountain Park Fire

Fire spreads from Rattlesnake Island

View of the fire from Westbank

Satellite scene.
Source: NASA Earth Observatory

Evacuees for Flood & Wildfire Disasters in Canada

(PSC National Hazards Database)

	Hazard (Jan 2000 – June 2015)					
	Number of Evacuees* for Flood Events			Number of Evacuees* for Wildfire Events		
Provinces	#	Evac_Ave	Evac_Max	#	Evac_Ave	Evac_Max
BC	5	502	1,050	6	5,242	20,000
BC, AB	0	–	–	1	48,501	48,501
AB	5	21,535	100,000	8	2,164	12,055
AB, SK	1	2,065	2,065	0	–	–
SK	4	796	1,100	8	789	2,800
MB	9	1,709	3,623	6	1,077	3,330
ON	10	827	1,900	7	991	3,292
QC	4	580	1,619	6	1,333	3,000
						–
						000
						100
NT	1	300	300	2	100	100
Totals	49	2,987	100,000	51	2,647	48,501

** Selected events where number of evacuees was more than 100 people.*

Fort McMurray Wildfire, AB, May 2016: ~88,000 evacuees
Oroville Dam Crisis, CA, Feb 2017: ~188,000 evacuees

PNW Example of Future Exposures: Cascadia Subduction Zone

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Selected Impact Zones for Tofino

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Count of Communities in British Columbia by Type

Regional District	Count by Community Type						
	City	District municipality	Village	Town	Island municipality	Mountain municipality	Grand Total
Alberni-Clayoquot	1	2					3
Bulkley-Nechako		3	4	1			8
Capital	3	8		2			13
Cariboo	2	2					4
Central Kootenay	2		6	1			9
Central Okanagan	2	2					4
Columbia Shuswap	2	1		1			4
Comox Valley	1		1	1			3
Cowichan Valley	1	1		2			4
East Kootenay	3	3	2			1	9
Fraser Valley	2	3	1				6
Fraser-Fort George	1	1	2				4
Greater Vancouver	13	4	3		1		21
Kitimat-Stikine	1	3	1				5
Kootenay Boundary	4		4				8
Mount Waddington		1	2	1			4
Nanaimo	2	1		1			4
North Okanagan	3	2	1				6
Northern Rockies		1					1
Okanagan-Similkameen	1	1	1	3			6
Peace River	2	4	1				7
Powell River	1						1
Skeena-Queen Charlotte	1	1	3				5
Squamish-Lillooet		2	1			1	4
Strathcona	1		4				5
Sunshine Coast		1		1			2
Thompson-Nicola	2	3	5			1	11
Grand Total	**51**	**50**	**42**	**14**	**1**	**3**	**161**

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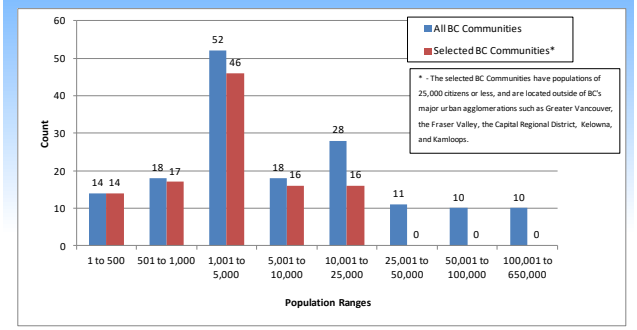
Community Sizes by Census Population (2016)



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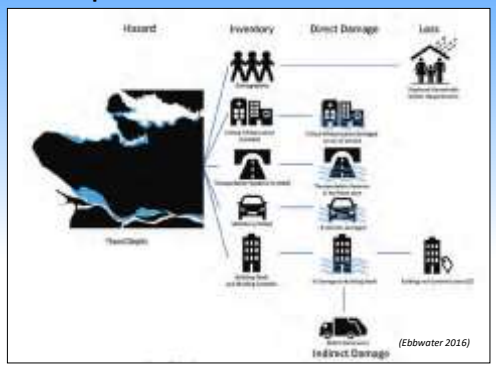
Summary

