Hazard Identification and Risk Assessment for the Province of Ontario

Emergency Management Ontario
Ministry of Community Safety and Correctional Services 2012

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Approved
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Scientific Content Reviewers
- Dr. John Adams (Geological Survey of Canada, Natural Resources Canada)
- Dr. Jan Ayslworth (Geological Survey of Canada, Natural Resources Canada)
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- Dr. Réjean Couture (Geological Survey of Canada, Natural Resources Canada)
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Dear Colleagues:

A revised Ontario Provincial Hazard Identification and Risk Assessment (HIRA) Report, dated September 2011, is attached via an electronic link. This document is founded on a comprehensive study of the hazards that currently and/or historically confronted the Province of Ontario, as well as those that have the potential to occur.

Emergency Management Ontario has prepared this document with the assistance of many key stakeholders and scientific experts. The Ontario Provincial HIRA provides risk assessments for natural, technological, and man-made hazards in accordance with the definition of an emergency within the Emergency Management and Civil Protection Act. This HIRA is a reference document for application at the provincial level; however, the process described herein can be adopted at ministry, municipal, community, or private sector levels.

Thirty-nine hazards are listed in this document and discussed under four main headings: Definition, Description, Provincial Risk Statement, and Case Study. An analysis of the risk of each hazard for the Province is provided at the Risk Analysis section.
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Hazards are interlinked and dynamic, subject to change with unprecedented consequences, and may transcend provincial and national boundaries. Thus the HIRA Report will be updated routinely when new information about hazards that could impact Ontario (i.e. causes, frequency, and potential impact) becomes available. Updates will be widely distributed across Ontario to assist emergency managers when reviewing their HIRA documents.

Questions concerning the content of this Provincial Hazard Identification and Risk Assessment Report may be directed to Patricia Martel, Hazard Identification and Risk Assessment Officer at 416-314-8623 or Patricia.Martel@ontario.ca.

Yours truly,
Allison J. Stuart
Assistant Deputy Minister and Chief

Statement of Authorization

This Provincial Hazard Identification and Risk Assessment is compiled, adopted, and published under the authority of the ADM Chief EMO. The effective date of this document is January 25, 2012.

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Allison J. Stuart  Date
ADM and Chief EMO

Definitions

Acceptable Risk: The level of potential losses that a society or community considers acceptable given existing social, economic, political, cultural, technical and environmental conditions (Glossary of Terms, 2011).

Assessment: The evaluation and interpretation of available information to provide a basis for decision-making (Glossary of Terms, 2011).

Building Code: A set of ordinances or regulations and associated standards intended to control aspects of the design, construction, materials, alteration and occupancy of structures that are necessary to ensure human safety and welfare, including resistance to collapse and damage (Glossary of Terms, 2011).

Business/Financial Impact: The negative economic consequences of the occurrence of a hazard.
Changing Risk: A variable in the HIRA methodology that allows for the inclusion of information on changes in the likelihood and vulnerability of the hazard.

Climate change: “A change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcing, or to persistent anthropogenic changes in the composition of the atmosphere or in land use.” (IPCC, 2007)

Community: A generic term that includes both municipalities and First Nations (Glossary of Terms, 2011).

Comprehensive Emergency Management: It is an all-encompassing risk-based approach to emergency management that includes prevention, mitigation, preparedness, response and recovery measures (Glossary of Terms, 2011).

Consequence: The outcome of an event or situation expressed qualitatively or quantitatively, being a loss, injury or disadvantage (Glossary of Terms, 2011).

Critical Infrastructure (CI): Interdependent, interactive, interconnected networks of institutions, services, systems and processes that meet vital human needs, sustain the economy, protect public safety and security, and maintain continuity of and confidence in government (Glossary of Terms, 2011).

Critical Infrastructure Impact: The negative consequences of the occurrence of a hazard on the interdependent, interactive, interconnected networks of institutions, services, systems and processes that meet vital human needs, sustain the economy, protect public safety and security, and maintain continuity of and confidence in government.

Current Risk: The present level of risk associated with a hazard.

Damage Assessment: An appraisal or determination of the effects of a disaster on people, property, the environment, the economy and/or services (Glossary of Terms, 2011).

Declared Emergency: A signed declaration made in writing by the Head of Council or the Premier of Ontario in accordance with the Emergency Management and Civil Protection Act. This declaration is usually based on a situation or an impending situation that threatens public safety, public health, the environment, critical infrastructure, property, and/or economic stability and exceeds the scope of routine community emergency response (Glossary of Terms, 2011).
Emergency: A situation or an impending situation that constitutes a danger of major proportions that could result in serious harm to persons or substantial damage to property and that is caused by the forces of nature, a disease or other health risk, an accident or an act whether intentional or otherwise (Emergency Management and Civil Protection Act) (Glossary of Terms, 2011).

Emergency Area: A geographic area within which an emergency has occurred or is about to occur, and which has been identified, defined and designated to receive emergency response actions (Glossary of Terms, 2011).

Emergency Management: Organized activities undertaken to prevent, mitigate, prepare for, respond to and recover from actual or potential emergencies (Glossary of Terms, 2011).

Emergency Management Program: A risk-based program consisting of prescribed elements that may include prevention, mitigation, preparedness, response and recovery activities (Glossary of Terms, 2011).

Emergency Plan: A plan developed and maintained to direct an organization’s external and/or internal response to an emergency (Glossary of Terms, 2011).

Environmental Damage: The negative consequences of the occurrence of a hazard on the environment, including the soil, water, air and/or plants and animals.

Frequency: How often a hazard occurs at an intensity that may result in an emergency, disaster or service disruption.

Hazard: A phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage. These may include natural, technological or human-caused incidents or some combination of these (Glossary of Terms, 2011).

Hazard Identification: A structured process for identifying those hazards which exist within a selected area and defining their causes and characteristics (Glossary of Terms, 2011).

Historical Risk: The level of risk associated with a hazard in the past. The level of risk may have been altered by changes in consequence, frequency or prevention, preparedness, mitigation, response or recovery practices.

Human-Caused Hazard: Human-caused hazards are hazards which result from direct human action or inaction, either intentional or unintentional. This includes hazards that arise from problems within organizational structure of a company, government etc.
**Impact:** The negative effect of a hazardous incident on people, property, the environment, the economy and/or services (Glossary of Terms, 2011).

**Incident:** An occurrence or event that requires an emergency response to protect life, property, or the environment (Glossary of Terms, 2011).

**Land Use Planning:** The process undertaken by public authorities to identify, evaluate and decide on different options for the use of land to help mitigate and prevent disasters by discouraging settlements and construction of key installations in hazard-prone areas (Glossary of Terms, 2011).

**Mitigation:** Actions taken to reduce the adverse impacts of an emergency or disaster (Glossary of Terms, 2011).

**Monitor and Review:** The part of the HIRA process in which the HIRA is reviewed and changes in the likelihood and consequences of the hazards is updated.

**Municipality:** “Municipality” means a geographic area whose inhabitants are incorporated (*Municipal Act*) (Glossary of Terms, 2011).

**Natural Hazard:** Natural hazards are those which are caused by forces of nature (sometimes referred to as ‘Acts of God’). Human activity may trigger or worsen the hazard; (for example deforestation may increase the risk of a landslide) but the hazard ultimately is viewed as a force of nature.

**Preparedness:** Actions taken prior to an emergency or disaster to ensure an effective response. These actions include the formulation of emergency response plans, business continuity/continuity of operations plans, training, exercises, and public awareness and education (Glossary of Terms, 2011).

**Prevention:** Actions taken to avoid an emergency or disaster and the associated impacts of a hazard (Glossary of Terms, 2011).

**Property Damage:** The direct negative consequences of the occurrence of a hazard on buildings, structures and other forms of property.

**Psychosocial Impact:** The negative response of community or a subset of the community to a hazard caused by their perception of risk. This includes human responses such as self-evacuation, mass hysteria, hoarding and other potential undesirable responses.

**Recovery:** The process of restoring a stricken community to a pre-disaster level of functioning (Glossary of Terms, 2011).
**Resources:** These are personnel and major items of equipment, supplies, and facilities available or potentially available for assignment to incident operations and for which status is maintained. Resources are described by kind and type and may be used in operational or support capacities (Glossary of Terms, 2011).

**Response:** The provision of emergency services and public assistance or intervention during or immediately after an incident in order to protect people, property, the environment, the economy and/or services (Glossary of Terms, 2011).

**Return Period:** The average time between occurrences of a defined event (AMS, 2000).

**Risk:** The product of the probability of the occurrence of a hazard and its consequences (Glossary of Terms, 2011).

**Risk Analysis:** The process by which hazards are prioritized for emergency management programs at that particular point in time based on their frequency and potential consequences.

**Risk Assessment:** A methodology to determine the nature and extent of risk by analyzing potential hazards and the evaluation of vulnerabilities and consequences (Glossary of Terms, 2011).

**Severity:** The extent of disruption and/or damages associated with a hazard (Glossary of Terms, 2011).

**Site:** A geographical location of an incident (Glossary of Terms, 2011).

**Social Impact:** The direct negative consequences of the occurrence of a hazard on people, such as fatalities, injuries or evacuations.

**Technological Hazard:** Technological hazards are hazards which arise ‘from the manufacture, transportation, and use of such substances as radioactive materials, chemicals, explosives, flammables, modern technology and critical infrastructure’ (HIRA, 2005).

**Threat:** A person, thing or event that has the potential to cause harm or damage (Glossary of Terms, 2011).

**Vulnerability:** The susceptibility of a community, system or asset to the damaging effects of a hazard (Glossary of Terms, 2011)
1.0 Introduction
The core challenge faced by emergency managers is how to prevent, prepare, mitigate, respond and recover from a myriad of hazards. Several questions arise when faced with this challenge:

- What hazards exist in the province?
- How frequently do they occur?
- How severe can their impact be on the community, infrastructure, property, and the environment?
- Which hazards pose the greatest threat to the community?

This Hazard Identification and Risk Assessment (HIRA) document attempts to assist emergency managers in answering these questions in order to better improve public safety and to protect against property and infrastructure damage by providing a tool that can be used to assess the consequences and frequency of a hazard. The purpose of this is to identify which hazards should be the focus of emergency management programs at a particular point in time. A HIRA is intended to be an ongoing process. When hazards are identified as having a high level of risk, emergency management programs should attempt to minimize this risk through prevention, preparedness, mitigation, response and recovery measures. If these measures are successful, then the risk of the hazard will decrease. An ongoing HIRA process will eventually address all of the identified hazards since as the risk of a particular hazard decreases, it will score lower in the next HIRA revision, allowing another set of hazards to be focused on.

A HIRA is a comprehensive document that outlines the hazards and their associated risks in a designated area; for the purposes of this document the designated area is the province of Ontario. It is not intended to be used as a prediction tool to determine which hazard will be the next emergency, since consequence, in addition to frequency, is assessed. It is a risk assessment tool that can be used to assess which hazards pose the greatest risk in terms of how likely they are to occur and how great their potential impact on public safety may be.

There are three reasons why a HIRA is useful to the emergency management profession:

- It helps emergency management professionals prepare for the worst and/or most likely risks.
- Allows for the creation of exercises, training programs, and plans based on the most likely scenarios.
- Saves time by isolating hazards that can not occur in the designated area.

A HIRA is important for emergency management at a Provincial level since residents of Ontario expect the Provincial government to actively monitor and reduce the risk of a potential emergency. Since the Provincial government plays an active role in emergency management, a great deal of expense is incurred through the prevention, mitigation,
Hazard identification and risk assessment for the Province of Ontario. Since a HIRA can assist in highlighting the most likely/worst risks and assist in developing training exercises, it can help to reduce financial costs which can then be redirected towards other emergency management projects.

Ontario has adopted measures to protect the public and their property from emergencies through the work of Emergency Management Ontario and the dedicated and hard-working ministry, municipality, First Nations, and public sector emergency managers. With the creation of the Emergency Management Act, Ontario entered a new phase in its mandatory emergency management programs which focused on a risk-based approach. The first step outlined by the Act to reduce risks is to identify the hazards and assess their associated risks to determine which hazards are most likely to result in an emergency. In order to do this in a successful manner, systematic risk assessments (such as a HIRA) can be used to shift the focus of emergency management programs away from being merely reactive to also being pro-active. The addition of a pro-active approach to emergency management through a stronger focus on prevention, preparedness, mitigation, in addition to response and recovery can result in a more disaster-resilient Province of Ontario.

1.1 Purpose

Emergency management programs in Ontario are required by the Emergency Management and Civil Protection Act to be risk-based. Section 4 of this Act requires that ‘in developing its emergency management program, every municipality shall identify and assess the various hazards and risks to public safety that could give rise to emergencies and identify the facilities and other elements of the infrastructure that are at risk of being affected by emergencies’. 2002, c. 14, s. 4. Section 7 of this Act requires that ‘in developing an emergency management program, every minister of the Crown and every designated agency, board, commission and other branch of government shall identify and assess the various hazards and risks to public safety that could give rise to emergencies and identify the facilities and other elements of the infrastructure for which the minister or agency, board, commission or branch is responsible that are at risk of being affected by emergencies’. 2002, c. 14, s. 7. Hazard identification and risk assessment (HIRA) is a critical part of every emergency management program in Ontario.

The Provincial Hazard Identification and Risk Assessment (HIRA) document is intended to provide guidance on how to conduct a HIRA. Hazard identification and risk assessment is an ongoing, ever evolving process. The purpose of a HIRA is to anticipate future emergency situations and to identify which hazards should be considered a priority at a particular point in time for emergency management programs. It must be remembered that new hazards may emerge or evolve over time and that emergency management tools and processes may alter the hazards’ priority in subsequent revisions.
1.2 Scope

The Ontario Provincial HIRA provides guidance for risk assessment for natural, technological and man-made hazards in accordance with the definition of an emergency in the *Emergency Management and Civil Protection Act*. This document has been generated for use at a Provincial level; however, the process contained within can be adopted at a ministry, municipal or private sector level. The HIRA can provide all levels with guidance on how to undertake their own risk assessments which can lead to consistent assessments and improved information on risk.

The goal of this document is to identify the hazards that have occurred or have the potential to impact the Province of Ontario. It is intended to provide a step by step guide to planning and developing a HIRA using the Provincial HIRA methodology.

1.3 Addressing Hazards through Policy, Programs and the Five Components of Emergency Management

The adoption of a risk management approach in the *Emergency Management Act* shifts the focus to the causes of risk rather than the emergencies that may result from risk. This allows resources to be allocated effectively in order to prevent or minimize losses. The Province is implementing comprehensive emergency management programs (based on the five main components of prevention, mitigation, preparedness, response and recovery) through a progressive comprehensive program standard. This is a significant shift for Ontario, given that the *Emergency Plans Act* spoke only to plans (preparedness) and response. The new *Emergency Management and Civil Protection Act* laid the foundation for a coordinated provincial mitigation strategy.

Ontario has experienced hundreds of significant emergencies and disasters. Some types of emergencies occur annually. During the period 1995-2009, Ontario averaged 21 emergency declarations annually. A trend is also apparent concerning growing Provincial vulnerability to some hazards due to changing factors such as population density, urbanization, technology dependence, as well as threats of sabotage and terrorism. It is significant that in March 2003, the Premier of Ontario declared the first Provincial Emergency under the *Emergency Plans Act* - “A Health Emergency Related to Severe Acute Respiratory Syndrome (SARS)”. The emergency has reinforced the priority of having robust, comprehensive emergency management programs, soundly based on risk. This approach can reduce the impact of future events and speed recovery.

1.4 Structure

The Ontario HIRA document is structured to provide information on the identified hazards and their associated risks in Ontario while providing guidance on how to conduct a risk assessment using the provincial methodology. There are four basic steps in developing and maintaining a HIRA which are displayed in diagram 1.
Diagram 1. The basic steps in developing and maintaining a HIRA.

**Hazard Identification**
This step in the HIRA process aims to identify the hazards that are relevant for the area included in the risk assessment. This requires a systematic review of all hazards and their causes in order to determine whether they may pose a threat to the area. Since there may be different ways in which a hazard may occur and many different types of damages, it is important to learn all of the potential causes and vulnerabilities which may lead to each hazard occurring as an emergency situation. This step may involve the consultation of the scientific community, insurance companies, historical records and government agencies.

**Risk Assessment**
During this step of the HIRA process, the level of risk for each hazard is examined. This may involve the examination of past occurrences, possible scenarios and an examination of the current vulnerability of the society and area to the hazard. The likelihood of the hazard occurring at an intensity that could result in damage, the potential impacts of the hazard on people, property, the environment, business and finance and critical infrastructure should be examined. It is important to be as thorough as possible since the information gathered at this step will be critical in assisting decision makers in identifying which risks will not be considered tolerable.

To determine the past consequences of hazards within the Province of Ontario, credible sources should be used, such as:
1. The Canadian Disaster Database
2. Environment Canada
3. Ontario Hazards
4. The Provincial Emergency Operation Centre Reports
5. The Ontario Fire Marshal
6. Ministry Reports and Information
Risk Analysis
The information collected in the risk assessment step will be examined using the HIRA methodology. The desired outcome of the risk analysis is the identification of which hazards should be considered a priority for emergency management programs at that particular point in time based on their frequency and potential consequences.

Monitor and Review
It is important to remember that a HIRA is an ongoing process and hazards and their associated risks must be monitored and reviewed. A HIRA provides information on which hazards should be considered a priority for emergency management programs at a particular point in time. Changes in hazard frequency or mitigation practices etc. may reduce the risk of a particular hazard in subsequent revisions and refocus efforts on another hazard. Over time with subsequent revisions, as the various hazards are identified as priorities for emergency management programs and actions are taken that alter and minimize their risk, all hazards will eventually be cycled through and examined.

2.0 Hazard Identification
The hazards listed below are those which were identified for Ontario after an extensive historic and scientific literature review. These are hazards which have occurred or may occur within the province and to the degree in which they result in significant damage to people, property, critical infrastructure, the environment or business.

Note: Any list of hazards must be used with caution. A hazard may be a secondary effect of a previous/current hazard. Hazards and risk are not static. New hazards and risks may emerge or unknown hazards which have existed in the past, before there were records, may re-emerge. If a new hazard is identified, it should be added in subsequent revisions.

2.1 Natural Hazards
Natural hazards are those which are caused by forces of nature (sometimes referred to as ‘Acts of God’). Human activity may trigger or worsen the hazard; (for example deforestation may increase the risk of a landslide) but the hazard ultimately is viewed as a force of nature.

- Agricultural and Food Emergency
  - Food Emergency
  - Farm Animal Disease
  - Plant Disease and Pest Infestation
- Drinking Water Emergency
- Drought/Low Water
- Earthquake
- Erosion
- Extreme Temperatures
  - Heat Wave
  - Cold Wave
- Flood
  - Riverine Flooding
2.2 Technological Hazards

Technological hazards are hazards which arise ‘from the manufacture, transportation, and use of such substances as radioactive materials, chemicals, explosives, flammables, modern technology and critical infrastructure’ (HIRA, 2005).

- Building/Structural Collapse
- Critical Infrastructure Failure
- Dam Failure
- Energy Emergency (Supply)
- Explosion/Fire
- Hazardous Materials Incident
  - Fixed Site Incident
  - Transportation Incident
- Human-Made Space Object Crash
- Mine Emergency
- Nuclear Facility Emergency
- Oil/Natural Gas Emergency
- Radiological Emergency
- Transportation Emergency
  - Air
  - Marine
  - Rail
  - Road
2.3 Human-Caused Hazards

Human-caused hazards are hazards which result from direct human action or inaction, either intentional or unintentional. This includes hazards that arise from problems within organizational structure of a company, government etc.

- Civil Disorder
- Cyber Attack*
- Sabotage
- Special Event
- Terrorism/CBRNE
- War and International Emergency

* Hazards that have been added to the list from the 2005 Provincial Hazard Identification and Risk Assessment.

Hazard Narratives Natural Hazards

Natural hazards are those which are caused by forces of nature (sometimes referred to as ‘Acts of God’). Human activity may trigger or worsen the hazard; (for example deforestation may increase the chance of a landslide) but the hazard ultimately is viewed as a force of nature.

Agricultural and Food Emergency

Definitions

**Agricultural and Food Emergencies:** emergencies which result from events affecting either the food or the agricultural sector, or a combination of the two. In the food sector, these may arise through changes in food security, food quality or food safety which threaten the nutritional wellbeing of significant groups of the population. In the agricultural sector, the concern is with events which threaten agricultural production and livelihoods in such a way as to constitute emergencies. Most often, agricultural events which constitute emergencies do so because they are likely to lead to food emergencies through their effect on food security. (UN, 1998)

**Farm Animal Disease:** any deviation of the farm animal body from its normal or healthy state. Infection can spread from animals to animals and from animals to humans (zoonotic) (EMO, 2005).

