The AIR Earthquake Model for Canada

Canada experienced one of the most powerful earthquakes in world history when an M9.0 event struck just offshore of western North America in 1700. If a similar earthquake were to strike today, it would cause tens of billions of dollars in insured losses. The AIR Earthquake Model for Canada provides the most up-to-date information to support risk management strategies that will effectively mitigate the impact of the next big quake.

In 2012, the Insurance Bureau of Canada (IBC) commissioned AIR to conduct a comprehensive study of seismic risk in Canada. This study was performed using the AIR Earthquake Model for Canada, the first catastrophe model in the industry to provide an integrated view of loss from all earthquake-related perils: ground shaking, fire following, tsunami, liquefaction, and landslide.

The AIR model will play a critical role in helping insurance industry stakeholders better understand and manage their exposure to earthquake risk while demonstrating compliance with the Earthquake Exposure Sound Practices outlined in OSFI Guideline B-9.

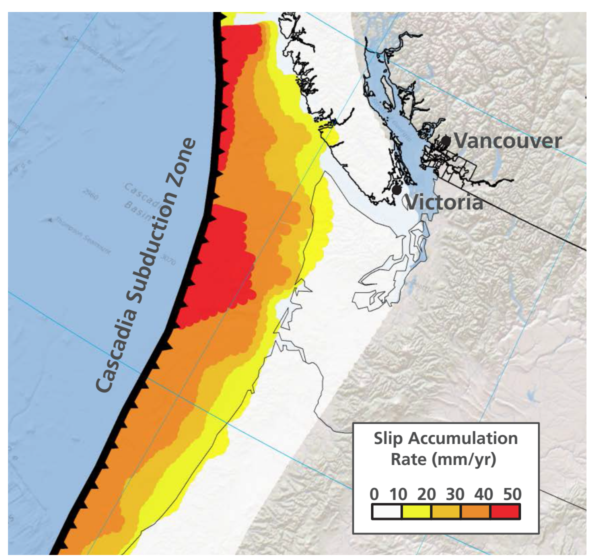
> “The findings of the AIR study will help us raise awareness of the need to plan for and mitigate the risks of a major earthquake...the study is a valuable tool and will be shared with governments, regulators, disaster preparedness organizations, the banking community, the insurance industry, and the public.”
>
> – Don Forgeron,
> IBC President and CEO

The Most Comprehensive View of Seismic Hazard in Canada

Canada experiences about 4,000 earthquakes each year. While most are too small to be felt, at least 24 significant earthquakes have struck Canada in the past three centuries. In western Canada, these earthquakes are produced by the Cascadia subduction zone—a geological twin of the Sumatra subduction zone that spawned the devastating 2004 earthquake and tsunami—and the Queen Charlotte-Fairweather transform fault system offshore of British Columbia. With a history of producing smaller-magnitude, but still significant earthquakes in Canada’s most densely populated provinces of Quebec and Ontario, seismic sources in the eastern region of the country are also cause for concern.

Using historical earthquake data provided to AIR by the Geological Survey of Canada, as well as published reports by Canadian seismologists, AIR scientists have created the most comprehensive model of Canada’s seismic hazard available.

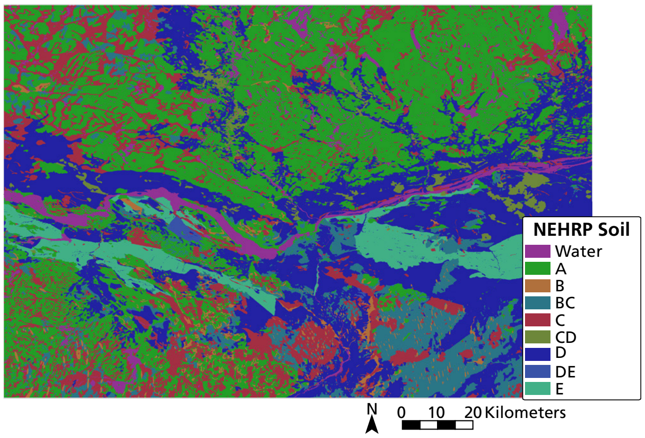
In western Canada, AIR augments historical seismicity information with regional and local GPS data on active faults to develop a *kinematic block model* for the region around the Cascadia subduction zone. Kinematic block models are physically based models that provide information on the accumulation of seismic energy due to the “locking” of tectonic plates in subduction zones; they are especially useful for estimating the recurrence rates for rare, very large magnitude earthquakes.



The kinematic block model reveals regions (shown in dark red) within the Cascadia subduction zone where there is the highest accumulation of seismic energy. (Source: AIR)

In eastern Canada, the historical data are critical, as this "intraplate" region lacks known active faults. Here, damaging earthquakes have been produced by ancient faults in seismic zones such as the Charlevoix-Kamouraska seismic zone and the Laurentian Slope seismic zone.