- Significant range, variety and magnitude of hazard exposures in British Columbia
- Need to identify and mitigate hazard exposures
- Many communities outside of the main urban areas will require:
  - Baseline CI datasets (in GIS format)
  - Technical / analytical support

2. CRITICAL INFRASTRUCTURE AND THE DISASTER CYCLE

Hazard Impacts on Communities and their CI Assets



CI Sectors: Canada

Public Safety Canada | Sécurité publique Canada

CI Sectors: Germany

Federal Office of Civil Protection and Disaster Assistance

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CI Sectors: USA

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CI Sectors and Subsectors (BC Model 2009)

1 – Energy and Utilities	**3 – Manufacturing (& Services)**	**7 – Water (& Waste)**
1.01 – Electric – Generation	3.01 – Chemical	7.01 – Water Supply & Distribution
1.02 – Electric – Transmission	3.02 – Defence	7.02 – Waste Water Management
1.03 – Electric – Distribution	3.03 – Asphalt	7.03 – Drainage
1.04 – Natural Gas – Extraction	3.04 – Concrete	7.04 – Solid Waste Management
1.05 – Natural Gas – Transmission	3.05 – Forestry	**8 – Transportation**
1.06 – Natural Gas – Distribution	3.06 – Mining	8.01 – Roads
1.07 – Oil & Gas – Extraction	3.07 – Metal	8.02 – Rail
1.08 – Oil & Gas – Transmission	3.08 – Manufacturing	8.03 – Rapid Transit
1.09 – Oil & Gas – Distribution	**4 – Finance**	8.04 – Ports & Harbours
1.10 – Liquid Propane Gas	4.01 – Banks & Credit Unions	8.05 – Air
1.11 – Nuclear	4.02 – Insurance	**9 – Safety (& Public Protection)**
1.12 – Coal	4.03 – Securities Exchange	9.01 – Police
1.13 – Ethanol	4.04 – Sector Support	9.02 – Fire
1.14 – Steam	**5 – Health Care**	9.03 – Ambulance Service
2 – Communications & Information Technology	5.01 – Acute Care	9.04 – Emergency Facility
	5.02 – Primary Care	9.05 – Other
2.01 – Communications	5.03 – Community Care	**10 – Government**
2.02 – Internet	5.04 – Public Health	10.01 – Municipal
	5.05 – Support Services	10.02 – Provincial
	6 – Food	10.03 – Federal
	6.01 – Agriculture	
	6.02 – Processing	
	6.03 – Distribution	

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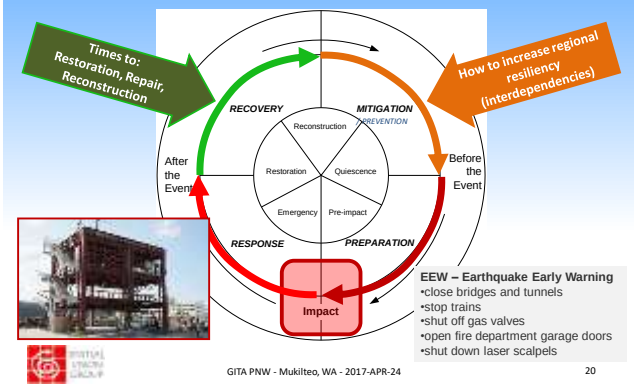
The Disaster Cycle



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Selected Descriptive Statistics of BC CI Customers

Measure		Approximate Number
Population (2016)		4,648,000
Municipalities, Regional Districts		161
Number of Businesses		196,000
Number of Private Dwellings		2,063,000
Power customers		2,100,000
Gas customers		1,000,000
Medical Services Plan (2015/2016)	*Registrants*	4,895,000
	Patient Count	3,919,000

Sources: Statistics Canada, BC Stats, BC MSP, Wikipedia. Values rounded to 1,000's.