**Food Contamination:** broadly defined as any situation that involves or could involve food which might pose a high risk to humans (EMO, 2005). The contamination or adulteration of food by physical, chemical or biological agents is invariably the cause of such food emergencies.

**Agricultural Plant Disease:** generally defined as any series of harmful physiological processes caused by irritation of the plant by some invading agent. These invading
agents are typically referred to as plant pathogens, and include viruses, bacteria, fungi and algae.

Pest Infestation: The occurrence of one or more pest species in an area where their numbers and impact are viewed as being at intolerable levels. Pest infestations are classified by the feeding habits of the pest: foliage feeding or root feeding, resulting in significant and widespread damage to agricultural plants.

Description
This emergency can be separated into three categories: food contamination, farm animal disease and agricultural plant disease and crop infestation. Emergencies can also be classified as to the type of hazard they generate, such as human health, food security, limiting production or catastrophic economic disaster.

Farm Animal Disease: Farm animal disease emergencies may occur due to an outbreak of a disease or another animal health-related hazard. The predominant negative impacts related to most foreign animal disease are due to animal movement restrictions and the disruption of market chains. An animal disease may be introduced through living animals, animal products and by-products, people and other species (including insects) and contaminated objects (OMAFRA, 2009). Some examples of animal diseases are foot/hoof and mouth disease; swine influenza/fever and avian influenza.

The degree and type of negative impacts caused by animal disease depends on the type of disease and whether it affects both animals and humans (zoonotic) or just animals alone (OMAFRA, 2009). For some types of disease, such as avian influenza, different subtypes may pose different levels of risk. For example, there are 16 subtypes of avian influenza, most of which only infect birds, however, the H5N1 and H7N1 subtypes have been known to be contagious to humans since it tends to acquire genes from viruses that infect other species. The H5N1 and H7N1 subtypes of avian influenza can lead to severe illness and death in humans.

If the disease is very contagious, then it is likely that it is already incubating in many animal populations (depending on the species and its distribution) by the time it is detected. If the disease is zoonotic and can be transmitted to humans, then a human health issue may arise which could possibly result in injuries and even fatalities. Animal disease has the potential to cause socio-economic damage for an area that relies heavily on the livestock and livestock products industry. Some animal diseases may have a negative environmental impact if they can be transmitted between livestock and wildlife.

An animal disease emergency may result in:
- A loss of confidence in the safety of the food industry and in people not trusting domestic livestock products.
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- Large production losses for livestock products (e.g. meat, milk, wool) which may result in a lack of available products for public consumption.
- The loss of favourable genetic traits and overall genetic variation in livestock.
- Expensive prevention and control measures to prevent or halt the spread of disease.
- Exports may be halted resulting in a major loss of income.
- Maybe harmful to humans in close contact with an infected animal
- May trigger a human health emergency if the disease can be transmitted to humans.
- May cause harm to wildlife populations if they are susceptible to the disease.
- May result in animal welfare issues.

Food Contamination: A food emergency resulting from contamination may occur when food is tainted by a microbial, chemical or physical agent that is harmful to humans, through natural processes, human error (such as unsafe food handling practices), sabotage or through acts of terrorism (“agroterrorism”) with the contaminated food having been released into the market. Agroterrorism can be defined as the deliberate introduction of a chemical or a microbial disease agent, either against livestock, crops or into the food chain, for the purpose of undermining stability and/or generating fear (Florida Department of Agriculture and Consumer Services, 2004). This will be discussed further in the terrorism section.

Food emergencies include:
- Contamination of food, especially if there is the probability of illness or death if the product is consumed.
- Reports of serious allergic reactions
- Food borne disease outbreaks
- Sabotage (or the threat of sabotage) involving food that could lead to injury.
- Natural, man-made or technological hazards that threaten the safety of food.

Food emergencies can be caused by microbial agents, such as:
- Bacteria and their toxins (e.g. E-coli and Botulism)
- Viruses (e.g. Norwalk and Hepatitis A)
- Parasites (e.g. Cryptosporidiosis and Giardia lamblia)
- Prions (e.g. Bovine Spongiform Encephalopathy/Mad Cow Disease)

Food emergencies can be caused by chemical agents, including:
- Antibiotic residues
- Pesticide residues
- Chemicals and metals

Food emergencies can also be caused by physical agents (e.g. glass fragments, needles, metal shards from processing equipment). Generally events relating to physical contamination of food are not widespread, but may pose serious risk to human health and can result in consumer fears and lack of confidence in the food supply. Food contamination by physical means may be the result of processing errors, sabotage or
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**Agricultural Plant Disease and Pest Infestation:**

Plant diseases and pest infestations are routine events that are usually successfully managed. Like animal diseases, plant diseases may result in loss of access to specific markets. However, every so often a disease or infestation becomes widespread and begins to cause severe economic and/or agricultural plant health problems. Invasive species in particular are a growing concern since many native species are susceptible and have not evolved proper defences. Seasonal weather patterns can increase or decrease the risk of plant disease and pest infestation. In particular, extreme temperatures, drought or severe precipitation can influence the number and distribution of diseases and pests. It is important to note that plant diseases and pest infestations can affect both agricultural (e.g. corn, apple trees) and wild (e.g. ash, pine) plant species.

Agricultural plant diseases include:
- Bacterial diseases (e.g. black rot)
- Fungal diseases (e.g. downy mildew)

Potential Pests include:
- The Emerald Ash Borer
- The Asian Longhorn Beetle

**Provincial Risk Statement**

**Farm Animal Disease:** Ontario is home to almost one quarter of the farms in Canada. The Census of Agriculture (2006) states that Ontario has approximately 57,211 farms. In 2001, 34,659 farms were livestock operations. The term ‘livestock’ includes both traditional species such as cattle, hogs, poultry and alternate species including bison, emus, etc. Farming is a billion dollar industry with Ontario’s total gross farm receipts in 2005 reaching $10.3 billion and operating expenses reaching $8.8 billion (Census of Agriculture, 2006).

Whether any social impacts are felt depends on whether the disease is zoonotic and can be transmitted to humans. If it is zoonotic, then it may result in sickness and/or fatalities in some people. The people most at risk of contacting disease are those who work with the afflicted animal species or their products and by-products. It is very unlikely that there would be many fatalities due to the small group of people at risk compared to the general population, unless the disease is able to be transmitted easily from human to human. In this case, it would cease to be classified as an animal disease and would then be classified as a human health emergency. Mental health problems may arise, especially among people whose livelihood is dependant on livestock operations.
Property damage is unlikely to result from animal disease, however, depending on the type of disease, some buildings and structures may not be suitable for use until after decontamination has taken place.

It is important to note that some diseases originate in or can be transmitted to wildlife (e.g. Chronic Wasting Disease, Tuberculosis etc.). This can sicken or kill large percentages of the wild species in the populations affected. Response measures may be more difficult when dealing with a wild population.

A severe outbreak of a serious farm animal disease in Ontario that affects international trade in livestock or farm animal products has the potential to harm not only Ontario’s economy, but also that of Canada as a whole. The agricultural industry is a major contributor to the Canadian economy (EMO, 2005). The demand for Canadian agricultural exports related to those species affected by a disease outbreak would decrease. The Canadian Animal Health Coalition on the Economic Impact of a Potential Outbreak of Foot and Mouth Disease in Canada (2002) has predicted that the Canadian economy could suffer a total net economic loss ranging between $13.7 to $45.9 billion depending on how widespread an outbreak is and how easily it can be contained and controlled. According to this report, even a single case of an animal disease located in Canada may have the potential to stop exports for more than three months (OMAFRA, 2009). Consumer confidence may also be lost and consumers may avoid purchasing products that they believe to be risk. This was seen during the 2009 H1N1 pandemic when pork sales declined in several different countries despite assurances from the World Health Organization and governments that pork was safe.

**Food Contamination:** The social impacts of a food emergency resulting from food contamination vary depending on the type of agent (microbial, chemical or physical) but may include illness (including potential allergic reactions) or possibly even fatalities. The most common symptoms associated with food contamination include (but are not limited to): stomach pain, diarrhoea and vomiting. The symptoms may be different depending on the type of agent. Food shortages are unlikely in Canada since the wealth of the country allows for the importation of food. However, the shortage of a major staple could result in an increase in price and demand for alternative foods.

A food contamination emergency is unlikely to result in property or environmental damage. However, a slight risk does exist depending at what stage of food production contamination occurs at and whether any subsequent harm can be done to wild species.

One of the greatest impacts of a food contamination emergency aside from its potential impact on human health is business/financial interruption. In the case of the contamination of a product that is shipped over a large area and used to make many other products, recalls may be widespread and cover an extensive range of products. These result in a major loss of revenue for the companies affected. Consumer confidence may be lost and people may avoid products and/or brands that are
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unaffected but which they associate with the food contamination. The public can also lose faith in the government and its ability to regulate under such circumstances.

Public perception and fear can also factor into food safety emergencies, and timely, coordinated emergency response is a public expectation. Public awareness and education about the risks associated with food borne illness is a priority, since food borne diseases are generally preventable.

**Agricultural Plant Disease and Pest Infestation:** Ontario has 24% of the agriculture industry in Canada. The most common plant-based farm types in Ontario include grain, oilseed and horticulture. The Ontario Ministry of Agriculture, Food and Rural Affairs monitors agricultural plant disease and pest infestations and has published guidelines for the management of outbreaks. While diversity of plant species can help to lower the risk of a plant disease or pest infestation having a major negative impact on the economy and human health, a greater number of diverse agricultural products also brings new disease detection and control challenges. The introduction of new species, new genetic lineages, increased international trade and travel, can result in the introduction of new diseases and pests (referred to as exotic or invasive species) or an increase in established ones. Invasive species can be introduced to Ontario in many different ways including natural migration, through product packaging and through transportation (cargo containers, baggage, etc.). The speed of travel in particular, has allowed insects and other pests to make trips of greater distances than they would have been able to survive in the past.

Little property damage due to plant disease and pest infestation is likely. However, depending on the type of disease or pest, secondary hazards, such as forest fires may be caused. For example, an infestation of the Asian long horn beetle could result in the death of hundreds of trees in an area which could then provide more fuel for a potential forest fire.

It is important to note that domesticated crops are not the only varieties at risk of plant disease and pest infestations. Wild species of plants remain at risk as well. Widespread outbreaks can result in the damage or death of many plants over a large area. This may affect the quality of the habitat or the amount and/or quality of food for herbivores. An increase in dry, dead plant matter (including trees) may lead to an increase in fires.

A severe outbreak of plant disease or pest infestation could have severe negative economic consequences. Entire crops could be lost and livelihoods destroyed. An outbreak could force the closure of the Ontario market for export to other provinces or countries. Depending on the type and extent of the disease or pest, tourism and other industries may also be affected.

**Case Study - Listeriosis Outbreak 2008 – Food Contamination**

In July 2008, routine surveillance of public health data by the Ontario Ministry of Health and Long-Term Care detected an increase in the number of listeriosis cases being
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reported across Ontario. In August 2008, analyses of these cases indicated a common source for the outbreak. Maple Leaf Consumer Foods was identified as the source of the positive food samples. As the outbreak continued, reports of listeriosis from the same source came in from other provinces where the contaminated foods had also been distributed.

The majority of these cases were either residents of long-term care homes or hospitals. Four confirmed cases were not hospitalized or did not reside in an institution prior to the onset of the illness, and a small number of confirmed cases have information pending. The average age among confirmed cases was 78 years, (the ages of confirmed cases ranged 42 to 98 years) and 68% of confirmed cases were women.

Ontario had 43 cases linked to the outbreak: 41 outbreak confirmed cases, 1 probable and 1 suspect case (samples were unavailable for testing for the suspect and probable cases). The last confirmed case in Ontario had an onset date of September 24, 2008.

A total of 22 deaths occurred among people who had been confirmed to be infected with listeriosis. Of these deaths, 15 were listed as having listeriosis as an underlying or contributing cause while 7 of the deaths were listed as having an undetermined cause. (Ministry of Health and Long-Term Care, 2008)

Drinking Water Emergency

Definition

A widespread and/or severe incident of contamination of drinking water or disruption of supply, that presents a danger to or otherwise negatively impacts the general health and well being of the public.

Description

The quality and quantity of water, which is essential to maintaining good public health can be negatively affected by:

- Natural events (e.g. flooding, emerging pathogens, flu impacting Operators, earthquakes, temperature extremes)
- Technological events (e.g. chemical spill, farming by-products, computer failure, sewage treatment or septic system failure)
- Human-caused events (e.g. sabotage, human error)

Or by a combination of those listed above (e.g. manure from a farm enters the water supply and encourages the growth of bacteria). The key components of a safe drinking water supply include the source, treatment facilities, treated water storage (elevated and in-ground), the distribution system, computer controls and monitoring, operators, and quality monitoring by sampling and analysis.
Waterborne disease or contamination can result in illness and death. Resultant infections may be transmitted to others by secondary means. A large number of residents from the affected area may seek medical attention whether or not they have begun to show symptoms. The influx of people seeking medical attention and treatment has the potential to place significant strain on the public health system. Delays in the onset of symptoms may result in continued exposure as the outbreak remains undetected. Depending on the contaminant, it may take a long time, sometimes months, for the quality to be restored to a safe level.

Many different bacteria can be found in untreated water. Most are harmless to humans; however, some are pathogenic, such as the O157:H7 strain of Escherichia coli (E-coli) which can cause chronic illness or death. Some farming by-products (e.g. manure) and chemicals can encourage the growth of bacteria, algae and other species which can affect water quality. Industrial activity using chemicals or a chemical spill close to a water supply can also result in a decline in water quality. The response measures required depend on the type and amount of chemical. Strict land use zones and practices have been used to avoid or minimize contamination. Ground and lake water is treated before it becomes drinking water in order to remove bacteria and other contaminants.

The type of rock and soil can also influence water quality. The type of soil and rock can also increase the risk of contamination by chemicals or bacteria. Soils and rock with a high porosity (e.g. karst topography) allow more water to seep into the ground and to groundwater at a faster rate. A water quality emergency is usually isolated to the area serviced by the local utility that utilizes the affected water. Natural events or failures in construction may result in fractured distribution piping and resultant contamination of drinking water. Large fires or losses of water may result in water demand exceeding the capacity of reservoirs and treatment systems, necessitating the distribution of untreated water.

**Provincial Risk Statement**

Ontario has abundant water resources. The Province borders on four of the Great Lakes and additionally has more than a quarter of a million lakes and rivers. Ontario also has abundant groundwater supplies.

In Ontario, the Safe Drinking Water Act and the Clean Water Act provide standards for water quality testing and the regulations for drinking water systems and source water protection. Compliance with these acts is mandatory. Drinking water is regularly tested in order to ensure water quality and the operators of drinking water systems are required to be certified and trained.

The population of Ontario, like any other human population, is vulnerable to drinking water emergencies. Waterborne disease or contamination can result in illness and even in multiple fatalities. Common symptoms include gastrointestinal pain, gastrointestinal infection and diarrhoea. A large number of residents from the affected area may seek medical attention whether or not they have begun to show symptoms. The influx of people seeking medical attention and treatment has the potential to place significant strain on the public health system. Delays in the onset of symptoms may result in continued exposure as the outbreak remains undetected. Depending on the contaminant, it may take a long time, sometimes months, for the quality to be restored to a safe level.
medical attention whether or not they have begun to show symptoms which can strain the resources of the local health system. Areas with a high population density that is reliant on one or very few water sources are particularly susceptible. Many remote communities are particularly at risk since the delivery of other sources of water may be time-consuming and expensive.

The property and infrastructure of Ontario is unlikely to be harmed by a drinking water emergency with the exception of the water supply, which due to the nature of this hazard is vulnerable. However, both water treatment plants and distribution systems may require sanitation processes to be completed before they are able to serve the public again.

The environment is somewhat vulnerable to a drinking water emergency. The level of environmental damage depends on where in the system the water quality declined. If the decline occurred in the natural state of the water (e.g. a lake or river) then aquatic organisms and other species that drink from that resource may be harmed.

A significant decrease in drinking water quality or quantity, in particular one that poses a human health hazard could result in a significant economic loss to the affected community including business interruptions, a decline in tourism and investment, reduced property values and compensation payments to victims and their families (EMO, 2005).

A drinking water emergency may result in a loss of public confidence in government standards, regulations, officials and programs.

**Case Study - Walkerton 2000**

In May 2000, Walkerton’s drinking water became contaminated with a deadly strain of Escherichia coli O157:H7 (E-coli) in addition to Campylobacter jejuni bacteria. The bacteria were introduced to the water supply through a well located near a farm. While the farm followed proper practices, the Walkerton Public Utilities Commission operators did not. Subsequent studies have found the outbreak of illness could have been prevented if the operators had followed the standard water quality practices. As a result of the introduction of these bacteria, seven people died and more than 2,300 people became ill. Many suffered long-lasting health impacts. (O’Connor, 2002)

**Drought/Low Water**

**Definition**

While there is no universally accepted definition of drought; the Ministry of Natural Resources (MNR, 2009) defines drought or a period of low water as an extended period of time with one or more of the following:

- Three months or greater with below average precipitation which may be combined with high rates of evaporation.
Description
Droughts/low water conditions have occurred all over the planet for millions of years. They are a naturally occurring phenomenon that can also be triggered or exacerbated by human activities, such as the altering of ecosystems. Their root cause is a decrease in the normal amount of precipitation that the area receives. High air temperatures leading to higher rates of evaporation may increase the severity of the drought. The amount and type of vegetation in the affected area may also contribute to the severity through evapo-transpiration losses.

The first signs of a drought are a decrease in surface and underground water levels and soil moisture. Plants begin to grow slower or die which can lead to the starvation of the animals that rely on them for food.

There are several secondary hazards associated with droughts/low water conditions. Plant disease and pest infestations may become more prevalent. As plants die, erosion may result in the loss of soil nutrients necessary for plant vitality. The loss of plant life leads to a drying of the vegetation which can result in conditions favourable to forest fire (Billing, 2003). Drought/low water is a large scale hazard and may even affect several Provinces at one time.

Provincial Risk Statement
Ontario has experienced drought/low water conditions in the past and is likely to continue to do so in the future. Short periods of dry conditions growing occur at some time
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every year, while longer droughts (over four weeks in duration) occur approximately once every 3 years in Ontario (Brown & Wyllie, 1984).

Drought/low water conditions from mid-1997 through 1999 in southern Ontario concerned municipalities, conservation authorities and the province to the extent that it led the province to develop the Ontario Low Water Response (OLWR) Plan to ensure that Ontario is prepared for low water conditions in the future. The Plan was developed in 1999, implemented in 2000 and revised in 2003. The Ontario Low Water Response was developed by the Province of Ontario in order to assist in the preparation, co-ordination and to support local response to a drought (MNR, 2009). South-western and eastern Ontario experienced an extended period of low rainfall and high temperatures as recently as 2001.

Concern about the future of water resources in Ontario still remains due to the recent drought/low water conditions within the province, coupled with the risk of climate change which may result in an increase in severity and frequency of drought/low water conditions.

A study by Kreutzwiser et al. (2003) on the drought sensitivity of municipal water supply systems in Ontario identified several characteristics that increase the system’s sensitivity to drought. These include:

- Groundwater and river water sources
- Rapid population growth
- Aging water system components
- Poorly maintained water system components
- Limited storage capacity relative to demand
- Lack of demand management measures
- Industrial growth
(Kreutzwiser et al., 2003)

People in Ontario are not particularly vulnerable to drought/low water emergencies. It is extremely rare in developed countries for people to die or be injured by drought. In fact, there were no deaths or fatalities reported in any of the droughts recorded in Ontario. People living in isolated areas and those who rely on wells for water may require assistance.

Property is not especially vulnerable to drought/low water; however, a sudden decrease in groundwater does have the potential to increase the occurrence of land subsidence (sinkholes) in some areas. Hydroelectric production is dependent on the water supply and output may decline during a drought/low water emergency.

Agriculture and the environment are vulnerable to drought/low water emergencies. A shortage of water, especially if combined with high air temperatures can cause vegetation to be stunted or die. Since wildlife has greater mobility, which can assist in
Helping them find sources of water, they are less likely to be affected as severely as plants during a drought. However, if the drought is particularly long or severe, then wildlife may suffer as well. Irrigation practices have lessened the impact of drought on agriculture and livestock. However, as with wildlife, if the drought is particularly long or severe, they too may suffer losses. The loss of soil moisture and plant life can lead to soil erosion causing further damage.