Using the most detailed geological and soil maps that are available for Canada, the AIR model also accounts for variations in soil type that can dramatically alter the intensity and nature of ground shaking.



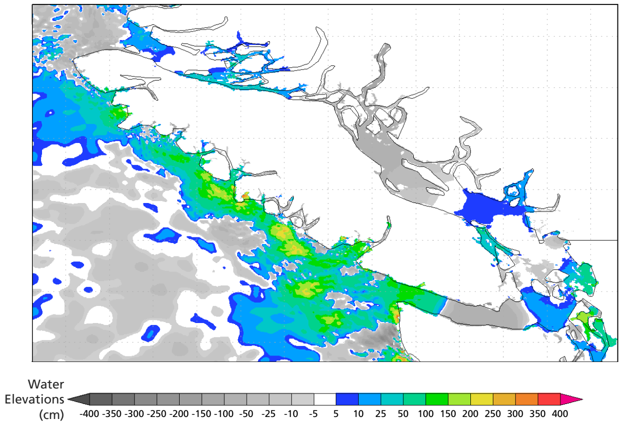
Detailed soil maps, particularly in regions of high exposure concentration such as Ottawa (shown above), are an important data source for the model's hazard component. (Source: AIR)

The Industry's Only Fully Probabilistic Tsunami Model for Western Canada

The Cascadia subduction zone and the Alaska-Aleutian megathrust can generate devastating tsunamis that pose great risk to life and property. The Great Alaska Earthquake of 1964 generated a tsunami that damaged hundreds of homes on Vancouver Island.

The AIR model explicitly captures tsunami occurrence, intensity, and damage using a fully probabilistic approach. For each tsunamogenic earthquake in the catalog, the AIR model captures the entire lifespan of the resulting tsunami.

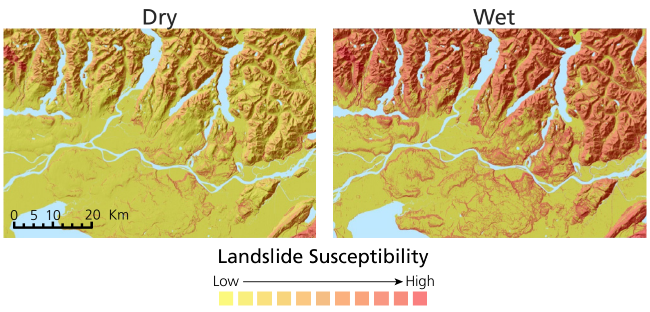
The AIR model also captures the effect on properties of debris borne by tsunami waves. Tsunami-prone regions of the coast are characterized as zones of light, moderate, or heavy debris determined from the industry exposure database. The resulting damage is a function of construction type.



The AIR simulation of the tsunami triggered by the M9.0 Cascadia subduction zone earthquake of 1700 captures the interaction with the shores of small inlets between the mainland and Vancouver Island near the end of the tsunami's life. (Source: AIR)

Explicit Modeling of Earthquake-Triggered Landslides

Buildings and infrastructure in Canada's mountainous regions—such as the Southern Coast Mountains of British Columbia—are at risk from earthquake-triggered landslides. If an earthquake were to strike, landslide damage to power lines and pipelines in these regions would have far-reaching effects, even if other structures escape serious damage. While lacking the mountainous terrain of western Canada, eastern Canada is not immune to landslides; notable landslide hazard exists near the St. Lawrence River in Quebec.



The AIR model captures how saturated soils increase landslide susceptibility during earthquakes. (Source: AIR)

The AIR Earthquake Model for Canada is the first to explicitly simulate earthquake-triggered landslides. With high resolution digital elevation data, soil strength information, and water saturation data as its foundation, the module determines landslide susceptibility using a physics-based model relating critical acceleration and permanent ground displacement. Modeled ground shaking intensity is then coupled with landslide susceptibility to estimate damage and loss.

Multilevel Fire Following Module

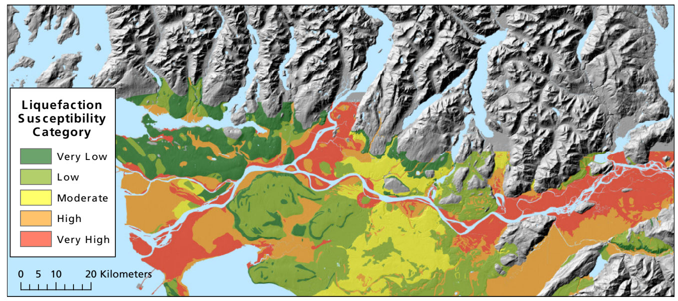
Several factors contribute to the risk of fire following an earthquake. Local ground shaking intensity in combination with regional building density impacts the number of fires ignited by damage to electrical wiring, gas pipelines, and overturned household objects. Earthquake damage to roads and water distribution pipelines may significantly hamper fire suppression efforts.