Selected Estimates of CI Assets in BC

CI Sector	Examples of CI Subsector	Asset Types	Estimated #	Critical Services
01 – Energy & Utilities	Regulated utilities	-	30	3
	Power generation	generation sites	100+	1
	Power transmission	transmission lines	20,000 km	1
	Power distribution	towers & poles	96,000	1
	Oil & Gas	substations	290	1+
		distribution lines	60,000 km	
		transmission pipelines	10,000 km	
		stations	750	
02 – Communications & IT	Telephone	cell towers	10,000+	100s
03 – Manufacturing	Chemical manufacturing	facilities	13	10s
04 – Finance	Finance	branches & processing centres	825	10s
05 – Health Care	Hospitals	Hospitals	100	100s
06 – Food	Food processing subsector	employees	31,500	100s
	Food wholesale	employees	13,500	10s
	Food retail & services subsector	employees	167,000	10s
		restaurants	9,600	
07 – Water (& Waste)	Water supply/sewage treatment	# of systems	300	1s
	Dams	# (all types)	2,500	10s
08 – Transportation	Provincial roads	all road types	700,000 km	1,000s
	Airports	bridges/overpasses	2,200	1,000s
		airports	50	
09 – Safety	Police Services	buildings	925	100s
	Ambulance Services (BCAS)	communications sites	275	10s
		stations	187	
10 – Government	Provincial	buildings	3,500	100s to 1,000s
		ESS sites (schools, etc.)	3,000	10s

* Primary sources: Wikipedia (Wikipedia 2017), Spatial Vision Group (2009).

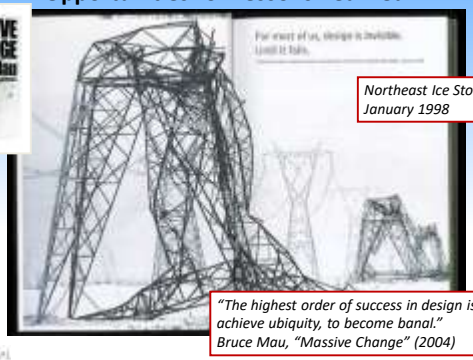
Summary

- We need to know the current state, condition and fragility of our CI
- What is the fragility of CI assets for each hazard type (?)
- Times to repair, restoration and reconstruction?
- How to better coordinate / improve regional CI resilience:
  - … within each sector?
  - … between sectors?
  - … during an actual disaster?

- **Establish baseline Critical Infrastructure (CI) datasets to support risk identification and mitigation at the community & regional district levels**

3. MODELLING CRITICAL INFRASTRUCTURE INTERDEPENDENCIES

Post-Disaster Rationalization, Opportunities for Lessons-Learned



Northeast Ice Storm January 1998

"The highest order of success in design is to achieve ubiquity, to become banal."
Bruce Mau, "Massive Change" (2004)

Post-Disaster Rationalization, Opportunities for Lessons-Learned

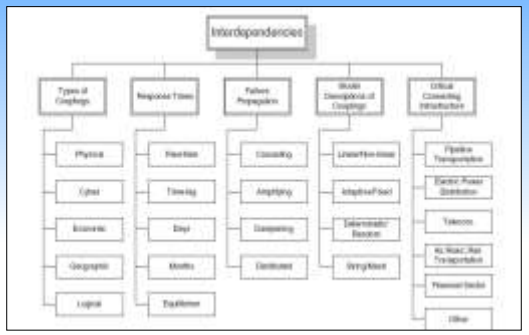
Joni Mitchell = A Critical Infrastructure Resilience Visionary:

"You don't know what you've got 'till it's gone"
- Big Yellow Taxi, 1970

Graphical View of CI Interdependencies

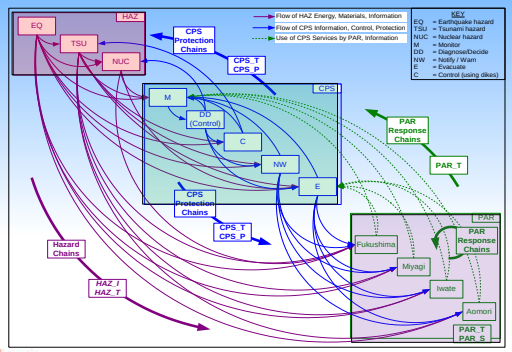
(Marti 2014)

Taxonomy for Modelling CI Interdependencies



(Haimes et al 2008)

Systems Framework Applied to the Great Tohoku Earthquake, Tsunami and Nuclear Accident



Integrated Systems Modelling Framework for Analysis and Simulation

Model the time- and location-dependent flows of information, materials, momentum, energy, etc. between systems.