Industries which rely on large volumes of water for production, such as manufacturing, may also suffer during periods of drought/low water. They may be forced to decrease their production or find other methods of production that are less dependent on water. This could have significant economic repercussions for a company.

**Case Study - Southwestern and Eastern Ontario Drought 2001**

In the middle of the growing season, parts of southwestern and eastern Ontario experienced their driest eight weeks on record. Crops were severely damaged. Some areas received less than 15% of their normal rainfall during the 54 days. Over a stretch of 82 days, several communities in southern Ontario had no significant rainfall. During the same period, some localities had 21 days with temperatures above 30°C. Summer rains were spotty. The Ottawa River came within 11 cm of its lowest level in 50 years on August 14.

(Environment Canada, 2010)

**Earthquake**

**Definition**

‘An earthquake occurs when slip along a fault in the earth. Energy is released during an earthquake in several forms, including as movement along the fault, as heat, and as seismic waves that radiate out from the “source” in all directions and cause the ground to shake, sometimes hundreds of kilometers away’ (Natural Resources Canada, 2009).

**Description**

Earthquakes can occur anywhere but are most common on active fault lines found at tectonic plate boundaries (Natural Resources Canada, 2009). Earthquakes are caused by the movement and deformation of the tectonic plates caused by the heating and cooling of rock underneath them. Every so often, the stress on the rocks accumulates until it is suddenly released in a rapid burst of movement: an earthquake.

Earthquakes have also been recorded by seismic instruments (and occasionally felt by people) in areas that are nowhere near plate boundaries. These earthquakes are referred to as ‘intraplate earthquakes’. There are several theories on what causes these earthquakes, including that they occur along ancient fault lines or that they are caused in part by postglacial uplift, but their cause is not fully understood. Movement is usually an extremely slow process with the rates of plate movements between 2 to 12 centimetres per year at tectonic plate boundaries (Natural Resources Canada, 2009) and is even slower in intraplate earthquake zones with deformation occurring at a rate of only a few mm/year (Stein and Mazzotti, 2007). This results in fewer earthquakes and
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makes their frequency and potential consequence difficult to estimate. While intraplate earthquakes are much rarer than plate boundary earthquakes, ones of the same consequences in continental shields can cause stronger shaking at greater distances from the epicentre (the origin point of the earthquake) than plate boundary earthquakes. This occurs primarily because the crystalline rock common to these shield regions transmits stronger shaking over greater distances. Earthquakes in intraplate areas such as the New Madrid seismic zone in the United States are 30-100 times less frequent than those in California due to the rate of movement and deformation.

Although most earthquakes are natural, human activities have caused small earthquakes. These include mining activities (including underground collapses and rockbursts), oil recovery and the filling of reservoirs behind large dams. Underground nuclear explosions are also known to have caused minor earthquakes near the test site (Natural Resources Canada, 2009).

Earthquakes are measured by their consequence, ‘a measure of the amount of energy released during an earthquake’ (Natural Resources Canada, 2009). While the first magnitude scale was the Richter scale, today there are several different regional magnitude scales, of which the most universal today is the moment magnitude scale, which assesses the amount of energy released by an earthquake. This scale is logarithmic which means that a magnitude six earthquake releases approximately 30 times more energy than a magnitude five earthquake but is 900 times greater than an earthquake of magnitude four. According to Natural Resources Canada (2009), a magnitude of five is generally viewed as the threshold for damage to occur.

The shaking produced by an earthquake at a given site is measured by the intensity, which describes its impact on natural features, buildings and people (Natural Resources Canada, 2009). The Modified Mercalli intensity scale ranges from one (the earthquake is recorded by instruments but is not felt by people) to twelve (total destruction of buildings).

The amount and type of damage depends on the magnitude of the earthquake, the distance from the earthquake epicenter (the origin point of the earthquake), the depth of the earthquake, the frequency of the ground motion, the kind of faulting and the soil and rock type of an area (Natural Resources Canada, 2009).

<table>
<thead>
<tr>
<th>Richter magnitudes</th>
<th>Earthquake effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 2.0</td>
<td>Not felt.</td>
</tr>
<tr>
<td>2.0-2.9</td>
<td>Not felt by people, but recorded by seismographs.</td>
</tr>
<tr>
<td>3.0-3.9</td>
<td>Usually felt by humans, but rarely causes damage.</td>
</tr>
<tr>
<td>4.0-4.9</td>
<td>Noticeable visible shaking of indoor items such as windows, hanging objects etc, rattling noises.</td>
</tr>
<tr>
<td>Richter Scale</td>
<td>Property Damage</td>
</tr>
<tr>
<td>---------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>5.0-5.9</td>
<td>Poorly constructed buildings may be severely damaged. At most slight damage to well-designed buildings. Dishes may fall and break; plaster and bricks may crack and fall.</td>
</tr>
<tr>
<td>6.0-6.9</td>
<td>Can cause damage in areas up to about 160 kilometres across in populated areas. Chimneys collapse, houses moved from their foundations.</td>
</tr>
<tr>
<td>7.0-7.9</td>
<td>Can cause severe damage over greater distances. Buildings collapse, bridges twist.</td>
</tr>
<tr>
<td>8.0-8.9</td>
<td>Can cause serious damage in areas several hundred miles across. Objects thrown into the air.</td>
</tr>
<tr>
<td>9.0-9.9+</td>
<td>Devastating in areas several thousand miles across.</td>
</tr>
</tbody>
</table>

Table 1. The Richter Scale and Property Damage. Based on information from Natural Resources Canada (2009) and the USGS (2009).
<table>
<thead>
<tr>
<th>Scale</th>
<th>Shaking and Damage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Shaking not felt, no damage</td>
<td>Not felt except by a very few under especially favourable conditions.</td>
</tr>
<tr>
<td>II</td>
<td>Shaking weak, no damage</td>
<td>Felt only by a few persons at rest, especially on upper floors of buildings.</td>
</tr>
<tr>
<td>III</td>
<td>Shaking felt, no damage</td>
<td>Felt noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motorcars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.</td>
</tr>
<tr>
<td>IV</td>
<td>Shaking light, no damage</td>
<td>Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.</td>
</tr>
<tr>
<td>V</td>
<td>Shaking moderate, very light damage</td>
<td>Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.</td>
</tr>
<tr>
<td>VI</td>
<td>Shaking strong, light damage</td>
<td>Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.</td>
</tr>
<tr>
<td>VII</td>
<td>Shaking very strong, moderate damage</td>
<td>Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.</td>
</tr>
<tr>
<td>VIII</td>
<td>Shaking severe, moderate to heavy damage</td>
<td>Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.</td>
</tr>
<tr>
<td>IX</td>
<td>Shaking violent, heavy damage</td>
<td>Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.</td>
</tr>
<tr>
<td>X</td>
<td>Shaking extreme, very heavy damage</td>
<td>Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.</td>
</tr>
<tr>
<td>XI</td>
<td>Shaking extreme, near total damage</td>
<td>Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.</td>
</tr>
<tr>
<td>XII</td>
<td>Damage total</td>
<td>Lines of sight and level are distorted. Objects thrown</td>
</tr>
</tbody>
</table>
Table 2. The Modified Mercalli Intensity Scale (Natural Resources Canada, 2010)

Provincial Risk Statement
Despite being located far from tectonic plate boundaries, where the rate of activity is significantly lower than near a plate boundary, Ontario has experienced earthquakes in the past and will continue to do so in the future. Ontario exists in a zone known for intraplate earthquakes. Large intraplate earthquakes have occurred before in Ontario. Three of the largest recorded occurred within 350 km of Ottawa; the M5.8 Montreal earthquake (1732), M6.2 Temiscaming earthquake (1935) and the M5.8 Cornwall-Massena earthquake (1944). Studies that examine earthquakes that occurred before recorded history have shown that even larger earthquakes likely occurred. It is believed that two large earthquakes with an estimated magnitude of 7 occurred approximately 4,550 and 7,060 years ago and triggered massive landslides in the Ottawa Valley (Ploeger et. al, 2009). While no damaging earthquakes have occurred since 1944, scientific studies have suggested that large earthquakes (M 7) may occur in the future (Ploeger et. al, 2009). However, additional studies have suggested that recurrence times between large earthquakes may be hundreds to thousands of years.

The majority of the earthquake activity in Ontario is in eastern Ontario. A study done by Halchuk and Adams (2004) examined the earthquake risk for select cities across Canada, including Ottawa, Toronto, Niagara Falls and Windsor. Ottawa was found to face a risk from both nearby and faraway earthquakes, and that nearby events were dominated by moderate and large earthquakes. Toronto was found to face a risk from nearby earthquakes as well as a particular hazard from large, distant earthquakes. The earthquake risk for Niagara Falls was dominated by nearby earthquakes although distant earthquakes still pose a risk. Windsor was found to face a risk from local moderate earthquakes from the underlying Southern Great Lakes zone (Halchuk and Adams, 2004).
"The damage potential of an earthquake is determined by how the ground moves and how the buildings within the affected region are constructed. Expected ground motion can be calculated on the basis of probability, and the expected ground motions are referred to as seismic hazard. The seismic hazard map layer indicates the relative seismic hazard across Canada. The map is a simplification of the National Building Code of Canada seismic hazard map for spectral acceleration at a 0.2 second period (5 cycles per second), and shows the ground motions that might damage one- to two-storey buildings. The probability of strong shaking (strong enough to cause significant damage in a fraction of these buildings) is more than 30 times greater in the regions of highest hazard (at least a 30 per cent chance of significant damage within towns of these regions every 50 years) than in the regions of lowest hazard (less than 1 per cent chance in 50 years). In the region of moderate hazard, there is a 5 to 15 per cent chance that significant damage will occur every 50 years." (Onur, Seemann, Halchuk and Adams, 2005).

Earthquake risk is not uniform throughout the country and is not uniform even with the province. According to Stephen Halchuk and John Adams (Natural Resources Canada, 2010), the simplified seismic hazard map for Ontario shows that the probability of strong shaking is very low (less than 1% chance of it occurring in 50 years) for the northern and western part of Ontario. The probability of strong shaking in southern Ontario is slightly higher, but the highest probability is in eastern Ontario where it is estimated that there is a 5-15% chance that significant damage would occur to a fraction.
of one- to two- storey buildings in a town during a 50 year time period (Halchuck and Adams, 2010). As pointed out by Halchuk and Adams, the above estimates are fairly crude, due to the nature and frequency of this hazard, and refer to damage in a single town.

Figure 2. The simplified seismic hazard map for Ontario on the same hazard scale as the above map. Natural Resources Canada (2005).

In general, earthquakes in Eastern Canada (including Ontario) are fairly small. There are approximately 300 earthquakes recorded a year in Eastern Canada but in a typical year only about four will exceed magnitude four. Based on past records, only about three earthquakes a decade will be greater than magnitude five (EMO, 2005). The strongest shaking from earthquakes in the past 250 years in Ontario ranged from intensity VII (1935 earthquake) to VIII (1944 earthquake). These earthquakes caused structural damage to stone walls and chimneys. The more common earthquakes with a magnitude between three and four which occur once or twice a year in Ontario give rise to shaking with intensity less than III. Earthquakes with this intensity can cause hanging objects to swing and can be felt indoors. The movement may feel stronger by people who are on upper floors (EMO, 2005).

Earthquakes are a large scale hazard. A strong earthquake can be felt by bordering provinces and countries. Hence Ontario could experience significant shaking from a large earthquake in the St. Lawrence valley seismic zone. Such intraplate activity can produce earthquakes almost as powerful as plate boundaries, but at a lower frequency of occurrence (Stein and Mazzotti, 2007). For example, intraplate activity caused the New Madrid earthquakes between 1811 to 1812 in the United States. This series of five
Earthquakes had estimated magnitudes of approximately 7 to 8 on the Richter scale (USGS, 2009). The shaking from these earthquakes was felt over a very large area which was two or three times larger than the 1964 Alaska earthquake, the largest earthquake in North America in recorded history. It is believed that these earthquakes would have resulted in considerably more fatalities and injuries if the area had been more populated at the time (USGS, 2009). It is unknown whether an earthquake of such magnitude could occur in Ontario. However, even if so, the return period between such events would be thousands, if not tens of thousands, of years.

There are three seismic zones in Ontario where scientific instruments such as seismographs have recorded clusters of earthquakes (EMO, 2005). These zones are referred to as the Western Quebec, Southern Great Lakes and North-eastern Ontario Seismic Zones:

**The Western Quebec Seismic Zone**
The Western Quebec Zone includes the Ottawa Valley from Montreal to Temiscaming. This large zone also includes the Laurentians and Eastern Ontario. Large urban centres located in this zone include Montreal, Ottawa-Hull and Cornwall. Two large earthquakes with magnitudes greater than five occurred here in 1935 and 1944 (HIRA, 2005).

**Southern Great Lakes**
This zone is classified as having a low to moderate level of seismicity compared with the more active zones to the east, along the Ottawa River and in western Quebec. On average, only two or three earthquakes with a magnitude greater than 2.5 are recorded annually. Only three magnitude five earthquakes have occurred in the past 250 years in 1929, 1986 and 1998. All of these have had epicentres across the border but were widely felt in Ontario (Natural Resources Canada, 2009).

**North-eastern Ontario**
Northern Ontario has historically experienced a very low level of seismic activity. This area has averaged only one or two earthquakes per year with a magnitude greater than 2.5. In 1905 and 1928 this zone experienced earthquakes each with a magnitude of five. Several studies have identified the Ottawa area as having the highest risk of an earthquake in Ontario. Although this area may have the highest risk within Ontario, it is classified as having a moderate risk compared to other parts of Canada. Since this is a heavily developed area a significant earthquake close to this area has the potential to cause considerable damage.

Several scientific studies such as Ploeger et. al (2007) has noted that intraplate earthquakes are felt over a larger area than plate boundary earthquakes of the same magnitude. This is likely due to the relatively stable and un-fractured crust in the continental interior and the presence of soft and deep sediments in some areas. Soft and deep sediments can amplify seismic waves and this effect has resulted in areas of greater historical losses in eastern Canada.
Potential Impacts
While strong earthquakes are very rare in Ontario and a significant earthquake has never occurred in Ontario based on the historic record, the people and property/infrastructure of Ontario would be very vulnerable to this hazard. A powerful earthquake could cause buildings and structures such as bridges to collapse, trapping people in the debris. People can also be killed or injured by falling debris such as glass, chimneys, book cases and roof tiles. Further fatalities and injuries may occur during aftershocks if buildings compromised by the original earthquake are re-entered. Fires caused by ruptured gas mains etc, may also pose a risk.

Poorly constructed buildings and building with high, unsupported roofs are more likely to be damaged during an earthquake. Unanchored building materials and contents will further increase the amount of damage. The type of soil and rock the building is located can also influence the amount of damage. Buildings on a thick layer of loose sand, silty clays; soft and saturated granular soils; sand and gravel may experience more damage than a building built on deep, unbroken bedrock and stiff soils (Natural Resources Canada, 2009). The movement from an earthquake can alter the soil characteristics from solid to liquid which can make the ground suddenly unable to support a building’s foundation. This may result in the cracking or collapse of a building (Natural Resources Canada, 2009).

The National Building Code of Canada has been revised to include a 2,475 year return period (an earthquake with a 2% chance of exceedance in 50 years) for earthquakes (Atkinson, 2007). This is applied to the design of new buildings and the evaluation of existing buildings. Due to the infrequent nature of this hazard and that the lifespan of a building is approximately 50 years, a scientific examination of the revised building code concluded that this adjustment is perhaps redundant from an economic and engineering perspective; but that it is certainly sufficient from a public safety perspective (Searer et. al, 2007). Therefore, the outcome of a large earthquake in Ontario is not likely to be even remotely as severe as the outcome of the 2010 Haitian earthquake.

Other damage can include the complete or partial destruction of rail lines, highways and bridges. Falling debris may block roads. Telecommunications structures may suffer damage. Electricity, gas lines and water mains may rupture resulting in outages. As noted in past earthquakes, environmental damage is usually noticeable only after a particularly strong earthquake. Powerful earthquakes have caused landslides, altered waterways (in terms of direction of flow, volume and debris), caused land subsidence, created ruptures and fissures etc.

An earthquake that is powerful enough to result in a declared emergency is likely to disrupt business and financial activities. Stores and offices would have their goods and fixtures in disarray, some of which would require repair. Buildings may need to be inspected to ensure that they are safe before customers and workers can enter. The
secondary hazards of an earthquake including power outages, water main breaks, gas being shut off etc. would all hinder business activities.

Fear and panic are possible after a large earthquake; since the earthquake is usually followed by aftershocks and since earthquakes are very infrequent in Ontario.

**International Case Study - New Madrid Intraplate Earthquakes**

The New Madrid earthquakes of 1811-1812 were a series of three very large earthquakes in the New Madrid region of the United States. Due to the large area of damage (600,000 square kilometers), the widespread area of perceptibility (5,000,000 square kilometers), and the physiographic changes that occurred, these earthquakes are ranked among the largest in the history of the United States since its settlement by Europeans. They were by far the largest east of the Rocky Mountains in the U.S. and Canada. Because there were no seismographs in North America at that time, and very few people in the New Madrid region, the estimated magnitudes of these earthquakes vary considerably.

The first earthquake, ~M7.7, occurred at about 2:15 am in northeast Arkansas on December 16, 1811. The second shock, ~M7.5, occurred in Missouri on January 23, 1812, and the third, ~M7.7, on February 7, 1812, in Missouri and Tennessee. The ground shaking was not limited to these main shocks; there is evidence of many strong aftershocks.

The earthquakes caused the ground to rise and fall - bending trees until their branches intertwined and opening deep cracks in the ground. Landslides occurred along the steep bluffs and hillsides; large areas of land were uplifted permanently; and still larger areas sank and were covered with water. Huge waves on the Mississippi River overwhelmed boats and washed others onto the shore. High banks caved and collapsed into the river; sand bars and points of islands gave way; whole islands disappeared. Only one life was lost due to collapsing buildings, but chimneys were toppled and log cabins were thrown down as far as Cincinnati, Ohio, St. Louis, Missouri, and in many places in Kentucky, Missouri, and Tennessee. Little damage to man-made structures was caused by these earthquakes mainly because of the sparse population in the area.

(United States Geological Survey, 2010)
Erosion

Definition
“The wearing away and removal of soil particles by running water, waves, currents, moving, ice or wind…” (Maine, The Hazards We Face, p. 17, 2001).

Description
Erosion is an ongoing natural process and is only considered to be a hazard when it threatens humans, property or the environment (MNR, 2010). Erosion can be caused or exacerbated by natural or human processes. Locations with little vegetation are more susceptible to erosion by wind, water and other processes. Erosion can result in instability of structures built on eroding soil, soil and nutrient loss, decreased crop yields, damage to aquatic ecosystems and dust storms.

Natural Causes of Erosion:
- Heavy and/or prolonged rainfall
- The effect of gravity on soils that rest on steep slopes
- Wind
- Flooding, wave action and/or currents.
- Movement of glaciers
- Droughts, dry spells and/or high temperature

Human Causes of Erosion
- The overgrazing of hoofed livestock
- Removal of vegetation
- Construction
- Poor agricultural practices

Erosion is a natural, ongoing process for shorelines and occurs at all water levels, although it is more apparent during periods of high water levels. When the water levels are high, the wave energy directly impacts bluffs and dunes, leading to visible erosion of the shoreline. However, during low water levels, the energy impacts the lake bed resulting in the ongoing deepening of the shoreline called down-cutting (Baird and Associates, 2005).

Some soils have slower rates of erosion than others due to their physical characteristics. Soils that have faster rates of water infiltration, good structure and high amounts of organic material such as sand, sandy loam, and loam textured soils take longer to erode than other types (OMAFRA, 2003). Erosion is in most cases, a small scale hazard. It naturally occurs in all landscapes, but only in isolated instances does it become a hazard.

Provincial Risk Statement
Erosion is a natural occurrence that has been altering the shorelines of the Great Lakes since they were formed 12,000 years ago. Erosion of soil is of particular concern for agricultural and beach properties in Ontario but rarely occurs at a scale or during a time...
period that would result in emergency management concerns. This is in part due to the Provincial Policy Statement, under the Planning Act. The Provincial Policy Statement obligates decision makers to restrict development in areas that are prone to erosion (MNR, 2010). Despite this, millions of dollars a year are spent by private landowners in order to prevent and mitigate erosion hazards threatening their property (MNR, 2010).