In the AIR model, fire ignitions are simulated based on ground motion, and fire spread is modeled at the city block level using a technique that accounts for building spacing and combustibility, ignition location, and wind conditions. Fire suppression is based on fire engine movement and water availability, and the AIR model explicitly accounts for the Vancouver Dedicated Fire Protection System, which was installed to mitigate post-earthquake fire spread.

Explicit Modeling of Liquefaction

When violent ground shaking causes water-saturated soils to lose their strength, liquefaction is the result. As liquefied soil shifts, buildings can suddenly tilt or even topple. Buried utility lines, pipelines, and ducts can rupture.

Liquefaction risk in Canada is explicitly captured in the AIR model for six regions of high exposure concentration in British Columbia, Quebec, and Ontario. As liquefaction susceptibility is strongly correlated with soil type and water depth, AIR uses many sources of topographic, soil, and groundwater data to produce a comprehensive picture of liquefaction risk.

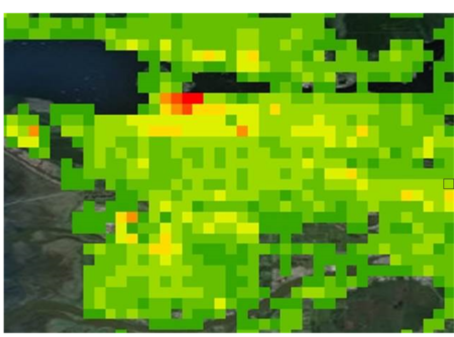


Parts of British Columbia are notably susceptible to earthquake-triggered liquefaction. (Source: AIR)

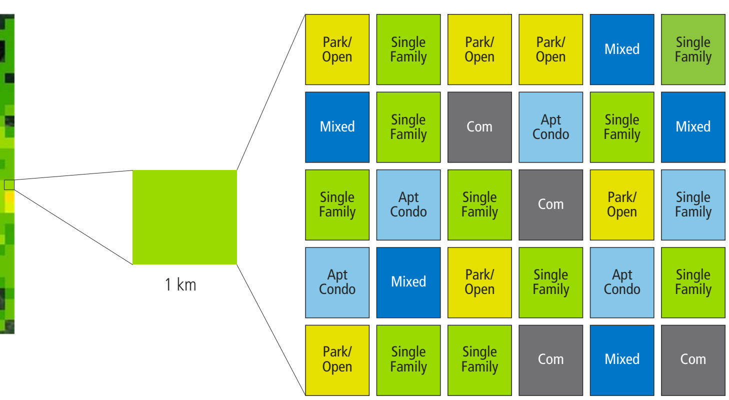
Damage Functions Provide a Robust Multi-Peril View of Vulnerability

In developing the model's damage functions, AIR partnered with Canadian scientists and engineers and incorporated the most up-to-date published research on building vulnerability. AIR also conducted a comprehensive evaluation of the evolution of Canada's building codes.

The model features unique damage functions for shake, tsunami, liquefaction, and landslide for 75 construction classes and 48 occupancy classes. These damage functions fully



Grid cells were categorized using high resolution building data.

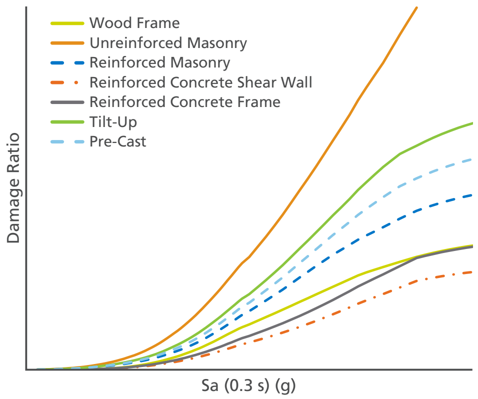


For each grid cell, land use and occupancy data are used to assign characteristic blocks.

Fire spread is first modeled at the city block level, taking into account variation in building type, ignition location, and wind conditions. (Source: AIR) capture the relationship between each hazard and the vulnerability of affected structures. Both seismic and wind design codes are incorporated in AIR's damage estimation process for Canada, acknowledging that constructing a building to withstand high wind loads also confers improved seismic resistance.

Further highlights of the AIR model's vulnerability module include:

- Damage functions for all five modeled perils for buildings, contents, and business interruption
- Detailed age bands that are fully consistent with the evolution of Canada's building codes
- Damage functions for buildings with unknown risk characteristics are exposure-weighted averages of damage functions for buildings of known attributes, which leverage AIR's industry exposure database
- Damage functions for complex industrial facilities are included for the shake, fire following, and tsunami perils



Examples of shake damage functions for buildings used in the AIR model. (Source: AIR)

Leveraging AIR's Detailed Industry Exposure Database for Canada

AIR's industry exposure database (IED) for Canada consists of the latest available information on risk counts, building characteristics, and construction costs, at a 1-km grid resolution. Developed using a wide variety of local sources, the IED captures the characteristics of Canadian properties at a high level of detail.