System state differential equations:

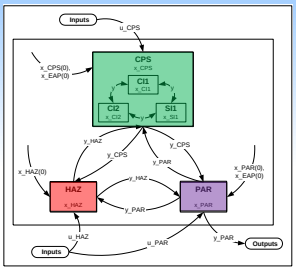
$$\underline{SX}' = SA \cdot \underline{SX} + SB \cdot \underline{IN} \quad \text{System States}$$

$$\underline{SY} = SC \cdot \underline{SX} + SD \cdot \underline{IN} \quad \text{System Outputs}$$

$$\underline{SZ} = SO \cdot \underline{SX} + SE \cdot \underline{SX} \quad \text{Observations}$$

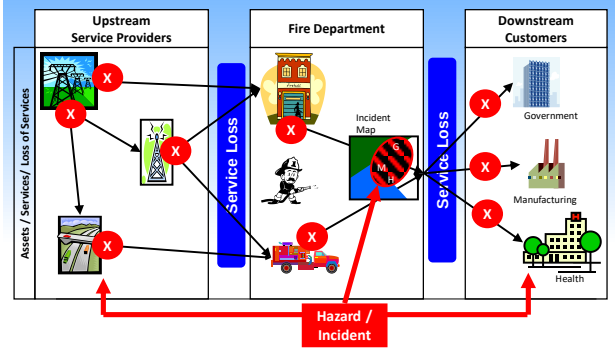
System state and input matrices:

$$SA, SB \approx \begin{bmatrix} HAZ & CPStoHAZ & PARtoHAZ \\ HAZtoCPS & CPS & PARtoCPS \\ HAZtoPAR & CPStoPAR & PAR \end{bmatrix}$$



Hospital evacuation during flood

Concept of Cascading CI Failures



CI asset owners are both customers of upstream CI services, and CI service providers to downstream customers.

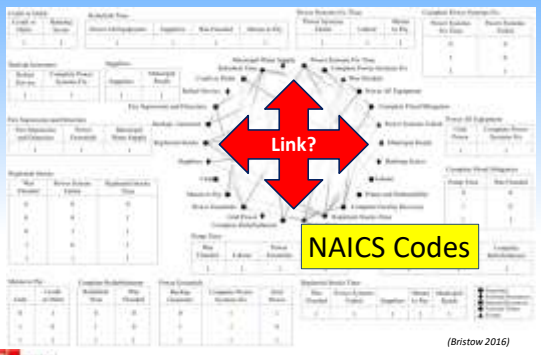
Estimating Impacts and Consequences: Hazard and Loss Models

- **HAZUS Canada:**
  - Canadian implementation of the DHS/FEMA HAZUS toolset
  - CanHUG – Canadian HAZUS User Group
- **OpenQuake – Global Earthquake Model:**
  - Global Earthquake Model (GEM) foundation
  - Suite of tools to assess earthquake hazard and risk
  - Model specific impacts of ground-shaking on CI assets
  - Free and Open Source Software (FOSS)

Estimating Cascading Losses and Times to Repair: CI Interdependency Models

- **National Critical Infrastructure Model (Canada):**
  - Chouinard & Hales, Defence Research & Development Canada (DRDC), Canada DND
  - Model non-spatial interdependencies using a CI functional model
  - Uses NAICS codes
  - NAICS = North American Industry Classification System
- **GMOR**
  - Graph Model for Operational Resilience
  - D. Bristow, Dept. of Civil Engineering, University of Victoria
  - Resilience and recovery planning for multi-infrastructure systems
  - Estimates times to recover depending upon CI damage
  - Assess the value of different risk treatments
  - Inputs: GIS data of CI assets, NAICS function/service codes