Much of the shoreline property around the Great Lakes is privately owned.

The areas of Ontario that are at greatest risk of erosion are:

- **River and Valley Slopes** – these areas have a higher risk due to fluvial processes (rivers, streams, precipitation etc).
- **Shorelines** – Shoreline property and natural features such as dunes are at risk from erosion by waves, currents, ice, and fluctuations in water levels.
- **The dynamic beach hazard limit** - the combined flooding hazard limit, plus, the dynamic beach allowance of 30 m on the Great Lakes - St. Laurence River system (or 15 m on large inland lakes).
- **Deforested areas and areas prone to forest fires** - The loss of vegetation affects the amount of surface water run off. Vegetation not only slows erosion by up taking water, but it also anchors the soil in place.
- **Agricultural lands** – The exposure of the topsoil, the building of ditches, livestock grazing, tilling and land management practices all directly impact the rate of soil erosion.

Vulnerability of the human population of Ontario to erosion hazard is nominal. Erosion is usually a slow process rather than a rapid one, so it is unlikely to cause injuries or fatalities. However, embankments and slopes may be weakened through erosion and may be more likely to fail which may present a hazard to anyone walking on them at the time.

Erosion occasionally can result in property and infrastructure damage. The Provincial Policy Statement minimizes the number of occurrence of damage due to erosion; however it still poses an isolated threat to property and infrastructure in at risk areas, such as along shorelines and in deforested areas. The damaged area is normally fairly localized and may only affect one property at a time. While severe erosion could lead to the collapse of a building, in reality, most property owners use mitigation practices to protect their land (Baird and Associates, 2005).

The loss of soil from farmland may be reflected in reduced crop production potential, lower surface water quality and damaged drainage networks. Erosion can alter natural landscapes and ecosystems through the removal of soil and nutrients which can negatively affect plants and animals. The increased sediment in rivers, streams or lakes can negatively affect aquatic ecosystems by affecting the oxygen and nutrient levels and the visibility.
International Case Study - Dust Bowl 1930 – 1936

The Dust Bowl refers to a period from 1930 – 1936 of severe dust storms that resulted in severe agricultural and economic damage. The dust storms were caused by severe drought conditions and erosion which resulted in the soil being easily picked up by wind and blown away. These conditions affected 400 000 km² with the worst affected areas being Texas and Oklahoma, and parts of New Mexico, Colorado, and Kansas.

The loss of soil greatly impacted agriculture and forced hundreds of thousands of people to leave their homes and seek work elsewhere. (Environment Canada, 2010)

Extreme Temperatures

Definitions

Heat Wave: “Environment Canada (1996) provides a...definition of a heat wave as a period of more than three consecutive days of maximum temperatures at or above 32 °C. However, adverse heat impacts on humans have been noted at less extreme temperatures and shorter duration” (Smoyer-Tomic, Kuhn, Hudson, 2003).

Cold Wave: “Environment Canada issues Cold Wave Warnings for Ontario based upon temperature thresholds that vary by geographic location. The warnings are issued when temperatures are expected to fall within 24 hours from above normal or seasonal temperatures to very cold temperatures. The warnings are issued in South central and south-western Ontario, when minimum temperatures are expected to fall to -20°C or less with maximum temperatures not expected to rise above -10°C. For the rest of Ontario, they are issued when minimum temperatures are expected to fall to -30°C or less with maximum temperatures not expected to rise above -20°C (Environment Canada, 2005).

Description

Heat waves and cold waves are caused by the variability of surface meteorological variables, including air temperature and extreme temperature events, is primarily governed by atmospheric circulation. The impacts of heat and cold waves depend on how adapted communities are to extreme temperatures. Several other factors that affect the impact of heat and cold waves are: the frequency of occurrence, their severity and how long they last.

For heat waves, humidity and the nightly minimum temperatures can also influence the severity of impact. Heat waves are often accompanied by high humidity. This can make the temperature feel hotter than it actually is and since it results in a decreased ability for the human body to cool itself, it can led to an increase in human health problems. The nightly minimum temperatures during a heat wave can influence the impact as well. Since temperatures cool over night, this can provide relief from the heat. If the nightly minimum temperatures remain high, this can result in a greater impact.
Secondary Hazard - Poor Air Quality

Air contains a number of different pollutants which vary in concentration depending on the location. Some of these pollutants, in particular, what is referred to as ‘smog’ (ground-level ozone) is created when some of these pollutants undergo a complex set of photochemical reactions in the presence of sunlight. Conditions that increase the amount of smog include: large volumes of traffic, sunshine, calm winds and high temperatures. Temperature controls the length of time it takes for smog to form. Therefore, the higher the temperature, the faster the smog can form. Large volumes of traffic emit the chemicals needed to produce smog. Calm winds can prevent the smog from dispersing.

Since heat waves are periods with high temperatures that are often associated with sunny skies and calm winds, air quality can be much poorer than area during a heat wave. Poor air quality can cause or contribute to health problems in people and animals harm the environment and decrease visibility.

The impacts of a cold wave can be increased with the presence of a high wind-chill value. Wind-chill, which worsens the health impacts of a cold wave by increasing the rate of heat loss, is defined by Environment Canada as “how the combined effect of wind and temperature would feel on your face if you were walking at a normal pace (4.8 km/h)”. Cold waves can occur for long periods of time compared with heat waves.

Provincial Risk Statement

Heat waves and cold waves occur annually in Ontario. The majority of heat waves occur in Southern Ontario. Some areas of Southern Ontario experience 5-15 hot days per year. In fact, the city with the greatest number of extreme heat events in Canada is the City of Toronto with approximately four heat events per year (Smoyer-Tomic, Kuhn, Hudson, 2003). The opposite spatial distribution is seen for cold waves, with the majority of cold days occurring in Northern Ontario with fewer in the south. Most areas of Southern Ontario experience less than 10 cold days a year, while areas of Central Ontario can experience more than 20 cold days a year. Extreme Northern Ontario can experience over 100 cold days a year although it is virtually uninhabited. It should also be noted that due to the size of Ontario covers the average daily temperatures may differ by as much as 20 Celsius degrees (Environment Canada, 2009).
While some parts of the province are more susceptible to extreme temperatures than others, extreme temperatures are caused by large scale weather patterns and have the potential to impact the entire province.
As seen in Figure 3a, the area of Ontario with the highest average of days per year with maximum temperature $>30^\circ$C is Southern Ontario which also has the greatest population density with 12,100,000 of the province’s 13,069,200 people. This area also includes major urban centres such as Ottawa and Toronto. Urban centres have been found to have higher temperatures due to the ‘heat island effect’ in which the concrete and buildings retain heat and release it slow than surrounding areas.

Scientific studies have recorded an increase in the number of fatalities associated with heat waves, particularly in Southern Ontario and Quebec (Smoyer et al., 2000). The Toronto Heat-Health Alert System relates a ‘heat emergency’ to a greater than 90% chance of increased rates of mortality. A study done by Kalkstein and Smoyer (1993) found a significant increase in mortality rates for temperatures above 33$^\circ$C in Toronto. Heat waves during the early summer have been linked to an even higher mortality rate than those that occur later when people have adapted more to the heat. The elderly and the infirmed are especially at risk from extreme temperatures as their bodies may not be able to regulate temperature as well as they used to and they may have difficulty taking measures to decrease their exposure. According to Statistics Canada (2006), 13.8% of the population of Ontario was over the age of 65. It has been estimated that this percentage will double within four decades.

As seen in Figure 3b, the area of Ontario with the highest average of days per year with minimum temperatures $<-20^\circ$C is in Northern Ontario which is significantly less populated than Southern Ontario. Populations in this region are more isolated but are often more self-sustaining for a longer period of time due to their isolation. A cold wave that hits an area where the population is not as accustomed to cold temperatures and less self-sustaining may be more negatively affected.

Heat waves generally do not result in as much property damage as many of the other identified hazards. Damage can be caused by the thermal expansion of materials and is a fairly rare occurrence in Ontario. Damage is more likely in urban areas due to the amount of critical infrastructure including roads and bridges within the area and due to the demands that a large population may place on a utility service. Smaller communities with fewer utility resources may also be more prone to utility outages.

Buildings and other structures such as bridges can experience moisture loss in concrete during a heat wave, particularly when it occurs along with low relative humidity which can result in cracking. Extreme heat can also alter road surface conditions by increasing the rutting of paved roads and causing ‘bleeding’ of asphalt which could contribute to traffic accidents. Railway infrastructure can also be damaged by high air temperatures. Heat can result in the expansion or buckling of tracks which can delay trains or in extreme cases led to a train derailment.

Utilities, in particular electricity and water are susceptible to damage from extreme heat events. The demand for electricity and water increases during periods with high
temperatures and may exceed the supply. Rolling blackouts and restrictions on water usage may be implemented. Electrical infrastructure can be affected. The efficiency of transmission lines decreases due to high air temperatures and power lines may expand which can make them more susceptible to damage.

Cold waves generally do not result in as much property damage as many of the other identified hazards. Damage can be caused by the thermal contraction of materials and is a fairly rare occurrence in Ontario. Damage is more likely in urban areas due to the concentration of critical infrastructure including roads and bridges within the area and due to the demands that a large population may place on a utility service. Smaller communities with fewer utility resources may also be more prone to utility outages.

Like during a heat wave, the demand for electricity often increases during a cold wave. The demand for heating and lighting purposes may exceed the supply resulting in blackouts. If pipes and water mains are not properly insulated, the water may freeze and expand causing the pipes to burst. As the ice melts, this can cause flooding in homes. Some metals and materials become brittle and are more prone to failure during exposure to extreme cold temperatures. Fires may occur as a secondary hazard as people may resort to unsafe heating methods. Cold, denser air has a higher oxygen content which can increase the intensity of a fire. If water mains have frozen and/or ruptured, response may be hindered.

The Ontario environment is not particularly vulnerable to extreme temperatures. The majority of native plants and animals in Ontario have adapted to occasional heat waves and the environmental damage caused by a heat wave is often minimal. However, prolonged, higher than usual temperatures, especially when coupled with high humidity may result in heat stress in animals and plants, especially those that have been introduced to Ontario, including many agricultural plants. High temperatures can negatively affect animal activity, nutritional intake, reproduction and mortality. Plants, including agricultural crops may also suffer damage. A decrease in soil moisture availability can result in root damage which hinders the uptake of nutrients vital for the plant’s growth and survival. For some crops, a heat wave during the growing season may result in a decrease in the crop yield and grain quality.

While aquatic ecosystems are less likely to suffer negative impacts from a heat wave, a prolonged heat wave may result in some damage. High water temperatures have less dissolved oxygen which is necessary for the survival of marine organisms such as fish. Low oxygen levels and high water temperatures can also trigger increased nutrient pollution resulting in algal blooms.

The general negative effects of cold waves on animals are similar to those of a heat wave; decreased animal activity, nutritional uptake, reproduction and mortality. Greater quantities of food may be needed as animals burn more calories from reactions to the cold, such as shivering. A cold wave that occurs before crops have been harvested can
result in damage to fruit and other plants. A prolonged, extreme cold wave can result in rivers and lakes completely freezing which could kill marine life.

Ontario’s business and finances are slightly vulnerable to interruption from extreme temperatures. Any business/financial interruption is likely to be minimal, or related to secondary hazards rather than directly to the heat or cold wave. Agriculture and tourism are the industries that are most likely to be negatively impacted by a heat wave. The impact of a heat wave on agriculture depends on the availability of water. A prolonged, extreme cold wave can result in rivers and lakes completely freezing which may disrupt shipping. Agriculture may be negatively affected depending on the time of year in which the cold wave occurs.

**Case Study - Heat Wave 1988**

In 1988, a heat wave which lasted from July 5 – 11 affected Central and Southern Ontario and the Prairie provinces. Six afternoon highs of greater than 35°C were recorded. Toronto experienced its hottest day on record since 1953 with a high of 37.2°C. Air quality greatly decreased while water and electricity usage soared. Fourteen elderly people died in Ontario due to heat related factors. Environmental impacts were also noted. The water levels of the Great Lakes were recorded as being the lowest in more than a decade. (Canadian Disaster Database, 2005)

**Case Study - Cold Wave 1989 – 1990**

Provinces from British Columbia to Ontario experienced a cold wave from December 1989 to January 1990. In many areas, cold temperatures were combined with snow, ice and high winds which resulted in a power outage for approximately 60,000 houses in southwestern British Columbia. In Manitoba, five deaths from exposure to the cold temperatures were reported and two other people lost their lives in Alberta due to accidents. Frozen pipes burst in many buildings in Ontario. (Canadian Disaster Database, 2005)

**Flood**

**Definition**

‘An overflow or inundation of water from a river or other body of water which causes or threatens loss of life and property and environmental damage’ (MNR, 2010).

**Description**

Rivers, lakes and other bodies of water provide many benefits to nearby communities. They can provide a community with a supply of water for human, agricultural and industrial consumption, transportation routes for shipping and encourage recreational activities. Floodplains, which are generated by the natural fluctuations of a water body, provide fairly flat land which appears at first glance to be ideal for construction and a naturally fertile soil which is beneficial for agriculture. Because of these benefits and additionally because of the aesthetic appeal of being close to water, most of the world’s
population centres are located next to a source of water (WMO/GWP, 2008), many of which have a history of flooding.

Despite the benefits to communities, water bodies are also a source of risk. Flooding is a natural part of the water cycle which is usually caused by extreme meteorological and hydrological conditions, although human activities can contribute to flooding, generally by accentuating flood peaks (WMO/GWP, 2008) in part by altering drainage patterns. Floods have been identified by the Government of Canada (2010) as being the most frequent natural hazard in Canada.

Two people leave their flooded house by boat in Kashechewan, 2006 (EMO, 2006).

Flooding can be caused by:
- Extreme precipitation – provides a sudden, high volume input of water
- Snow melt – can provide a sudden, high volume input of water, especially during warmer temperatures
- Ice break-up – can release a significant amount of water and ice
- High winds – can result in a storm surge
- Soil moisture conditions – if the soil is already saturated, a greater percentage of precipitation will be available as runoff
- Ice jams – can act as a natural dam, allow large volumes of water and ice to build up until the jam breaks
- Wind chill – produces frazil ice
- Natural dams – beaver dams or earthen berms give way
- Structural failure (MNR, 2010)

The conditions leading to a flood begin with an influx of an amount of water into a river or stream. As the volume of water increases, the depth, width and speed of the river or stream increases. If enough water is added, then the stream channel which normally
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confines the water is overwhelmed and the water overtops the banks and moves into low-lying areas surrounding the stream (WMO/GWP, 2008). These areas, which are not underwater except during periods of flooding, are referred to as floodplains (MNR, 2010). As some of the water moves over the floodplains its velocity begins to decrease which results in the deposition of sediment carried by the water. Overtime the sediment builds up creating a natural levee which increases in height with each subsequent flood (Nelson, 2009). While a floodplain may appear to be an ideal location for human habitation, with fairly level ground and fertile soil, it is an indicator that future flood events are likely to occur in that area.

The Ministry of Natural Resources has three warning levels for floods:

- **Flood Safety and Watershed Conditions Bulletin**: unsafe lake, river and channel conditions exist.
- **Flood Advisory**: potential for flooding exists within specific watercourses and municipalities.
- **Flood Warning**: flooding is imminent or occurring within specific watercourses and municipalities.

(MNR, 2010)

There are several different types of floods:

- **Riverine**: A flood due to the increase of the water level beyond the capacity of a natural or somewhat natural floodplain.
- **Urban**: A flood can be considered an urban flood if it results in the widespread flooding of an urban area. It is caused by water exceeding the capacity of the urban watershed. It is differentiated from riverine floods since the social, property and business/financial impacts are potentially much greater.
- **Storm Surge**: Storm surge is defined as “an abnormal, sudden rise of sea (or lake) level associated with a storm event” (Goring, 1999).
- **Seiche**: A period of oscillation of an enclosed body of water that may result in large waves.

The severity of damage caused by a flood depends on the depth, the amount of property and infrastructure, flow velocity, duration, contamination, sediment load and the population vulnerability. The World Meteorological Organization and the Global Water Partnership (2008) have identified three categories of tangible flood property damage:

- Primary: damage to property, infrastructure, agriculture and belongings.
- Secondary: damaged caused by fire or electricity outage triggered by the flooding.
- Tertiary: the increase rate of property deterioration over time.

Improvements in flood prevention, mitigation, warning and response systems and procedures have greatly decreased the potential loss of life from flooding in developed
Hazard Identification and Risk Assessment for the Province of Ontario  UNCLASSIFIED countries (Nelson, 2009). However, floods still have the potential to cause significant property and economic damage and some require evacuations. After the floodwaters have subsided, exposure to objects contaminated by substances (e.g. sewage, chemicals) carried by the water and mould can led to health complications (Government of Canada, 2010).

Flooding can also negatively affect utilities and critical infrastructure (MNR, 2010). Utilities such as wastewater treatment, electricity and gas may be disrupted in the event of a flood. Emergency ground vehicles may be unable to respond if roads and bridges are flooded, washed out or covered by debris.

**Urban Flooding – A Closer Look**

The frequency of flooding, in particular urban flooding; appears to be increasing. Urban flooding occurs when the water volume, usually from extreme precipitation or nearby riverine flooding overwhelms the drainage capacity of an urban area (Parliamentary Office of Science and Technology, 2007). Extreme precipitation events, ageing drainage infrastructure and sewer back-up and an increase in built-up or paved land all increase the number of urban flooding incidents.

Urban floods have the potential to cause greater amounts of damage due to the greater concentration of people and property within an urban area. Due to the changes to the natural drainage patterns, runoff may collect and create new channels which flood areas which were not previously identified as having a significant risk of flooding. Studies have found that the economic damages caused by urban flooding are increasing (WMO/GWP, 2008). Communities with a large diversity of economic activities are less likely to suffer as great a loss as those with less diversity (WMO/GWP, 2008).

In addition, floods in urban areas have an increased risk of contamination by harmful substances due to the increased presence of sewage treatment plants, waste dumps and household and industrial chemicals. Once the flood waters subside, these substances may still pose a threat if they contaminate soil, ground or surface waters (WMO/GWP, 2008).

**Provincial Risk Statement**

The province of Ontario has a history of active flood planning and management (Conservation Ontario, 2009). The Ministry of Natural Resources, Conservation Authorities and municipalities all work to manage and respond to flooding (Conservation Ontario, 2009). The Canada/Ontario Flood Damage Reduction Program was established in 1975. This program recommended best practices including structural (e.g. dams) and non-structural (land-use planning) measures in order to prevent and mitigate flood damages. In order to prevent and mitigate flood damages, Ontario has more than 900 dams, dykes, channels and structures to diminish erosion. Conservation Ontario estimates that these structures prevent damage to more than 46,000 houses and save more than $100 million dollars a year in flood damages (Conservation Ontario, 2009). A study done in 1986 showed the success of the flood reduction measures put
into practice by the Ministry of Natural Resources, the Conservation Authorities and the municipalities. The study examined flood water levels and the estimated cost of damage due to floods in Ontario and Michigan. The findings were that although Ontario experienced higher water levels during flooding, the associated cost of damages was significantly less in Ontario than in Michigan (Conservation Ontario, 2009).

Most floods in Ontario are caused by extreme precipitation events, particularly during the summer months, and snowmelt/ice break up in the spring. As seen in figure 3, southern Ontario has the greatest number of heavy rainfall events. Areas in the central and northern regions may have fewer heavy rainfall events but those that are close to shorelines and/or tributaries may have more flooding events due to spring melt and the annual ice break up. Northern communities, such as those along the James Bay coast are particularly at risk due to the annual ice break up and their remote locations which can make evacuations difficult and more costly.

![Figure 4. The total number of heavy rain events for Ontario (Environment Canada, 2010).](image_url)

The Great Lakes can also contribute to the risk of floods for communities along their shorelines from storm surges or, much rarer, seiches. The worst flood in the recorded history of Ontario was caused by Hurricane Hazel in 1954. The heavy precipitation from the storm, the inability of the soil to hold more moisture due to previous rain and the alteration of natural streams and channels by humans, lead to severe flooding and the
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loss of 81 lives. Since flood management practices were implemented, the number of flood-related injuries and fatalities has greatly declined.

Flooding can result in loss of life due to drowning or, if the flood waters are carrying a significant amount of debris or ice, crushing. Motorists are vulnerable to floods since only about two feet of water can lift and carry away most cars (Raven Rescue, 2009). Health problems may arise after the flood due to contamination of standing water, the back up of sewers and the growth of mould in buildings that suffered water damage. Of all of the hazards in Ontario, flooding is the most likely based on past events, to require the evacuation of some or all of a community.