The benefits and uses of AIR's IED are numerous. It provides a foundation for all modeled industry loss estimates. Risk transfer solutions, such as industry loss warranties that pay out based on industry losses, rely on the IED. In addition, based on industry exposure weights by line of business, aggregate CRESTA and aggregate FSA exposures are automatically disaggregated to a 1-km grid during analysis.

Thorough Validation of All Model Components and Loss Estimates

To ensure the most robust and scientifically rigorous model possible, the AIR model has been built from the ground up, with each model component independently validated against multiple sources and data from historical events around the world. For example, modeled ground motion agrees well with recorded ground motion fields for Canadian earthquakes. Similarly, modeled damage ratios have been validated against actual observations and published reports for earthquakes in Canada to the extent that these data are available; further validation has been performed using extensive analyses of seismic resistance of buildings in the United States.

In addition to validating each model component individually, AIR has validated the model from the top down to ensure that final model results make sense. Loss estimates produced by the AIR Earthquake Model for Canada compare well with loss data from historical earthquakes that have caused significant damage in Canada, such as the M5.9 Saguenay 1988 earthquake.

The model has also undergone extensive peer review by a group of distinguished local and international experts. The hazard component was reviewed by Dr. Stephane Mazzoti of Montpellier University in France (formerly of the Geological Survey of Canada); the vulnerability component was reviewed by Dr. Marie Jose Nollet of the École de technologie supérieure in Montreal; and the fire following module was reviewed by Dr. Keisuke Himoto of Kyoto University in Japan and by Dr. Geoff Thomas of Victoria University in New Zealand.

In addition, AIR collaborated with independent experts during model development. Dr. Robert McCaffrey of Portland State University in the U.S. provided assistance during development of the hazard component, and Dr. Oh-Sung Kwon of the University of Toronto aided the development of the vulnerability component.

Model at a Glance

Modeled Perils	Earthquake ground shaking, fire following, tsunami, liquefaction, and landslide
Stochastic Catalogs	Time-dependent and time-independent 10,000-year catalogs seamlessly integrated with the time-dependent and time-independent stochastic catalogs for the AIR Earthquake Model for the United States
Supported Construction Classes and Occupancies	— 75 construction classes and 48 occupancy classes are supported for shake, tsunami, liquefaction, and landslide — Complex industrial facilities, which are represented by 62 occupancy classes, are supported for shake, fire following, and tsunami — Fire following is supported for all construction types except infrastructure — Unknown Damage Functions for instances when exposure information (e.g., construction type, occupancy, or height) is unavailable
Industry Exposure Database	Provides a foundation for all modeled industry loss estimates
Supported Policy Conditions	AIR's detailed software system supports a wide variety of location, policy, and reinsurance conditions that are specific to Canada.

Model Highlights

- Explicitly models the full range of earthquake-triggered perils, including ground shaking, fire following, tsunami, liquefaction, and landslide.
- Includes a standard time-dependent 10,000-year stochastic catalog that AIR has seamlessly integrated with our standard 10,000-year stochastic catalog for the United States, facilitating modeling of cross-border risks.
- Incorporates the most up-to-date analyses of seismicity in Canada from the Geological Survey of Canada, and employs kinematic modeling, active faults, and historical earthquake data to produce a comprehensive view of seismic hazard.
- Uses high-resolution soil maps to capture site amplification, liquefaction potential, and landslide potential.
- Features peril-specific damage functions for shake, fire following, tsunami, liquefaction, and landslide that have been validated using data from earthquakes around the world.
- Benefits from AIR's collaboration with local researchers during model development, and from a thorough peer review of all model components.

ABOUT AIR WORLDWIDE

AIR Worldwide (AIR) provides risk modeling solutions that make individuals, businesses, and society more resilient to extreme events. In 1987, AIR Worldwide founded the catastrophe modeling industry and today models the risk from natural catastrophes, terrorism, pandemics, casualty catastrophes, and cyber attacks, globally. Insurance, reinsurance, financial, corporate, and government clients rely on AIR's advanced science, software, and consulting services for catastrophe risk management, insurance-linked securities, site-specific engineering analyses, and agricultural risk management. AIR Worldwide, a Verisk (Nasdaq:VRSK) business, is headquartered in Boston with additional offices in North America, Europe, and Asia. For more information, please visit www.air-worldwide.com.

©2018 AIR Worldwide | A Verisk Business

AIR
A Verisk Business