CI Interdependency Modelling: Use NAICS Functions, Model links, Estimate Time to Repair



(Bristow 2016)

NAICS Sectors & Codes

Code	Sector
11	Agriculture, forestry, fishing and hunting
21	Mining, quarrying, and oil and gas extraction
22	Utilities
23	Construction
31-33	Manufacturing
41	Wholesale trade
44-45	Retail trade
48-49	Transportation and warehousing
51	Information and cultural industries
52	Finance and insurance
53	Real estate and rental and leasing
54	Professional, scientific and technical services
55	Management of companies and enterprises
56	Administrative and support, waste management and remediation services
61	Educational services
62	Health care and social assistance
71	Arts, entertainment and recreation
72	Accommodation and food services
81	Other services (except public administration)
91	Public administration

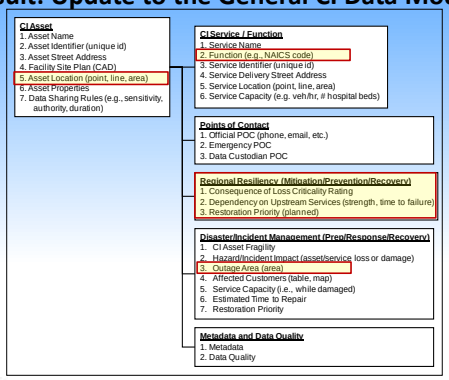
Code	Title
22	Utilities
221	Utilities US
2211	Electric power generation, transmission and distribution
2212	Natural gas distribution US
2213	Water, sewage and other systems US
22111	Electric power generation US
22112	Electric power transmission, control and distribution US
22121	Natural gas distribution US
22131	Water supply and irrigation systems US
22132	Sewage treatment facilities US
22133	Steam and air-conditioning supply US
221111	Hydro-electric power generation US
221112	Fossil-fuel electric power generation US
221113	Nuclear electric power generation US
221119	Other electric power generation US
221121	Electric bulk power transmission and control US
221122	Electric power distribution US
221210	Natural gas distribution US
221310	Water supply and irrigation systems US
221320	Sewage treatment facilities US
221330	Steam and air-conditioning supply US

4. DEVELOPMENT OF BC PROVINCIAL CI INVENTORY

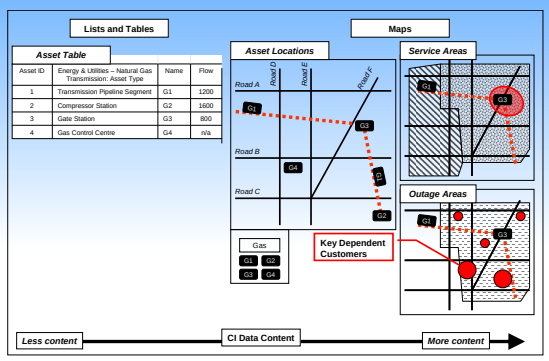
BC CI Inventory – 2017 Terms of Reference

- Gather, compile and deliver a geospatial inventory of British Columbia's ten CI sectors in Esri File Geodatabase format
- Prior work in BC:
  1. i2Sim – UBC CI Interdependency Simulation Study
     - Focused on UBC campus
  2. 2010 Vancouver Winter Olympics
     - Development of first comprehensive, multi-sector CI datasets
     - Three preparation exercises (Bronze, Silver, Gold) used the data
     - CI Data Sharing Study (Spatial Vision Group)
     - Data was destroyed after the Olympics were over