A flood can wash away buildings and roads and destroy bridges and communications towers. Emergency vehicles may not be able to reach people due to flooded or washed-out roads resulting in some people being isolated and stranded. Debris carried by the water can contribute to the damage. The water may be contaminated by chemicals and waste picked up by the water which may prevent or slow the restoration of property that is not outwardly damaged by the flood. Water damage and mould growth may add to the damage. Water quality and human health emergencies may arise as secondary hazards after a flood. Particularly in urban floods, sewage systems may be overwhelmed and damaged by the excess water. This may result in raw sewage backing up into homes. Electricity is likely to be halted to the affected areas in order to prevent accidental electrocution. Water quality may diminish due to bacteria, sewage or chemicals being introduced into the water supply by the flood.

Floods that are part of a natural cycle can actually be beneficial to the environment and provide nutrients to the soil. These floods result in little environmental damage. However, human caused changes to the environment have altered the runoff patterns in some areas resulting in changes in flood frequency and severity. These floods have the potential to cause more harm to the environment since they may occur in areas which did not previously experience floods and they may result in more erosion than would occur within a natural system. Another possible cause of environmental damage is that the flood water may be contaminated with raw sewage, chemicals or other contaminants.

A flood can result in a large business/financial interruption for a community. The degree of the interruption depends on the size of the affected area. The transportation of both people and goods may be halted if the roads are flooded. Electricity and gas may be shut off. Depending on the severity of the flood, the entire community may require evacuation. Water damage and mould growth may slow the reopening of businesses.

Flooding are the leading cause of declared emergencies in Ontario (Emergency Management Ontario, 2009). An examination of the history of flooding and insurance claims in Ontario suggests that flooding, in particular, urban flooding events are increasing in frequency and that damage costs are rising due to increases in the
population size, climate change, aging urban infrastructure and increasing property values. Conservation Ontario (2009) estimates that these factors could contribute to increasing damage costs from floods between 20-60%.

**Case Study - Peterborough Flooding 2004**
The city of Peterborough experienced urban flooding in 2004. More than 4,000 houses were affected by the flood waters and 100 people required rescues after flood waters trapped them in their cars. Sewer systems backed up and contaminated the flood waters. Due to the hazardous conditions created by the flood, gas and electricity were disconnected leaving many residents in the dark. (Canadian Disaster Database, 2005).

**Fog**

**Definition**

*A cloud based at the earth's surface consisting of tiny water droplets or, under very cold conditions, ice crystals or ice fog; generally found in calm or low wind conditions. Under foggy conditions, visibility is reduced to less than 1 km* (Environment Canada, 2009).

**Description**

Fog is usually a small-scale, brief hazard that is common particularly around the Great Lakes. There are many types of fog. The two most common types in Ontario that pose a risk to safety are advection and radiation fogs. Advection fog is generated when moist air travels over a cool surface. This type of fog can be widespread. Radiation fog is more localized and is generated by surface cooling in calm weather conditions. It often occurs close to open fields or streams in slight depressions. Fog often forms late at night and may persist through to the morning resulting in reduced visibility during rush hour traffic. Smoke can contribute to fog formation by providing condensation nuclei for water droplets to adhere to, which then becomes fog.

The most common social impacts attributed to fog can be considered partly the result of a secondary hazard, transportation accidents. Fog reduces visibility which can create hazardous driving conditions. When visibility has been reduced to less than 150 m,
studies have shown that drivers are more likely to underestimate their speed and fail to successfully judge the distance between vehicles (Moore and Cooper, 1971). Radiation fog has been found to pose a greater threat to drivers than advection fog. Since advection fog can be fairly consistent and widespread, drivers generally adjust their speed for the uniform fog conditions. Radiation fog is not as consistent and visibility may change suddenly. Studies on how drivers respond to sudden changes in visibility have found that responses differ greatly and can include ‘continuing on blindly’ to ‘slamming on the brakes’ both of which can result in accidents (Lavdas and Achtemeir, 1995). Radiation fog can also reduce visibility more than other types of fog due to the smaller droplet size and the greater concentrations of droplets (Musk, 1991).

### Provincial Risk Statement

Fog is a naturally occurring hazard in Ontario. It is normally fairly localized. As seen in Figure 4, thick fog is more common in Southern Ontario. The weather patterns, geography and the presence of the Great Lakes all contribute to the higher number of fog days. Fog is more likely to result in an emergency if it occurs in an area with a high traffic volume. Southern Ontario has the highest traffic volume in Ontario. It also has a higher population density, so more people are exposed to this hazard. Fog is generally a localized hazard and often only affects a part of a municipality. Widespread fog rarely encompasses more than a couple of municipalities.
Figure 5. The average number of hours per year with a visibility of zero kilometres due to fog (Environment Canada, 2003a).

The population, property/infrastructure, environment and business/finances of Ontario are not particularly vulnerable to fog. Fog rarely results in negative social impacts. However, it has been known to result in traffic accidents due to a lack of visibility which may result in fatalities and injuries. The risk increases if the fog occurs during either the morning or evening rush hour in an area with a high traffic volume. Fog is unlikely to directly cause any property or infrastructure damage.

Case Study Windsor 1999

Dense fog and high speed resulted in the collision of at least 40 vehicles, including transport trucks, vans and cars on Hwy. 401 near Windsor. At least 40 vehicles collided, including transport trucks, vans and cars. Seven deaths and 33 injuries were reported. A fire caused by the crash caused the road's asphalt to melt, and destroyed many of the vehicles.
(Environment Canada, 2010)

Forest/Wildland Fire

Definition
‘An unplanned and uncontrolled fire burning in vegetation fuels such as forest, grass and brush (MNR, 2009).

Description
Fire is an important part of the natural cycle of forest maintenance. However, if it or the smoke produced by the fire encroaches on human settlements or interests it can become a dangerous hazard to human, animal and plant life, property and business (Blanchi et al., 2002). There are two ways in which a forest/wildland fire can be ignited: natural or human caused. Human caused fires are the most common type in Ontario with approximately two thirds of all fires caused by human activities. The only natural cause is lightning. Fires caused by lightning can occur anywhere that a thunderstorm passes close by. Therefore, some of the fires occur in very remote areas that are not easily accessible to humans. Human caused fires are ignited by human activities in a forest/wildland area and may be intentional (e.g. prescribed burns) or non-intentional (e.g. campfires). Human caused fires tend to be closer to human settlements since increased human access to the forest results in a greater chance for a human caused fire to be started. The percentage of fires with a natural cause versus the percentage of fires with a human cause varies across Canada. On average two thirds of forest/wildland fires in Canada are human caused (NRCAN, 2007).

A fire requires dry, organic matter such as surface litter and/or conifer needles to continue and spread. The moisture content of the fuel has an important influence on the duration and spread of the fire. Dry organic matter ignites and burns faster than
organic matter with high moisture content. The temperature of a forest/wildland fire is also dependant on the type and moisture content of the fuel (NRCAN, 2007). Weather conditions play an important role in forest/wildland fires. Prolonged, dry weather, especially drought conditions, can increase the amount and quality of the organic matter available as fuel. ‘During extreme drought conditions, the moisture content of living brush and tree crowns may be lowered, fires may crown more readily, and some of the woody vegetation may die’ (Keetch and Byram, 1968). In addition, drought can dry out areas which have served as natural firebreaks in the past (Keetch and Byram, 1968). Wet weather conditions decrease the quality of the fuel and can suppress fire. Wind can provide another requirement for the ignition and spread of a fire, oxygen. High wind speeds can assist in spreading the fire and can create an environment for fire suppression that is even more dangerous than in calm weather conditions. Plant disease and infestation can also increase the risk, intensity and size of a forest/wildland fire. Some plant diseases and infestation result in the death of trees and plants, thereby contributing to the amount of organic matter available for fuel.

There are three types of forest/wildland fires which are classified based on the level at which they occur:

- **Subsurface fires** ‘burn in the organic matter beneath the surface litter, and are sustained by glowing combustion’ (MNR, 2010). Subsurface fires can burn deep below the surface, especially in material such as peat. Although this type of fire usually does not span a large area, they can be active for months, even years. Subsurface fires can generate surface fires long after the initial fire was believed to be suppressed (NRCAN, 2007).

- **Surface fires** are responsible for the least amount of environmental damage and are often easier to suppress since they burn the organic matter on the forest floor.

- **Crown fires** can burn the length of entire trees. Since this type of fire reaches the crown of trees, it is more exposed to wind than fires which occur lower in the protection of the forest. Wind and falling debris from the burning tree increases
the speed at which this fire can spread. According to MNR (2010), this type of fire is the most difficult to suppress.

The Canadian Forest Fire Weather Index (FWI), a subsystem of the Canadian Forest Fire Danger Rating System (CFFDRS), is used in Ontario to assess the behaviour of potential forest fires:

**Low**: smoldering or self-extinguishing fire. Flame height: less than 10 centimeters.

**Medium**: creeping or gentle surface fire. Direct manual attack by firefighters with hand tools and water is possible. Hand-constructed fire guard should hold. Flame height: up to 1 meter.

**High**: moderately vigorous surface fire. A hand-constructed fire guard will probably fail. Heavy equipment (bulldozers, pumpers, and aircraft) is generally successful in controlling the fire. Flame height: up to 2 meters.

**Very high**: intense surface fire. Frequent torching is possible. Control efforts at the fire's head may fail. Flame height: up to 3 meters.

**Extreme**: crown fire. Control is very difficult. Suppression action restricted to the fire's flanks. Indirect attack with aerial ignition (backfiring) may be effective. Flame height: 3 to 25 meters or more.


**Provincial Risk Statement**
Organized forest fire protection has been active in Ontario since 1885. The Forest Fire Prevention Act R.S.O. designates the Ministry of Natural Resources (MNR) as the lead ministry with the responsibility to prepare for forest fire emergencies in Ontario’s fire region, crown lands, on some lands managed by MNR and as directed by numerous municipal agreements (EMO, 2005). The Forest Fire Management Strategy for Ontario (2004) provides a broad direction for the fire management program and is the strategy of fire control practiced together with land management objectives. The Forest Fire Management Strategy for Ontario considers environmental, social and economic criteria.

The average number of forest fires a year in Ontario ranges from 800 to 3,000. Fires are more common during the spring (before canopy cover is renewed and while there is still a large amount of dry vegetation on the forest floor) and summer (when lightning is more frequent). Both of these seasons tend to have periods of hot, dry and windy weather which can benefit the spread of fire. In Ontario, 60% of all forest/wildland fires are caused by human activities. The most common source of these fires is campfires (MNR, 2009). Fires caused by lightning strikes frequently burn a much larger area than the human-caused fires (Podur and Martell, 2009), although these areas are more likely to be unpopulated. New and emerging pests are contributing to the fire hazard.
pests, such as the pine beetle, damage and kill trees which increase the amount of dry, dead organic matter that can provide fuel for a fire.

Of particular concern are fires that occur within or close to the Wildland Urban Interface. This is any area where buildings and/or structures (whether residential, industrial, recreational or agricultural) are located adjacent to or among combustible forest/wildland fuels (EMO, 2005). Some examples of the different wildland-urban interface areas in Ontario are: Cities, buildings, structures (including subdivisions, cottages, recreational facilities etc) that either contain forest or brush within their limits; are situated within a broad expanse of forest or brush or those that are located adjacent to forest or brush. Growing populations and the expansion of people into Wildland Urban Interface areas have increased the potential impact of a forest fire, in particular, on property damage and large scale evacuations.

When forest fires approach populated areas, they can endanger lives. However, due to improvements in fire prediction and forest fire management, deaths due to forest fires remain uncommon in Ontario. Additionally, injuries due to forest fires are also uncommon although there are often health concerns about air quality and smoke. Evacuations are the most common social impact associated with forest/wildland fires. Evacuations may occur due to smoke even if the community is not directly threatened by the fire itself. As population density increases in the wildland urban interface, evacuations can grow in size.

Property and infrastructure in Ontario are vulnerable to forest fire. Forest fires can result in substantial property and infrastructure damage. Buildings and structures within the path of the fire may be completely burned. Buildings that remain structurally intact after a fire has ended may have had their contents damaged due to smoke. Roads can be damaged as the fire passes over them. Electrical lines can also be destroyed by fire resulting in power outages.

Forest fires are a natural feature of the forest ecosystem. While a forest fire may have what appear to be negative effects, these often turn out to be beneficial in the long-term to the health and maintenance of the ecosystem. Many species are adapted to fire. Some species of tree (such as jack pine) used fire to release their seeds from their cones. Fire also benefits vegetation by enriching the soil with ash, allowing more light and precipitation to reach the forest floor through the removal of some of the canopy and reducing the competition for some species. Fire can help control invasive species (including insects, plants and diseases) that have not evolved in areas in which fire is a natural part of the maintenance of the landscape.

The majority of animals are able to escape forest fires so the effects of fires are believed to be fairly minimal in the long term (MNR Ontario, 2010). Marine ecosystems may be negatively impacted by forest fires. Erosion and changes in water temperature caused
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by the loss of vegetation due to a fire can impact water quality negatively affecting cold water fish habitats (MNR, Ontario, 2010).

Forest/wildland fires can have a negative business/financial impact if they occur near communities and necessitate the evacuation of large numbers of people. Resources needed for suppression may be costly. The forestry sector is the industry most likely to be negatively impacted by forest fires, although tourism can also be severely affected.

Case Study - Forest Fire 2002
In 2002, forest fires and their smoke threatened the health and safety of several communities in Northern Ontario. Fires were close to Kee-Way-Win First Nation, the Townships of Terrance Bay and Schrieber, the Village of Rossport, Pays Plat First Nation and Deer Lake First Nation. Concerns about the proximity of the fires and the smoke that they produced resulted in the evacuations of more than 1,000 people. Evacuees were taken to Thunder Bay, Geraldton and Sioux Lookout. A total of six communities declared emergencies.
(Canadian Disaster Database, 2005)

Freezing Rain

Definition
‘Rain or drizzle, which falls in liquid form and then freezes upon contact with the ground or a cold object, forming a coating of ice’ (Environment Canada, 2010).

Description
Winter weather includes a variety of different types of precipitation including snow, rain and freezing rain. The type of precipitation depends primarily on the distribution of temperature with height in the lower atmosphere and at the earth’s surface. In order for freezing rain to form, there must be a layer of air with temperatures above-freezing over a layer of air near and at the surface with below-freezing temperatures. When the air temperature above the warmer air is below-freezing snow crystals begin to grow into snowflakes. Freezing rain will form if snow falls into a warmer layer of above-freezing air that is deep enough for the snow to melt and then passes through a below-freezing layer of air near and at the surface. The depth of the below-freezing layer is important in determining whether freezing rain or ice pellets will form. If the below-freezing layer is too deep (greater than 500-1000 metres), the droplets may freeze again and reach the ground as ice pellets. If the below-freezing layer is shallower than 500-1000 metres, the droplets will cool to a temperature that is only a few tenths of a degree below freezing. These droplets are super cooled and will remain as a liquid. These will freeze on contact with the ground or cold objects near the ground, such as roads, trees, and power or telephone wires. In some instances, freezing rain may form by a different mechanism in which the droplets originate as liquid water rather than snow or ice and there is no layer of above-freezing temperatures to pass through (Klaassen et al., 2003.)
An injured person is taken for medical treatment by emergency response workers after the 1998 ice storm.

A long lived freezing rain event is often referred to as an ‘ice storm’. Ice storms can deposit layers of ice onto the ground and object that are heavy enough to cause damage. The amount of ice accumulation depends on the duration and intensity of the freezing rain event. Freezing rain may not be continuous during an ice storm but may occur in successive waves.

**Provincial Risk Statement**
Freezing rain is a frequent hazard in Ontario. Northern and Central Ontario experience the greatest number of days per year with freezing precipitation (Figure 5) with an average of over 17 days per year. Southern Ontario has fewer days per year with an average of just over 11 days. In Ontario, the most severe ice storms/freezing rain events usually occur from November to March with approximately one half occurring between the last two weeks of December and the first two weeks of January. In general, these have lasted between 12 hours and 1-2 days (Environment Canada, 2009). Freezing rain can be a small scale or a large scale hazard, depending on the size of the storm system.
Figure 6. The average number of hours per year with freezing rain, based on data from 1953/54-2000/01 (Environment Canada, 2009; source: Klaassen et al. 2003)

The population of Ontario is not very vulnerable to freezing rain. Fatalities and injuries directly related to freezing rain are rare. However, they are possible. The Ice Storm of 1998 resulted in 28 fatalities and 945 injuries in Canada. Most fatalities and injuries are due to secondary hazards, such as transportation accidents caused by the poor driving conditions generated by the freezing rain.

Property and infrastructure is moderately to highly vulnerable to freezing rain. Transportation and electrical infrastructure are particularly sensitive to freezing rain. The layer of ice deposited by freezing rain, in addition to fallen branches and sometimes whole trees can make roads and bridges impassable. Power lines can be disrupted either by broken branches or by ice accumulation. If the ice accumulation is great enough, structures such as communications towers may crumple, disrupting communications systems. Buildings may be damaged by ice accumulation and the resulting water seepage. People can become trapped in their homes without essential
services such as electricity and heat. Health care facilities may be significantly impacted and experience capacity overload.

Plants, in particular deciduous trees are especially sensitive to the effects of freezing rain. After the ice storm of January 1998, some tree branches were found to have experienced ice accumulation that was approximately fifty times their own weight (Quebec, 1999). When the weight of the ice reaches a critical limit the tree branches break which can result in substantial damage to the canopy. Agriculture, particularly maple syrup production and orchards may suffer substantial losses. Gardens and ornamental plants can also be damaged. Animals overall seem to cope well with the effects of freezing rain, however, a strong event with heavy accumulation may make it more difficult for them to find food. Birds tend to fair worse than other animals.

Freezing rain, in particular ice storms with a long duration and that result in a large ice accumulation can significantly disrupt business and financial transactions in several different ways. Freezing rain can result in power outages and can severely hinder road and rail travel which could led to financial loss, especially if it occurs for several days.

**Case Study Ice Storm 1998**

Provinces from Ontario to New Brunswick received between 50 to greater than 100 mm of freezing rain from January 6 to 10th, 1998. The freezing rain fell primarily in a corridor extending from Kingston to Ottawa to Montréal to the Monteregie area south and east of Montréal, and on into New Brunswick. Fifty-seven communities in Ontario declared an emergency and approximately 250,000 customers (an estimated 1,500,000 people) were left without electricity. The accumulation of ice crumpled communications towers and broke tree branches. The broken branches and the layer of ice left on roads made driving difficult. (Canadian Disaster Database, 2005)

**Geomagnetic Storm**

**Definition**

*temporarily and severe disturbance of the upper atmosphere and of the near-Earth space environment caused by the magnetic activity of the Sun (based on National Research Council, 2008).*

**Description**

Geomagnetic storms originate from erupting sunspots on the surface of the sun. Active solar regions release coronal mass ejections (CMEs). CMEs are large clouds of ionized gas that carry superheated particles at a speed of approximately two million miles per hour (OCIPEP, 2002). If the CME is directed towards the Earth, it can impact the Earth’s magnetosphere and cause a geomagnetic storm. This type of activity causes the aurora borealis and aurora australis. However, the effects of a strong geomagnetic storm are not limited to just the lights of the auroras; they can also damage electronics and communications systems. Countries at high latitudes are more at risk of the effects of...
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g geomagnetic storms, but the impacts of an extreme storm could be far reaching. It is important to note that an EMP (electromagnetic pulse) blast would have similar affects to a strong geomagnetic storm. EMPs can be caused by the denotation of a nuclear weapon.

Auroras, such as the one pictured; occur during strong geomagnetic events (NOAA, 2010).

Society relies on a complex system of dependencies and interdependencies between critical infrastructures. If a part of the infrastructure is damaged or unavailable it can result the damage or disruption on other types of infrastructure which result in short and long-term disruptions and impacts (National Research Council, 2008). The United States National Research Council held a workshop in 2008 in an attempt to assess the societal and economic impacts of a severe geomagnetic storm. This report stated that a large electrical outage caused by a geomagnetic storm is a low frequency but high consequence event with negative impacts ranging from a breakdown of the pumps required to distribute potable water to a communication blackout. A severe storm would cause these services to be unavailable for a significant period of time and according to the National Research Council: “The resulting loss of services...in even one region of the country could affect the entire nation and have international impacts as well” (National Research Council, 2008). Since a geomagnetic storm has the potential to cause a long term power outage, generators may run out of fuel before electricity is restored.

Some of the potential impacts of a severe geomagnetic storm include:

- People reliant on technology for survival (e.g. medical devices) may not survive.
- Perishable food and medicine would spoil due to a lack of refrigeration.
- Food shortages may occur due to the halt of the production and distribution process.
- Many service stations would be unable to provide gasoline since pumps usually run on electricity.
• People would be unable to access their financial records and withdraw cash. Credit and debit cards would be unusable.
• Elevators would no longer function in high rise buildings, restricting access to homes and workspace for some people.
• Potable water would not be available since the pumps required for its distribution require electricity.
• Communications systems would be down, possibly causing widespread hysteria since people may not be able to get information on this hazard. 911 would likely be out of service.
• Transportation, including most cars, trains and aircraft would not function. Street and traffic lights would not function.
• Alarms would not function.
• Information stored on computers or other electronics may be lost.

While past geomagnetic storms have caused damage (e.g. Quebec, 1989); future storms could be much stronger. Historical records have shown that the strongest geomagnetic storm in recent history was the Carrington event in 1859, before widespread electrical technology was used. This storm caused telegraph disruptions and widespread vivid auroras. If an event of this magnetic occurred in today’s society with its dependence on technology, it would cause much more severe and widespread damage (National Research Council, 2008).

**Provincial Risk Statement**

Ontario is located at fairly high latitude. Because of this, the province faces a greater risk of geomagnetic storms than locations which are geographically more southern. Ontario also is dependent on technology and electricity for critical functions and systems such as the food supply, water distribution, banking, transportation and communications.

People are not directly vulnerable to geomagnetic storms, with the exception of those who are dependant on electrical and technological medical devices and perishable medications. The population, however, is much more vulnerable to the critical infrastructure failures that would be triggered by a geomagnetic storm. For example, the City of Toronto alone has greater than 2,000 buildings, many of which are residential, that are in excess of over 300 ft in height. Only New York City has more high-rise buildings in North America. Vulnerable groups such as seniors who make up approximately 13% of Ontario’s population (Canadian Mental Health Association, 2010) and people with physical disabilities who live in high-rises may be unable to leave or get to their homes without assistance. Potable water would stop flowing since the pumps require electricity. People in high-rises could lose their potable water in less than a day after a geomagnetic storm with other building and small communities having access to water for at most a couple of days. If a geomagnetic storm occurred during the winter, heating systems would fail which could lead to deaths from hypothermia and property damage from burst pipes. A large amount of the food production and distribution process in Ontario also requires electricity.
Property is not particularly vulnerable to geomagnetic storms. As stated previously, however, infrastructure is. Any infrastructure which is dependent on electricity and technology is extremely vulnerable. Widespread power outages could occur. The Toronto and Ottawa subways and street cars would immediately stop functioning, stranding passengers. Many vehicles are built with technology that could be compromised by a powerful geomagnetic storm. Health care would be greatly impacted if the fuel for hospital generators ran out before the power was restored or if medicine and medical supplies were not able to be refrigerated or transported to them. Satellites could stop functioning and result in a disruption of communications. Geomagnetic storms can also corrode pipelines which could negatively impact the distribution of oil and natural gas.

The environment is not known to be particularly vulnerable to geomagnetic storms. Some species, such as migratory birds may be negatively affected but are unknown to suffer physical harm.

Ontario has the largest economy of the Canadian provinces and territories. Ottawa is the capital of Canada and Toronto is considered to be the economic capital of the country. If a geomagnetic storm were to affect both of these areas both the government and the finances of the country would be greatly impacted. The Toronto Stock Exchange is the world’s eighth largest stock exchange in terms of the market value. A severe geomagnetic storm could halt the stock exchange, business and trade and as a result its impacts would be felt in other countries.

What makes the impact of this hazard far more severe than first appears is that the time required to restore power, transportation, water service, technology etc. is unknown. For most of the technology involved, it is not a simple matter of bringing everything back online with the power grid. Crucial components are likely to be irreparable. Many of these components are not stockpiled in sufficient numbers for an event like this and would have to be order and manufactured. Since the manufacturing industry and the critical infrastructure it relies on are likely to be impacted by the geomagnetic storm if they are located within the affected area, this may not be possible unless national or international assistance is provided. Depending on the strength of the geomagnetic storm and the extent of the area impacted, recovery could take months to years. Some experts believe that a full recovery would not be possible within the province, countries or multiple countries that are affected.

A geomagnetic storm is not a widely known hazard. Because of this, if a severe one should occur and disrupt communications systems, there may be widespread panic. The indeterminable amount of time before electricity and communications systems are restored may also fuel any panic.

**Case Study - Geomagnetic Storm of 1989**
One of the worst geomagnetic storms of the 20th century severely disrupted Canada’s energy sector in 1989. Geomagnetically induced currents (GIC) caused by the
geomagnetic storm overloaded Hydro-Quebec’s transformers. This resulted in the tripping, or deactivation, of reactive power compensators at electrical substations causing a drop in voltage and the malfunctioning of power lines. The electrical system collapsed. It took approximately nine hours for the system to be brought back on-line. It is estimated that this storm resulted in the loss of 19,400 megawatts of electricity and millions of dollars in revenue.
(Office of Critical Infrastructure Protection and Emergency Preparedness, 2002)

Hail

Definition

Hail is defined as precipitation consisting of particles of ice in various shapes that is generally observed during thunderstorms. Environment Canada (1996) defines hail as having a diameter of 5 mm or more (Environment Canada, 1996).

Description

Hail is mostly likely to occur in Canada between May and September since it is generally a warm season phenomenon. The same general conditions required for thunderstorm formation are required for hail production: atmospheric instability, strong windshear, low-level moisture and a mechanism that can release instability (Etkin and Brun, 1999). If the resulting thunderstorm has strong updrafts, then raindrops may be carried high into the thunderstorm where the air temperature is below freezing. The frozen droplet may be repeatedly dropped by downdrafts and carried up by updrafts. Each time the size of the forming hailstone may grow with the addition of another layer of ice. Eventually, when the hail is too heavy for the updraft to lift, it falls to the ground at speeds of 100 km/h or greater. On average, hail occurs in localized showers and has a short duration. Since hail is produced by severe thunderstorms, it may occur in conjunction with strong winds, lightning and extreme precipitation. Hail also commonly occurs prior to a tornado.

Environment Canada does not issue weather watches and warnings specifically for hail. However, hail size (diameter) is one of the three criteria used for issuing severe thunderstorm warnings (Environment Canada, 2010). The significant hail size for a severe thunderstorm warning is 2 cm; however, slightly smaller hail may cause damage.
The largest hail that causes the most damage is usually associated with severe thunderstorms, although not all hail is produced by thunderstorms that are classified as being severe by Environment Canada’s definition of severe thunderstorms (Environment Canada, 2010) and not all severe thunderstorms produce hail. Other weather conditions (e.g. those associated with heavy precipitation) may also produce small hail.

**Provincial Risk Statement**

South-western Ontario, along with the central and eastern prairies and south-central British Columbia experiences hail much more frequently than the rest of Canada. (Etkin and Brun, 1999). From 1977 to 1993 there were 1842 days with hail in Ontario. This is not particularly high; however it is not distributed evenly across the province. Southern Ontario has some areas which experience higher frequencies, possibly due to lake effects and topography. Areas with higher frequencies are found to the northeast, east and west of Toronto, near London and close to Halliburton (Etkin and Brun, 1999). Hail in Ontario is generally fairly small, about pea-sized and as a result, losses have been generally moderate when compared to other provinces, such as British Columbia and Alberta.

**Figure 7. The total number of potentially damaging hail occurrences (1979 – 2009) (Environment Canada, 2010b).**
As seen in Figure 7, the vast majority of the potentially damaging hail occurrences (in which the hail size is large enough to cause damage) occur in Southern Ontario. The areas in which damaging hail is more common also happen to be some of the most populated areas in Ontario. Additionally, the majority of Ontario’s most productive farmland for both crops and livestock is also in these areas. It is important to remember that not all damaging hail occurrences may be captured by this map; some may have gone unreported if they occurred in unpopulated areas.

Hail rarely causes fatalities and injuries since the majority of hailstones are fairly small and occur in conditions that discourage outdoor activities. However, larger hailstones have caused fatalities in Ontario in the past. In 1985, five fatalities in Ontario were caused by a hailstorm when the victims were unable to seek shelter in time.

Hail can cause property damage, mostly in the form of broken windows, dented automobiles and destroyed crops. However, if the hail is large enough, the entire roofs of houses and other buildings may need to be replaced and automobiles may not be repairable. Further damage may be caused from flooding due to both melting hail and rain entering buildings through broken windows and skylights.

The extensive agriculture in southern Ontario is vulnerable to damage, particularly early in the growing season and then right before the crop is picked. Since hail is a warm weather phenomenon, usually occurring between late April and September, hail can occur at almost any time of the farming cycle for many of the crops grown in Ontario. Tender fruit, young plants and tall stemmed crops are particularly vulnerable. Livestock may be injured, or rarely, killed by large hail. Greenhouses can easily sustain severe damage during a large hail event since large hail can easily shatter glass. Landscaping businesses with large numbers of unprotected plants and equipment may also suffer extensive damages.

**Case Study Southern Ontario Hailstorm 2008**

Several hail events occurred in Southern Ontario during the summer of 2008. On June 9 golf-ball sized hail occurred in Chatham-Kent. The hailstones pummelled crops, dented hundreds of vehicles, damaged aluminium siding and roofs. Two weeks later, the same communities experienced large hail again.

During another hailstorm, one orchard lost 80% of its fruit. A front-end loader was required in Grimsby to clear out drifts of gumball-sized hail. Twelve hours after the hailstorm, some backyards were still buried under 8 cm of nickel-sized hail. Other farms lost fields of beans and cucumbers. (Environment Canada, 2010).
Human Health Emergency

Definitions

**Human Health Emergency:** ‘A widespread and/or severe epidemic, incident of contamination or other situation that presents a danger to, or otherwise negatively impacts, the general health and well being of the human population’ (EMO, 2005).

**Epidemic:** Major incidents of human illness caused by the transmission of a specific disease. The occurrence, in a community or region, of cases of an illness (or an outbreak), with a frequency clearly in excess of normal (EMO, 2005).

**Pandemic:** An epidemic occurring worldwide or over a very wide area, crossing boundaries of several countries, and usually affecting a large number of people (WHO, 2007).

Description

Human health emergencies can arise from different origins. Some of these include:

- Virus
- Bacteria
- Parasites
- Fungi
- Prions
- Protozoa

Viruses, bacterium, parasites, fungi and protozoa are vital members of the ecosystem. The vast majority of them are harmless or even beneficial to human health. However, a small minority are dangerous to humans. When one of these species has been transmitted to a human host, it may cause illness or even death. The severity of the symptoms depends on factors such as the source of the illness and the health and age of the host.

There are several ways in which a human health emergency can be introduced and spread throughout a community:

**Direct contact:** a person can become infected through close physical contact (e.g. kissing, touching) a person who is already infected.

**Indirect contact:** a person can become infected by coming into contact with a surface that has been contaminated.

**Droplet contact:** a person can become infected from exposure to droplets that have touched the surfaces of the eyes, mouth or nose of an infected person. Sneezing and coughing are two methods in which this type of illness can be spread. This differs from airborne transmission since the droplets are too large to remain in the air for long periods.
Airborne transmission: a person can become infected from exposure to droplet nuclei and contaminated dust particles which are capable of staying airborne. Few diseases are capable of surviving airborne transmission (e.g. influenza, pneumonia).

Vector-borne transmission: a person can become infected through contact with an infected animal or insect. Mosquitoes are the most common vector for disease in humans. (Mount Sinai Hospital, 2007).

A human health emergency can be caused by a known agent of disease or an unknown one. Some diseases are reoccurring; they reappear in the human population after a period in which they may only be found in animal hosts. A new disease may arise from a previous unknown agent or result from the evolution of a previously known one. There are many factors that can cause a human health emergency, such as, the evolution of micro-organisms (including antibiotic resistant strains), the alteration of natural habitats, the increase frequency and the decreasing duration of global travel. Depending on the cause of the emergency, it may be isolated or local or (as in the case of a pandemic) it could be global in scale.

Provincial Risk Statement
A human health emergency could occur in any part of Ontario. The elderly are at a greater risk of suffering from illness or fatality due to human health emergency, although this depends on the agent of disease. The elderly often have health complications which can make them more vulnerable. As of 2006, senior citizens made up 13.6% of Ontario’s population and this is expected to increase in the future.

However, not all human health emergencies can disproportionately impact the elderly. The 1918 Influenza affected people who were considered to be healthy, young adults. It is believed that virus trigged a cytokine storm, an immune system response that ultimately resulted in the death of the infected individual. The pandemic H1N1 (2009) was also another influenza virus where the number of cases were higher in those under the age of 20.

International travel can introduce re-emerging and novel diseases into the population. Several airports in Ontario serve international flights, including Toronto’s Pearson Airport.

People living in remote communities, particularly in those in which housing is scarce, have a higher risk of being negatively affected by a human health emergency. Small communities and First Nations communities, particularly in northern Ontario may experience more illness or more fatalities due to cramped living conditions (which assists the spread of illness) and a lack of accessible medical care.

The population of Ontario is very vulnerable to a human health emergency, although public health practices (e.g. hand washing) have slightly lowered the risk when
compared to that of some other countries. Depending on the cause of the emergency, a large percentage of the population could become ill. Fatalities may occur depending on the mode of transmission and the virulence of the illness. Acute respiratory diseases, which have been suggested as the most likely cause of the next pandemic, include the influenza virus. While it is unlikely that a novel influenza strain or the re-emergence of a known one would be as devastating as the 1918 Influenza due to improvements in public health practices and supportive medical care, the death toll could still be significant if the majority of the population does not have any immunity.

While property is not vulnerable to human health emergencies, critical infrastructure in Ontario is very vulnerable. Some critical infrastructure services may suffer due to large numbers of workers being sick or caring for sick loved ones. The business and finances of Ontario are also very vulnerable to this hazard. The severity of the business and financial interruption depends on the transmission mode and the virulence of the illness. Some pandemic scenarios suggest that approximately 35% of the workforce may be ill and therefore, absent from work during a severe pandemic. This would result in a severe business and financial interruption.

Some psychosocial impacts may result due to a human health emergency. Some people may dismiss the risk and not take preventive or protective measures. Others may become alarmed and begin to stockpile supplies such as facial masks and isolate themselves.

**Case Study - H1N1 Pandemic**

From 2009 to 2010, Ontario and many other parts of the world experienced its first pandemic in more than 40 years. In April 2009, the first cases were being reported in Mexico and the United States. The rapid spread of the virus and its appearance in other countries resulted in the World Health Organization declaring a global pandemic on June 11, 2009. The pandemic was caused by influenza A virus subtype H1N1, which is commonly referred to as ‘swine flu’ or simply as H1N1.

First Nations Peoples, pregnant women, people suffering from obesity and people with compromised immune systems were identified as high risk for severe illness. The elderly were also at first warned that they may be especially vulnerable; however, it was later found that people born prior to 1957 already had some immunity towards the virus due to exposure to a similar strain.

There were at least 8,633 confirmed cases of H1N1 in Ontario, however, many other cases went unconfirmed and many people were able to recover without medical intervention. One hundred and twenty-eight people died due to the virus or complications related to the virus in Ontario.

( Ministry of Health and Long-Term Care, 2010)
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Hurricane

Definition

‘Hurricanes are tropical cyclones with maximum sustained surface winds of at least 118 kilometers per hour. Hurricanes are known as typhoons in the western Pacific, very severe cyclonic storms in the North Indian Ocean, and severe tropical cyclones in Australia. There are 5 classes of hurricane intensity as outlined by the Saffir-Simpson Scale’ (Environment Canada, 2010).

Description

In North America, the hurricane season runs from June to the end of November, with the peak from August to October. Hurricanes are not a localized phenomenon since they can last longer than two weeks if they are over open, warm water and can trek across the entire eastern seaboard (EMO, 2005). There are several requirements for the formation of a hurricane: it must form over ocean water at least 500 km from the equator with a temperature of at least 26.5°C; there must be sufficient atmospheric instability and the winds from sea level to about 9 km in altitude must not vary significantly in speed or direction.

A satellite image of Hurricane Isabel southeast of Ontario (NOAA, 2009)

Hurricanes are associated with high winds, extreme rainfall, storm surges, thunderstorms and tornadoes. Since hurricanes are not small-scale events, their effects can extend for hundreds of miles inland. The storm surge is often the most damaging part of the storm.

- A tropical storm is ‘a named storm with characteristics of a tropical nature as well as maximum sustained wind speeds of between 63 and 117 km/h (EMO, 2005).
- A post-tropical storm is a named storm that is losing or has lost its tropical characteristics (EMO, 2005).

The high winds of tropical storms and post-tropical storms are accompanied by heavy rain and sometimes, thunderstorms. Hurricanes do not produce hail and do not always produce lightning, although thunderstorms can occur along fronts that the hurricane
moves into during the transition to post-tropical. Since the hurricane has weakened significantly, tornadoes spawned by these storms are very rare but still a possibility.

In North America, the hurricane season runs from June to the end of November, with the peak from August to October. Hurricanes are not a localized phenomenon since they can last longer than two weeks if they are over open, warm water and can trek across the entire eastern seaboard (EMO, 2005). There are several requirements for the formation of a hurricane: it must form over ocean water at least 500 km from the equator with a temperature of at least 26.5°C; there must be sufficient atmospheric instability and the winds from sea level to about 9 km in altitude must not vary significantly in speed or direction.

**Provincial Risk Statement**

Southern Ontario experiences the greatest risk of hurricane/post-tropical storms in Ontario due to its location. A hurricane is a large storm system that may be capable of affecting all of southern Ontario and may even extend into the lower part of northern Ontario depending on the storm track. This coincides with the area of highest population and infrastructure density in Ontario.

Due to Ontario’s geographic position, hurricanes have almost always decreased to tropical storm strength or lower by the time they reach Ontario. Generally, hurricanes that move over land decrease to half of their wind speed intensity approximately every 12 hours. Although these named storms can reach Ontario, they are generally weakened and are often downgraded into either a ‘tropical storm’ or a ‘post-tropical storm’. Transition to a post-tropical storm does not always imply the storm is a downgraded threat however. Very heavy rainfall can still occur well inland, and in Eastern Canada, these types of storms can actually intensify during their transition to post-tropical (cf. Igor, 2010 in Newfoundland – Canadian Hurricane Centre). It is only through this post-tropical re-intensification that hurricane-force winds from a previous tropical storm or hurricane are possible in Ontario; otherwise the standard wind diminishment after landfall would apply and not permit a storm to maintain hurricane status as far inland from the Atlantic Ocean as Ontario.

On occasion, a weakened hurricane will collide with another storm system or weather front resulting in a strengthened storm. This happened in 1954 with Hurricane Hazel which is the only recorded tropical storm that brought sustained hurricane strength winds to Ontario. Even a weakened storm can still result in extreme precipitation, storm surges, flooding and strong winds.

Social vulnerability to hurricanes/extra-tropical storms has decreased greatly due to revisions to the Building Code and improvements in floodplain management practices since Hurricane Hazel in 1954. Fatalities and injuries are most likely to be caused by flooding or the storm surge. Tornadoes spawned by the hurricane may result in additional fatalities.
Ontario property and infrastructure is moderately vulnerable to hurricanes/post-tropical storms. Hurricanes can cause extensive property damage mostly from flooding and the high winds. Common damage includes flooded buildings, downed power lines, sewage backup, downed trees, damage to roofs and other forms of wind damage. Roads and rails may be impassable due to debris.

The environment and the business/finances of Ontario are not especially vulnerable to hurricanes/post-tropical storms. Environmental damage is usually more severe with a salt water storm surge, rather than the fresh water of the Great Lakes. Contaminated flood waters may result in some environmental contamination. The majority of hurricanes that have affected Ontario in the past have caused little to no business/financial interruption with the exception of Hurricane Hazel. Road closures and power outages may hinder financial activities.

**Case Study Hurricane Hazel**

In 1954, a weakened hurricane collided with a storm system and resulted in a strengthened storm referred to as ‘Hurricane Hazel’. Hurricane Hazel is the only recorded tropical storm that has caused sustained hurricane force winds in Ontario. The storm caused severe flooding in Southern Ontario. The Greater Toronto Area experienced the worst flooding in 200 years from this storm. Many bridges and houses were destroyed. The storm and its associated flooding resulted in 81 deaths and an estimated 7472 people were evacuated.