Result: Update to the General CI Data Model



Range of Possible CI Data Content to Share



Regional District GIS Data Availability in BC

Regional District	Has a GIS	Has a Web GIS	Has a GIS API	Has Open GIS Data Access
Alberni-Clayoquot	✓?	✗	✗	✗
Bulkley-Nechako	✓	✓	✗	✗
Capital	✓	✓	✓	✗
Cariboo	✓	✓	✗	✗
Central Kootenay	✓	✓	✗	✓
Central Okanagan	✓	✓	✗	✓
Columbia Shuswap	✓	✓	✗	✓
Comox Valley	✓	✓	✗	✗
Cowichan Valley	✓	✓	✗	✓
East Kootenay	✓	✓	✗	✓
Fraser Valley	✓	✓	✗	✗
Fraser-Fort George	✓	✓	✗	✗
Greater Vancouver	✓	✓	✗	✓
Kitimat-Stikine	✓	✓	✗	✗
Kootenay Boundary	✓	✓	✗	✗
Mount Waddington	✗	✗	✗	✗
Nanaimo	✓	✓	✗	✗
North Okanagan	✓	✓	✗	✓
Northern Rockies	✗?	✗	✗	✗
Okanagan-Similkameen	✓	✓	✗	✓
Peace River	✓	✓	✗	✗
Powell River	✓	✓	✗	✗
Skeena-Queen Charlotte	✗	✗	✗	✗
Squamish-Lillooet	✓	✓	✗	✗
Strathcona	✓	✓	✗	✗
Sunshine Coast	✓	✓	✗	✓
Thompson-Nicola	✓	✓	✗	✗

Open CI Data Sources in BC

Open Data CI Data Sources (Selected Examples)		
BC Ambulance Service	City of Richmond	Ministry of Labour and Citizens' Services
BC Ferries	City of Surrey	Ministry of Transportation and Highways
BC Oil & Gas Commission	City of Vancouver	National Geospatial-Intelligence Agency
BC Paraplegic Association	DataBC	NAVCan
BC Stats	District of Maple Ridge	NRCan
Canada Post	District of North Vancouver	Open Street Map (OSM)
CanVec	EnergyBC.ca	OpenFlights.org
Capital Regional District (CRD)	GeoBase	Public Safety Canada
City of Chilliwack	GeoBC	PWGSC
City of Coquitlam	GeoGratis Catalog	Regional District of Central Okanagan
City of Kelowna	Government of Canada – Open Data Portal	Solicitor General
City of Maple Ridge	INAC	Township of Langley
City of Nanaimo	Industry Canada	Translink
City of Pitt Meadows	Liquor Distribution Branch	Transport Canada
City of Port Coquitlam	Metro Vancouver	Universities (UBC/SFU, etc.)
City of Port Coquitlam	Ministry of Forests, Land, and Natural Resource Operations	Vancouver Coastal Health Authority
City of Prince George	Ministry of Health	

"Non-open" CI Data Sources in BC

Non-open Data CI Data Sources		
BC Assessment	ECOMM	MTS Allstream
BC Hydro	Ecowaste	Pacific Natural Gas
Bell	Emergency Management BC	Port Metro Vancouver
Canexus	EPCOR	RBC
Cara Foods	FNESS	RCMP
Central Credit Union	Fortis BC	Rogers Cable
Chevron Canada	ICI Society	Rogers Sugar
CN	Imperial Oil	Telus
CP	Insurance Board of Canada	Wastech
DMTI	Kinder Morgan	YVR

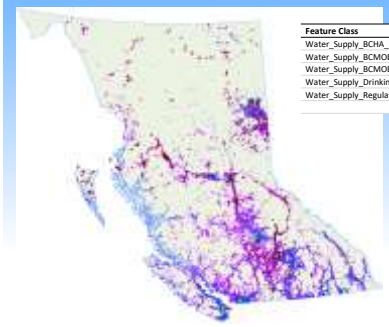
Examples of CI Results: Energy Sector

Feature Class	Feature Count
Energy_Hydroelectric_Generation_Facilities_points	196
Energy_Hydroelectric_Substations_points	319
Energy_Hydroelectric_Transmission_Powerlines_lines	1,549
Energy_Natural_Gas_BC_NatGas_Processing_Plants_points	78
Energy_Natural_Gas_Extraction_Facilities_points	15,053
Energy_OilGas_BC_Refineries_Terminals_points	11
Energy_Provincial_Crown_ROWs_Energy_Utility_HydroPower_areas	31,060
Energy_Transmission_Pipeline_Installations_points	354
Energy_Transmission_Pipelines_lines	792
Total Features	**49,412**