The impact of Hurricane Hazel in 1954 resulted in the implementation of various preparedness and mitigation measures in Ontario to lessen the effects of other hurricanes in the future. These have included (but are not limited to): monitoring and warning systems and flood plain development regulations.

(Canadian Disaster Database, 2005)

**Land Subsidence**

**Definition**

‘The sudden sinking or gradual downward settling of land with little or no horizontal motion, caused by a loss of subsurface support.’ (New York City, 2009).

**Description**

Land subsidence can be caused by natural or human activities such as the removal of groundwater, below surface mining and the pumping of oil (New York State, 2008). The removal of material from below the surface causes the land to settle downward creating a ‘sinkhole’. These can range from being barely detectable on the surface to being hundreds of feet in diameter.

The risk level for land subsidence depends on several factors:

- The type of soil and/or rock – areas with carbonate karst are more susceptible.
- The natural and human induced fluctuations of groundwater.
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- Underground human mining activities and the natural processing of rock.

Heavy precipitation on August 19th, 2005, resulted in a sinkhole that damaged Finch Avenue in Toronto (EMO, 2005).

Areas with mildly acidic groundwater with limestone, dolostone, marble or gypsum bedrock (karst) are more prone to land subsidence. The acidity of the groundwater dissolves the soluble karst resulting in sinkholes, springs, and caves and sinking streams. Land subsidence often occurs after a heavy precipitation event or during a rapid snowmelt (New York State Geological Survey). A positive feedback cycle may occur with the removal of the underlying, supporting rock creating further subsurface weakness and triggering other collapses. Land subsidence is a small scale hazard.

**Provincial Risk Statement**

Southern Ontario up to the boundary of the Canadian Shield has a large amount of karst bedrock. While mining is not particularly widespread in this area, human activities in particular have resulted in past land subsidence events. This large sinkhole measured five meters across and was fourteen meters deep. It was believed that a faulty storm drain underground and heavy precipitation triggered this event (The Ottawa Citizen, 2009).

The human population and the environment of Ontario are not particularly vulnerable to land subsidence since this is a small scale hazard which rarely results in fatalities. Land subsidence rarely results in fatalities or injuries. A couple of fatalities have been recorded around the world and generally occurred when a person stepped on a sinkhole that was in the process of just beginning to show surface signs of caving in. However, due to the relatively small scale of these events and the gradual widening of the hole, which is visible, deaths are unlikely.

Property and infrastructure, however, is much more vulnerable. Land subsidence has been known to result in property and infrastructure damage. Underground lines and
pipes may be damaged by the sinkhole resulting in a loss of water, internet service etc. to buildings in the area of the hazard. Large events have caused damage on the surface to buildings and roads. If the sinkhole is large enough, it may undercut a building enough that the building collapses into the sinkhole. Business/financial interruption is not normally associated with land subsidence, although an event that is large enough to damage subsurface infrastructure, such as water pipes may impact some of the local businesses.

**Case Study Toronto Sinkhole 2005**

On August 19th, 2005 heavy precipitation over Toronto caused the water level of the Black Creek to rise. The aging storm drain was unable to handle the increase in the volume of water, causing a section of Finch Avenue West, east of Dufferin Street to collapse. The resulting sinkhole was approximately seven meters deep. While large sinkholes have been recorded, the location of this one (on a heavily used expanse of road) and the depth of the pipe needing repair complicated the response. Two lanes of the four lane road were reopened in late 2005; however, the remaining lanes were not reopened until April 2006.

*(The Toronto Star, 2005)*

**Landslide**

**Definition**

*‘Movement of a mass of soil (earth or debris) or rock down a slope.’* (Cruden, 1991).

**Description**

The basic cause of a landslide is that geological material (rock, soil or debris) moves down-slope under the influence of gravity. However, if the geological material is particularly weak, sensitive or saturated with water, gravity can play a less important role. The specific causes; speed and type of movement of a landslide depend on the specific geology and topography of the region.

*The St. Jude, Quebec landslide in 2010 claimed the lives of a family of four who were buried in mud and debris in the basement of their home (Natural Resources Canada, 2010)*
Landslides can move in a variety of ways ranging from free fall, end-over-end toppling, sliding between relatively intact masses of other geological material, to the liquid-like flow of completely disintegrated materials. Many landslides display more than one type of movement, evolving from one to the next depending on the amount of disintegration and saturation to which the moving mass of rock, debris or soil is subjected. Some landslides move only short distances, coming to a stop near the base of the slope, while others can travel several kilometres from their point of origin. Some landslides can trigger additional landslides. While the majority of landslides that affect human populations occur on land, landslides can also occur underwater. The term ‘landslide’ encompasses many types of either fast or slow moving downward ground movement including:

- **Rock-falls** - detached movement of rock from a steep slope along a surface on which little or no shear displacement occurs; material then typically descends by falling, bouncing or rolling.
- **Debris flows** - type of landslide characterized by fast moving, unconsolidated, saturated debris; open-slope debris flows occur unconfined on a hill-slope; confined debris flows occur in a pre-existing channel.
- **Earth flows** - type of landslide characterized by slow to rapid movement of saturated earth in a liquid state.
- **Slumps and slides** – Down-slope movement of a soil or rock mass occurring dominantly on surfaces of rupture or relatively thin zones of intense shear strain. The failure surface can be planar or circular.
- **Earth spreads** – Extensional movement of a cohesive soil or rock mass combined with a general subsidence of the fractured mass of material into a softer underlying material; surface of rupture is not a surface of intense shear; spreads can result from liquefaction or flow (and extrusion) of the softer material. This type of landslide occurs in area with sensitive postglacial marine clay deposits, such as those near Ottawa, informally known as Leda Clay.

The cause of a landslide differs from its trigger. The ‘cause’ prepares the slope for a ‘trigger’ to put it into a state of movement. Landslides are often caused by events such as shoreline or riverbank erosion, floods, earthquakes etc., or by human activity (mining, construction, etc.). More than a third of landslides are triggered by heavy precipitation or snowmelt events. Landslides also commonly occur after vegetation has been destroyed; either by an event such as a forest fire or human activity; since there is no longer anything to hold back the soil.

**Provincial Risk Statement**
Ontario has relatively few major landslides when compared to provinces with steeper topography, such as British Columbia. However, significant landslides do sometimes occur in Ontario. At least seven landslides in Ontario have reportedly resulted in a loss...
Landslides are more frequent in areas of Ontario with unstable, steep slopes, or postglacial marine clay deposits and those with karst topography (EMO, 2005). Areas that have undergone rapid and expanse construction are also more at risk of a landslide since construction practices can alter some of the physical characteristics of a hillside.

The only recorded landslides in Ontario that resulted in fatalities occurred at Capreol (4 fatalities) and Crerar (8 fatalities) in 1930. These fatalities did not occur as a direct result of the landslides, but as a result of the subsequent train derailment. However, in other provinces landslides have directly resulted in fatalities and injuries so the possibility cannot be ruled out for Ontario.

Depending on the severity and type of the landslide, property damage can be severe, with buildings being completely removed from their foundations or crushed. However, the damage is normally fairly localized. Landslides can also destroy rail lines and roads potentially resulting in train derailments, traffic accidents and may prevent emergency vehicles from quickly reaching the affected site. Both above and below ground utilities may be affected including electricity, gas, sewage and water. (Boulder OEM, 2009).

Landslides alter the landscape of the affected area. Land is destroyed or altered both above and below the slope. If the debris from a landslide crossed a river, it may dam the river and either alter its course or create a lake or pond. Potential collapse of the debris dam presents another hazard. Underwater landslides may generate large waves that can cause damage on shore. Vegetation may be uprooted or crushed.

Since landslides tend to be a localized event in Ontario, they are unlikely to cause a business/financial interruption in most cases. However, should one occur in a populated area a small number of stores may be damaged. The secondary hazards, such as loss of electricity associated with a landslide are more likely to cause a disruption to local businesses. If the landslide damages or destroys an important rail line or transportation artery, the effects of the landslide may be felt at a greater scale.

**Case Study - Lemieux 1993**

Geologic studies in 1991 found that the town of Lemieux was in an area that faced a high risk of landslides. In order to avoid a future emergency, the town was preemptively relocated. Two years later, a landslide covered 17 hectares of agricultural land adjacent to the former town and blocked a nearby river for several days. The direct and indirect costs were estimated to be $12,500,000. (Canadian Disaster Database, 2005)
Lightning

Definition
‘Lightning is a large static discharge that develops most commonly within thunderstorms where convection and gravitational forces combine with an ample supply of particles to generate differential electrostatic charges’ (Clodman and Chisholm, 1994).

Description
The majority of lightning is produced by thunderstorms. The conditions required for thunderstorm growth; atmospheric instability, moisture and a rising mechanism, can lead to its development. Lightning is caused by the build up of particles with different electrostatic charges. The attraction between the positive charges in an object on the surface and negative charges in the base of a cloud results in the build up and discharge of electrical energy as lightning which can carry up to 100 million volts of electricity (EMO, 2005).

Lightning can occur from cloud-to-ground (referred to as ‘CG’ lightning) or cloud-to-cloud (referred to as ‘CC’ lightning). Lightning tends to strike higher elevations and tall structures since it is drawn to the shortest path to the ground. It also has a tendency to strike objects made out of materials that are good conductors of electricity, such as metals. Storms that produce lightning may also produce extreme precipitation, high winds, hail and tornadoes.

Provincial Risk Statement
Southern Ontario along with southern Saskatchewan and the foothills of Alberta has the highest frequency of lightning strikes in Canada. The number of days with lightning varies greatly across the province with the highest frequency (34 days a year) in southwestern Ontario to 15-20 days per year in northern Ontario (Phillips, 1991). Lightning is a localized, small scale hazard.
In general, the areas with the highest frequency of lightning activity happen to be some of the areas with the greatest population density. This area also includes many outdoor areas such as golf courses and beaches which attract a large number of people during the summer months. People who are outdoors are at a greater risk of being struck by lightning. Large outdoor gatherings, such as concerts and football games are also at risk since they often are held in a large open area. The charge from a strike can travel through wet ground and puddles resulting in multiple injuries and/or fatalities. The majority of lightning activity occurs from May to October in Ontario. July has more days with lightning than any other month, during which south-western Ontario may experience thunderstorms every four days or so (Phillips, 1991). Records show that the two-year average for emergency room visits due to lightning related injuries in Ontario is 2.5 times greater than all reported admissions in the rest of Canada. More than 60% of the fatalities and 65% of the injuries reported in Canada occur in Ontario (Mills et al., 2008).

Due to the small scale nature of this hazard, Ontario’s population is only slightly vulnerable to lightning. A lightning strike is a localized phenomenon. Because of this it often results in only one fatality at a time. However, given the proper conditions such as a large gathering of people outdoors standing on wet ground without adequate shelter,
There are several ways in which lightning can strike a person:

1. The lightning directly strikes a person.
2. The electrical current from the strike travels from an object touching a person into the body. This is referred to as contact voltage.
3. Splash or flashover voltage occurs when lightning strikes an object and then arcs to a person nearby.

Step voltage refers to when the current strikes the surface and fans out through the ground (Mills et al., 2008).

Lightning can result in fatalities and injuries in several ways:

1. It can send the heart into cardiac arrest or displace the normal rhythm of the heart.
2. Breathing can be stopped by either the paralysis of the chest muscles or by damage to the brain stem.
3. Infection due to severe burns on the skin.
4. Blunt trauma may be caused by the person/s being thrown by the force of the shock wave generated by the strike.

Indirect causes of fatalities and injuries may include:

1. Projectiles by the explosion of tree branches and bark due to the sudden vaporization of water in vegetation may cause trauma. Fires caused by the lightning strike.

Survivors of lightning strikes may be left with chronic injuries such as neurological damage, loss of hearing, psychological problems including memory problems, chronic pain and cataracts.

Ontario’s property/infrastructure, environment and business/finances are not especially vulnerable to lightning. Many buildings, particularly those at risk of lightning strikes are grounded to avoid damage. Any property or infrastructure damage due to lightning tends to be localized. Damage may include: damage to roofs and electrical systems and appliances, burn marks, damage to vegetation and fire damage ignited by the strike.
Like property and infrastructure damage, environmental damage is localized. Trees may be split or suffer bark damage. Any business or financial interruption due to lightning is normally either localized or caused by the secondary hazard of blackouts.

**Case Study - Lightning in Brampton 2009**

On August 12th, in the mid-afternoon, a small, weak thunderstorm that developed quickly northwest of Toronto. One of the lightning bolts from the storm struck and killed a 5-year-old boy and injured his mother and another child. Since it was a weak thunderstorm, it did not warrant a weather warning. Lightning left a metre-deep hole in a soccer field just in front of the goal posts and knocked six people off their feet. (Environment Canada, 2010)

**Natural Space Object Crash**

**Definitions**

**Comet:** “Comets are bodies of ice, rock, and organic compounds that can be several miles in diameter” (NASA, 2010).

**Meteorite:** A rocky or metallic body (mainly nickel and iron) from an asteroid or a meteoroid that “survives its passage through the Earth's atmosphere and lands upon the Earth's surface” (NASA, 2010).

**Description**

Comets and asteroids (which are referred to as meteorites if they impact the Earth’s surface) vary in size. The vast majority of these objects are small enough to burn up in the atmosphere and do not reach the surface. According to NASA (2010), more than 100 tons of dust and sand grain-sized particles from comets and asteroids enter the Earth’s atmosphere each day. However, some objects can be hundreds of kilometres in diameter. These space objects are only a threat if they are identified as Near-Earth Objects.
Comet Siding Spring appears to streak across the sky like a superhero in this new infrared image from NASA's Wide-field Infrared Survey Explorer. The comet, also known as C/2007 Q3, was discovered in 2007 by observers in Australia.

A comet or asteroid is considered to be a Near-Earth Object (NEO) if its orbit allows them to pass near the Earth. According to NASA’s Near-Earth Object Program, as of January 10th, 2010, 6671 NEOs have been identified, 1085 of which have a diameter of 1km or greater. 146 of these are classified by NASA as ‘Potentially Hazardous Asteroids’ which have the potential to make ‘threatening close approaches to the Earth’ (NASA, 2010). This does not mean that the asteroid will collide with the Earth; it simply means that there is a risk.

Space objects have impacted the Earth in the past and will continue to do so in the future, however, in general large impacts are rare. It is estimated that an object greater than 50 m in diameter impacts the Earth’s surface approximately every 100 years. An impact of this size would be disastrous on a local scale. An impact capable of causing global disasters, which would be causes by an object greater than a mile wide, is estimated to occur every few hundred thousand years.

**The Torino Scale**

<table>
<thead>
<tr>
<th>Risk</th>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>No hazard</td>
<td>0</td>
<td>The likelihood of a collision is 0 or is so low as to be effectively 0. Also applies to small objects such as meteors and bolides that burn up in the atmosphere as well as infrequent meteorite falls that rarely cause damage.</td>
</tr>
<tr>
<td>Normal</td>
<td>1</td>
<td>A routine discovery in which near the Earth is predicted that poses no unusual level of danger. Current calculations show the chance of collision is extremely unlikely with no cause or</td>
</tr>
<tr>
<td>Level</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>-------</td>
<td>-------------</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>A discovery, which may become routine with expanded searches of an object making a somewhat close but not highly unusual pass near the Earth. While meriting attention by astronomers, there is no cause for public attention or public concern as an actual collision is very unlikely. New telescopic observations very likely will lead to a re-assignment to Level 0.</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>A close encounter meriting attention by astronomers. Current calculations give a 1% or greater chance of collision capable of localized destruction. Most likely new telescopic observations very likely will lead to a re-assignment to Level 0. Attention by the public and public officials is merited if the encounter is less than a decade away.</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>A close encounter meriting attention by astronomers. Current calculations give a 1% or greater chance of collision capable of regional destruction. Most likely new telescopic observations very likely will lead to a re-assignment to Level 0. Attention by the public and public officials is merited if the encounter is less than a decade away.</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>A close encounter posing a serious, but still uncertain threat of regional devastation. Critical attention by astronomers is needed to determine conclusively whether or not a collision will occur. If the encounter is less than a decade away, governmental contingency planning may be warranted.</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>A close encounter posing a serious, but still uncertain threat of global catastrophe. Critical attention by astronomers is needed to determine conclusively whether or not a collision will occur. If the encounter is less than three decades away, governmental contingency planning may be warranted.</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>A very close encounter by a large object, which if occurring this century, poses an unprecedented but still uncertain threat of a global catastrophe. For such a threat in this century, international contingency planning is warranted, especially to determine urgently and conclusively whether or not an impact will occur.</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>A collision is certain, capable of causing localized destruction for an impact over land or possibly a tsunami if close offshore. Such events occur on average between once per 50 years and once per several 1000 years.</td>
<td></td>
</tr>
</tbody>
</table>
| 7     | A collision is certain, capable of causing unprecedented regional devastation for a land impact, or the threat of a
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Table 3. The Torino Scale for assessing asteroid/comet impact predictions (NASA, 2010).

An impact capable of endangering human civilization and resulting in a potential global climatic catastrophe (Torino Scale 10) is estimated to occur once per 100,000 years or less. An extreme impact which would result in mass extinctions (not included in the Torino Scale) is believed to only occur approximately every several million years (NASA, 2010). Not only does an impact create a crater in the Earth’s surface, but it can cause damage in other ways. The force of the impact can create an extremely hot plume of vapour that can be strong enough to vaporize rock at the impact site and which can create a ‘fireball’ that can cause additional fires. The high pressures in the atmosphere due to an impact can generate a shock wave and violent winds. The force of the impact can also generate seismic waves which can lead to strong ground shaking (G.S. Collins et al., 2004). Not all objects actually strike the ground. Some explode above ground as they enter the atmosphere. This creates a shock wave and a blast wave that radiates outwards. This is thought to be what happened in Tunguska, Siberia in 1908. The explosion resulted in an area of destruction approximately equal to the sizes of London, Moscow and Berlin added together (Mariga, 2008). Fortunately, this area was remote with few inhabitants and none believed to have been near the impact site. Approximately 2,200 km$^2$ of forest was felled and charred (Mariga, 2008). If an event similar to the Tunguska event happened over a city, it is estimated that the blast wave may be strong enough to level buildings and structures, and damage others further away from ground zero (Mariga, 2008).

Many of the objects that have successfully passed through the atmosphere have fallen over the ocean. Depending on the size of the object, tsunamis may be generated. Scale varies greatly for this hazard, from the small scale to the extremely large scale. A significant event would most likely be a large scale event.

**Provincial Risk Statement**

Comets and meteors have impacted the Earth in the past and will continue to do so in the future. However, large impacts are extremely rare events. Smaller objects strike the Earth more frequently (although they can still be considered rare events) but due to the size of the Earth, are still unlikely to harm Ontario. The location of the impact depends on the rotation of the Earth and the trajectory of the object. However, should a large object impact the Earth’s surface, the impact would be severe. If a smaller object, such as the size of the object that caused the Tunguska event (which occurred in a remote area and knocked over an estimated 80 million trees over 2,150 square kilometers)
Impact or explode over a major urban centre, then the centre would essentially be
destroyed. It is estimated that objects approximately this size enter the Earth’s
atmosphere approximately once every three hundred years. Once again, even should an
object this size pose a threat, there is no certainty that it would impact Ontario. (NASA,
Near Earth Objects, 2010).

While this is an extremely rare event, the population of Ontario is very vulnerable to a
natural space object crash due to the potential force of the impact. If a large object
were to impact a major metropolitan area, the social impacts would be very large. There
would likely be many fatalities due to the impact, the fireball and the shockwave. Near
the epicentre of the impact, it is likely that there would be a large number of fatalities
and few, if any, survivors. Further from the epicentre, fewer fatalities and more injuries
can be expected. Fires started from falling debris and ruptured gas lines may result in
addition fatalities and injuries. It is important to note, that the odds of an object of this
magnitude impacting an urban centre are extremely small. A large impact could have a
severe business/financial impact depending on the location of the impact. Power
outages in areas away from the epicentre would further increase the severity of the
interruption.