Examples of CI Results: Transportation Sector

Feature Class	Feature Count
Air_Aerodrome_Waterdrome_points	643
Air_Air_Traffic_Control_Centres_points	10
Marine_Anchorages_points	1,352
Marine_Coastal_Inland_Ferry_Terminals_points	160
Marine_Ports_Terminals_points	180
Rail_NRWN_BC_v1_Crossings_points	5,612
Rail_NRWN_BC_v1_Junctions_points	7,385
Rail_NRWN_BC_v1_Stations_points	382
Rail_NRWN_BC_v1_Structures_points	1,090
Rail_Network_NRWN_BC_v1_Tracks	9,496
Road_BC_Disaster_Routes_DRA_lines	8,105
Road_Culverts_points	181,101
Road_Retaining_Walls_points	569
Road_Structures_lines	9,907
Road_Structures_points	9,908
Road_Weighscales_points	32
Transit_Bus_Transit_Rail_Stations_points	121
Transit_Skytrain_Stations_points	58
Total Features	**236,165**

Examples of CI Results: Water Sector



Feature Class	Feature Count
Water_Supply_BCHA_Drinking_Water_Extraction_Point_points	876
Water_Supply_BCMOE_Aquifers_areas	1,129
Water_Supply_BCMOE_Drinking_Water_Well_Locations_points	15,564
Water_Supply_Drinking_Water_Sources_POD_points	46,094
Water_Supply_Regulated_Public_Water_Utilities_points	128
Total Features	**63,791**

Results

1. Gathered, compiled and delivered a geospatial inventory of British Columbia's ten CI sectors in Esri File Geodatabase format (10 gdb's)
2. Extended the existing Provincial CI Data Model
3. Identified opportunities for adding many more CI nodes using Provincial and commercial structure / business inventories

Sector	# of feature classes	# of features
Energy	9	49,912
Transportation	19	236,165
Internet / Communications Technology	4	27,459
Water	5	63,791
Safety	6	23,788
Manufacturing	2	327
Healthcare	1	197
Government	5	10,659
Food	0	0
Financial	1	1,608
Totals	**52**	**413,906**

Issues

1. Data Sources:
   - Structured: Source data is in GIS & RDBMS form
   - Semi-Structured: Source data is compatible with GIS, could be geocoded
   - Unstructured Data: Need AI & other encoding tools to pull out relationships and create links to pt/line/area geometries
2. Scale
   - Macro / Meso / Micro
3. Share / purchase?: private / commercial / competitive datasets
   - Assets <or> Service Areas/Restoration Priorities?
4. Data Size & Change:
   - A "Big Data" problem?
     - Volume
     - Variety
     - Velocity
   - Timeliness: your copy of CI data will be out-of-date tomorrow
5. The resulting set of compiled CI data is viewed by some as security-sensitive

Next Steps – Key Players

- Today's Talk:
  - Canada Federal:
    - Public Safety Canada - National Disaster Mitigation Program (NDMP)
    - NRCan – Hazard Models & CI Interdependency Models
  - BC Provincial:
    - Emergency Management BC
    - Geo BC / Data BC:
      - Open Data Portals
      - Portal for CI Data Sharing (future)
  - BC Regional Districts and Local Communities & ICI Society
- Other Players / Parallel Activities:
  - Canada-USA:
    - Pacific-Northwest Economic Region (PNWER):
      - WA, OR, ID, MT, AK + BC, AB
    - PNWER Disaster Resilience Group
  - Other BC: e.g.
    - Fraser Basin Council (FBC) – Lower Fraser River Dikes
    - City of Vancouver → Resilience to climate change
    - District of North Vancouver → Community Seismic Hazard Mitigation

Next Steps - Activities

1. Fill data gaps:
   - obtain / geocode BC Assessment Data
     - Manual Class & Actual Use Codes → convert to NAICS codes
   - assess commercial datasets
     - DMTI
     - Scott's Directories
2. Continue to build partnerships & leverage existing data & portals:
   - Leverage BC investment in webGIS and Open Data Portals
   - RD's and Muni's members of ICI Society
3. Pilot study focused on small BC communities