Property is also vulnerable to a natural space object crash. The impact, the fireball and
the shockwave can all cause property damage. At the epicentre of the impact, it is
possible that all structures will be vaporized or levelled. Critical infrastructure would
also be severely damaged. The severity of the damage will decrease with distance from
the epicentre. Depending on the size and trajectory of the object, environmental
damage may be isolated to local damage or may have global impacts. It is widely
believed that space object impacts have caused mass extinctions in the past, with
perhaps the most famous event responsible for the demise of the dinosaurs 65 million
years ago (Alvarez et al., 1980). It is believed that the impacts large enough to trigger
mass extinctions had long term impacts on the environment such as the altering of the
climate. It is theorized that debris from the impact ejected into the atmosphere would
block some of the sunlight and caused acid rain (NASA, 2010). Many plant species would
be unable to photosynthesis enough in order to survive. This in turn would impact
animal life. Water bodies could become contaminated with ash and debris, harming
aquatic ecosystems.

Space object collisions have been the focus of several major Hollywood movies in the
late 1990’s and are the subject of countless other movies, books and other media. The
likelihood of a major impact in the view of the public appears to be a much greater risk
than what the scientific community has calculated. If an object that could potentially
collide with Earth is identified before impact, mass hysteria, food hoarding and other
negative psychosocial impacts are possible.

International Case Study- The Tunguska Event 1908
On the morning of June 30, 1908, a large asteroid estimated to be 120 feet across and
weighing approximately 220 million pounds entered the atmosphere over Siberia.
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2012
Approved
Scientific estimates have placed the speed of the object at approximately 33,500 miles per hour. An object of this size travelling at this speed would have heated the surrounding air to 44,500 °F. At a height of approximately 28,000 feet, the object exploded due to the heat and pressure. This explosion produced a fireball and released enough energy to be equivalent to 185 nuclear bombs.

At the moment of impact, a man 40 miles away at the trading post at Vanavara in Siberia was thrown from his chair on the front porch. He described the heat as being so intense that he felt as though his shirt was on fire. The explosion destroyed 800 square miles of remote forest. Eighty million trees were knocked over, pointing directly away from the blast's epicentre. However, the trees at the epicentre of the blast were left standing upright with their limbs and bark stripped away. Damage such as this requires fast moving shock waves that are capable of breaking off a tree's branches before the branches can transfer the impact momentum to the trunk of the tree. Branchless trees similar to this would be found at the site of another massive explosion -- Hiroshima, Japan.

Fortunately, the area the explosion occurred in was fairly remote so no fatalities were reported with the exception of hundreds of domesticated reindeer. The explosion was so powerful that the shockwave registered on sensitive equipment as far away as England. (National Aeronautics and Space Administration, 2008).

**Snowstorm/Blizzard**

**Definitions**

**Snowstorm:** “A period of rapid accumulation of snow, often accompanied by high winds, cold temperatures, and low visibilities.” (Government of Michigan, 2001).

**Blizzard:** “The most violent winter storm, combining strong winds with cold temperatures and blowing or drifting snow, which reduces visibility to zero.” (Phillips, 1991)

**Description**

Snowstorms and blizzards generally occur during the winter but have been known to occur in the late fall and early spring in temperate climates. They are storm events in which the dominant form of precipitation is snow. At temperatures below freezing the density of snow is less dense than the density of liquid water. As a result, a storm that would have produced 2 cm of rain during the summer has the potential to produce 20 cm of snow during the winter, although there can be large variations depending on factors such as the type of snow (e.g. light, fluffy snow or wet, heavy snow) (Klaassen, 2010).

Environment Canada Ontario can issue several different warnings for snow-related events (Environment Canada, 2009):
Heavy Snow Warning: 15cm or more of snow is expected to fall within 12 hours.

Winter Storm Warning: greater than 25cm of snow is expected to fall within twenty-four hours or forecasters expect 2 or more of the weather conditions listed as potential warnings to occur. For instance, if more than 15cm of snow was expected to be accompanied by strong winds of more than 60km/h.

Snow Squall Warning: issued for areas to the lee of large bodies of water when 15cm of snow or more is likely to fall in 12 hours or less OR when the visibility is likely to be near zero in snow and blowing snow for four hours or more, even without warning levels of snowfall accumulation. These conditions usually are short in duration, however, some can be prolonged and if they occur in the same location, they can result in higher snowfall amounts.

Blizzard Warning: issued when all of the following conditions are expected to occur and last for four or more hours;
• Winds of 50km/h or more
• Visibility of 1km or less in snow and blowing snow.
• Wind chill values of –35 or lower

Unlike severe summer storms, severe winter storms are normally forecast well in advance. Winter storm warnings issued more than twelve hours before impact are not uncommon.

Provincial Risk Statement
While severe weather during the summer tends to be localized, winter severe weather can sometimes affect the entire province. Blizzards are fairly rare in Ontario with Toronto experiencing an average of three blizzard hours per year and Ottawa experiencing 4.5 (Phillips, 2001). Snowstorms are much more common. Central Ontario experiences 6 – 12 days per year with more than 10 cm of snowfall. Areas to the west and east of Georgian Bay tend to have the greatest number of snowfalls of greater than 25 cm in a day with some areas experiencing 1.2 days per year.
Areas downwind of the Great Lakes are prone to lake-effect snow between November and February (Kunkel, Westcott and Kristovich). Lake-effect snow refers to heavy, usually localized snow squalls which are generated by the difference in temperature between the cold air and the warmer water of the lakes. Conditions that can lead to the development of heavy lake-effect snow include a low pressure system and a ‘cold temperature anomaly...north of the Great Lakes’ (Liu and Moore, 2004). Snowstorms and blizzards may differ greatly in size. Some are fairly localized (e.g. lake effect snow) while others may span a significant portion of the Province.

People in Ontario are slightly vulnerable to snowstorms and blizzards. Familiarity with this hazard, as well as advanced forecasting has helped to decrease the population’s vulnerability. People trapped outside, in their vehicles or in isolated shelters without adequate heating may suffer from hypothermia. While hypothermia can directly result in fatalities and injuries through hypothermia, indirect causes of fatalities and injuries during snowstorms and blizzards are more common. Indirect causes include:

- structural roof collapse due to the weight of the snow (usually due to the accumulation of snow from more than one storm)
Hazard Identification and Risk Assessment for the Province of Ontario

- disruption of critical infrastructure
- major traffic accidents
- fire or carbon monoxide poisoning from alternate and/or unsafe heating sources
- physical overexertion
- flooding

The Building Code has reduced the vulnerability of property in Ontario to snowstorms and blizzards. Buildings that have not followed this code risk the collapse of roofs under the weight of the snow. Flat roofs are more vulnerable than sloped ones. Power and transportation infrastructure, however, faces a moderate to high vulnerability. Wet snow and/or the winds can cause tree limbs to snap, which can result in power outages. Power restoration can be hampered by unplowed roads. Without power, many buildings will not have a source of heat. Road, rail and air transportation can be brought to a halt during a blizzard or snow storm. Heavy snowfall may also make unplowed roads impassable. Poor visibility may further hamper transportation conditions.

Snowstorms and blizzards are a natural reoccurring hazard in Ontario. As a result, the majority of the native flora and fauna are well adapted to survive the impacts of such a storm. Animals that do not hibernate at this time of year may have some difficulty reaching sources of food. Dead trees may be toppled under the weight of snow and may result in some damage to living trees if they strike them while falling.

Businesses in Ontario are moderately vulnerable to snowstorms and blizzards. A large and prolonged snowstorm or blizzard can cause significant business and financial interruption. Since these storms can be quite big, a large portion of the province can be affected. Heavy snowfall and poor visibility may prevent people from coming to or leaving from work. The power outages that are frequently associated with these storms can result in further disruption.

**Case Study - Snowstorm 2010**

A heavy snowstorm stranded 237 drivers and passengers on Highway 402 near Sarnia, Ontario. The Ontario Provincial Police, Canadian Forces personnel and military helicopters were called in to rescue the stranded people who required assistance. A greater number of people were initially trapped; however, some people were able to leave the area on foot, abandoning their vehicles. Others, who had sufficient emergency supplies, chose to wait out the storm in their vehicles. Two hundred tractor trailers and 124 cars were trapped.

Several shelters and warming centers were set up to assist those affected by storm. Individual members of the community also helped by allowing people who were stranded by the storm to stay at their houses.

(Environment Canada, 2010)
Tornado

Definition
A violently rotating column of air, in contact with the ground, either pendant from a cumuliform cloud or underneath a cumuliform cloud, or often (but not always) visible as a funnel cloud (Glickman, 2000).

Description
Special atmospheric conditions are required for the formation of a tornado. The atmospheric conditions required vary slightly depending on the type of tornado, but essentially all tornadoes require low-level moisture, atmospheric instability and a lifting mechanism. These conditions can be met when a cool air mass from the north collides with warm, moist air from the south, forcing the warm air to rise quickly. As the warm, moist air rises, the water vapor in it begins to cool and condense. If the conditions are right, severe weather will form possibly including severe thunderstorms and/or tornadoes. Tornadoes can also be formed from thunderstorms embedded within hurricanes. The next step, the formation of the tornado itself, is still not fully understood. It is an area of current research e.g. VORTEX2

Tornadoes can be classified into one of two categories, depending on the type of storm that generates them: supercell tornadoes and non-supercell tornadoes. A supercell is a highly organized storm that can last for longer than one hour. Its defining characteristics include an intense updraft co-located with strong storm rotation in the vertical. However, a strong rotating updraft is not the only requirement for tornado formation since as many as 80% of all supercell thunderstorms do not produce a tornado (NSSL, 2010) and tornadoes can develop in non-supercell storms.
supercell tornadoes often begin as vertically spinning air near the ground caused by local windshear. The windshear can develop along boundaries between different regional air masses. When an updraft moves over the spinning parcel of air, it stretches the rotation vertically and intensifies it. This can result in a tornado.

Supercell tornadoes typically have a longer lifetime and have the potential to be violent. Non-supercell tornadoes, which include waterspouts, are generally weaker and shorter-lived than supercell tornadoes, but there have been exceptions to this in the past.

A simplified life cycle of a supercell tornado would begin with a funnel cloud forming at the base of a thunderstorm. Damage is then observed at the surface, even if the funnel cloud itself is not fully visible. The width of the tornado increases to its maximum size as it matures. At some point after this, the tornado begins to decrease in size that often results in a characteristic rope-like appearance. Even after the funnel cloud is no longer visible, a debris cloud and damage at the surface may still continue for a few seconds (Doswell, 2001).

However, tornadoes are dynamic hazards that may differ in how they are generated and the life cycle stages may not be clearly identifiable for all tornadoes. They can last for a few minutes or a few hours. It should also be noted that the appearance of the tornado does not indicate intensity. Some very large wedge shaped tornadoes have caused only slight damage while some small tornadoes have caused severe damage. While most tornadoes are much smaller, some, such as the Greensburg Kansas Tornado have been up to 2.7 km wide. Powerful storms can form multiple tornadoes or a multi-vortex tornado which is a single tornado with a number of smaller vortices within it (Environment Canada, 2010).

The high wind speeds and debris carried by the wind of the tornado are responsible for damage (Doswell, 2001). The intensity of a tornado is commonly assessed using the Fujita Scale (Fujita, 1981). The Fujita Scale uses damage to tornado intensity.

<table>
<thead>
<tr>
<th>Fujita Scale Number</th>
<th>Wind Speed (km/hour)</th>
<th>Type of Damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>64 - 116</td>
<td>Minor: May peel surface off of roofs; branches broken; shallow rooted trees pushed over.</td>
</tr>
<tr>
<td>1</td>
<td>117 - 180</td>
<td>Moderate: Broken windows, mobile homes pushed over or significantly damaged; most of the surface of roofs peeled off, exterior doors gone.</td>
</tr>
<tr>
<td>2</td>
<td>181 - 252</td>
<td>Considerable: Large trees snapped or uprooted, roofs torn off well built homes, frame homes may have their foundations shifted, light missiles generated.</td>
</tr>
<tr>
<td>3</td>
<td>253 - 330</td>
<td>Severe: Extensive damage to large buildings; cars thrown through air; all stories of well contrasted homes may be</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fujita Scale</th>
<th>Intensity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td><strong>Devastating</strong></td>
<td>Well constructed homes completely leveled; cars thrown; small missiles.</td>
</tr>
<tr>
<td>5</td>
<td><strong>Extreme</strong></td>
<td>Strong, well constructed houses removed from foundations and completely destroyed; steel reinforced concrete structures are badly damaged; car sized missiles thrown over 300 ft; high rise buildings experience significant structural deformation.</td>
</tr>
</tbody>
</table>

**Provincial Risk Statement**

Canada is second only to the United States in tornado frequency. According to Environment Canada, Ontario has an average of twelve tornadoes per year. However, this number can be deceiving as some tornadoes cause no damage to property, occur in unpopulated areas or simply go unreported. Southern Ontario experiences the greatest number of tornadoes in all of Canada (Etkin et al., 2001). This area also has the highest population density and the greatest amount of critical infrastructure in Ontario.

A 2003 study by King et al. suggested that lake-breeze circulations in Southern Ontario may be providing a trigger for the development of tornadoes. It was suggested that the lake breeze circulation may increase atmospheric moisture and wind shear, both of which are required for tornado development. This study also found a preferential corridor for tornado activity created by the suppression of thunderstorms over and downwind of the lakes, and enhanced moisture depth and wind shear between the lakes. This corridor extends to the west of Lake St. Clair and encompasses the cities of Windsor and Sarnia.

Tornadoes can occur at any time of the year and at any time of day. They are most common in Ontario from May to September, with a peak in occurrence in June and early July (Etkin et al., 2001). The majority of tornadoes occur in the afternoon and early evening.
The vast majority of tornadoes in Ontario are weak (ranking as F0 or F1 on the Fujita scale for tornado intensity). There have been no reported F5 tornadoes (the highest ranking on the Fujita scale) in Ontario. However, there is no evidence that suggests that an F5 cannot occur in Ontario. Four of the top ten most destructive tornadoes (up to June 2008) in Canadian history have occurred in Ontario (The Weather Doctor, 2008). Ontario is also not immune to tornado outbreaks, in which multiple tornadoes are reported.

On average, tornadoes in Canada result in two deaths and 20 injuries per year (University of Waterloo, 2010). However, the number of deaths and injuries can deviate significantly from the average if a strong tornado occurs in a populated area. The majority of deaths and injuries are caused by flying debris (NOAA, 2010).

Tornadoes can cause a wide variety of property and infrastructure damage, from broken windows to uprooted trees to the complete destruction of buildings. Houses, mobile homes and other buildings that are not anchored those without properly attached roofs and those that do not meet the guidelines of the National Building Code of Canada are especially vulnerable to damage. Several studies on the 1985 tornadoes in Barrie, in which eight people were killed and 155 were injured, found that more than 90% of the...
buildings in which the fatalities and/or injuries occurred did not have floors that were correctly anchored to the foundations and that the roofs were not securely fastened to the walls (Coping with Natural Hazards in Canada, 1996).

A tornado may result in power outages due to downed poles and power lines. In order to minimize the risk of an explosion, damaged properties often have their natural gas shut off. Roads may be blocked by debris preventing emergency vehicles from reaching the impacted area. Tornadoes have been known to topple huge swaths of forest and destroy orchards and field crops. Hazardous material concerns may arise after a tornado since the tornado may destroy a fixed site facility, destroy the container carrying the material during transport, and since debris including hazardous material can be carried a significant distance by the winds. Additional damage from hail, lightning and flooding may come from the same storm that produced the tornado. The Insurance Bureau of Canada has estimated the total damages from tornado disasters (as defined by the IBC) in Ontario from 1980-2008 to be $160 million.

A tornado is a fairly localized phenomenon; the largest are usually less than 2 km wide (Environment Canada, 2005) so the business/financial impacts are usually restricted to several businesses. However, there have been many instances in which nearly the entire financial district of small towns has been destroyed since they were in the path of the tornado. Since tornadoes can cause significant damage to buildings, recovery and restoration of a business to an acceptable level of activity may take quite a bit of time. Important documents, supplies and equipment can be destroyed or blown quite far away by the winds. Power outages caused by the storm increase the chances of business/financial interruption.

Case Study - Severe Weather Outbreak 2009
On August 20, 2009, Ontario experienced a tornado outbreak. On that single day, an estimated 10 million people in Ontario were in areas placed under a tornado watch or warning. The outbreak resulted in 19 tornadoes; which were rated, based on their damage as 5 F0s, 10 F1s and 4 F2s. One fatality, a young boy was reported at a conservation area. Given the number, location and the intensity of these storms, it was fortunate that more fatalities did not happen. At least 600 homes suffered damage; 38 had to be torn down. 69,000 people were without power at the peak of the storm. Major flooding was reported along the lakeshore.
(Environment Canada, 2010)

Windstorm

Definition
Windstorms can be defined as strong, non-tornadic winds that have the potential to cause damage in Ontario (Environment Canada, 2009).

Description
In Ontario, Environment Canada can issue two types of windstorm-related warnings:
High Wind Warning is issued when sustained winds of 60 km/h or more lasting at least 3 hours are forecast and/or any wind gusts of 90 km/h or more are forecast (Environment Canada, 2009).

A Severe Thunderstorm Warning may be issued since gusts of 90 km/h or greater are one of the criteria for a storm to be classified as severe. This warning is only issued if the winds are part of a thunderstorm.

Some of the more common types of windstorms are derechos and downbursts. A derecho is a large scale, sustained windstorm that is usually associated with a curved band of rain or thunderstorms referred to as “bow echoes”. In order to be classified as a derecho by the United States National Weather Service, a derecho must be a minimum of 240 miles in length and have wind gusts of greater than 57 mph must be reported at the majority of positions along the path of the derecho. The winds within a derecho can vary greatly from below 57 mph to greater than 100 mph. The sections of stronger winds within a derecho are caused by downbursts which can also occur in smaller scale and/or isolated thunderstorms.

A downburst is an especially powerful downdraft, a descending column of air which spreads out in all directions after reaching the surface (NWS, 2009). Downbursts originate from a thunderstorm. Downbursts are divided into two categories; macrobursts and microbursts depending on their size. Downbursts that occur over areas greater than 4 km are called macrobursts while those that occur over areas of less than 4 km are called microbursts. Downbursts can create straight-line wind damage so severe that it can easily be confused by the general public as tornado damage. Straight-line wind speeds from downbursts have been recorded at over 240 km/h.
Provincial Risk Statement

All most all areas of Ontario have experienced recorded wind speeds greater than 100 km/h, the majority of which were generated by weather systems such as thunderstorms, the passage of fronts, squall lines and low pressure systems. Windstorms can occur at any time of the year. If they occur during winter, they may be classified as a blizzard rather than a windstorm. November is the windiest time of year for the Great Lakes, but all of the records for one minute wind speeds have been recorded from June to August (EMO, 2005). Southern Ontario experiences the highest number of annual severe wind gusts, with Toronto experiencing an average of 7.2 days a year with wind gusts greater than 63 km/h. Windstorms can be a fairly large scale hazard depending on the strength and location of the pressure system causing the wind.

Figure 11. The total number of potentially damaging wind occurrences in grouped by Environment Canada Public Forecast Regions.

Although fatalities are possible during a windstorm, they are uncommon. The majority of fatalities and injuries are caused by crushing injuries from falling trees, building materials etc. and flying debris. People on boats risk drowning if the boat is capsized by the strong winds. Vehicles, especially trucks with a large surface area are more vulnerable to being blown over and causing injury to passengers. Mobile homes can be
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UNCLASSIFIED destroyed and are not a safe shelter during a windstorm. Microbursts have significantly contributed to past aircraft accidents.

The scale and severity of property and infrastructure damage depends on the wind speed and the area affected by the windstorm. Roads may be blocked by branches, fallen trees and other debris preventing emergency vehicles from accessing the affected area. Power lines and poles may be damaged resulting in a loss of electricity.

Windstorms together with tornadoes, hurricanes, extra tropical storms are responsible for the greatest number of insurance losses in Canada. The National Building Code of Canada (2005) provides standards that account for high winds. ‘The main building structure typically is designed for winds of 90+ km/h, which are then augmented by a 1.4 conversion factor to withstand wind gusts of 125+ km/h’ (The 2005 National Building Code of Canada). Since high winds pose a threat to aircraft, particularly during take off and landing, airports may delay or cancel flights for the duration of the windstorm.

Windstorms are a naturally occurring phenomenon that occurs every year. Particularly strong windstorms may result in significant tree damage, which may be mistaken for tornado damage. The degree of damage depends on the wind speed, the duration of the windstorm, the height of the trees and the exposure of the site (Foster and Boose, 1992). While some wildlife may lose some of their habitat due to the damage to forests, the majority of wildlife is not injured since they instinctively take shelter.

Windstorms normally do not cause a significant business/financial interruption. The greatest impact is usually felt by the air travel sector since aircraft cannot take off and land in high wind conditions for safety purposes.

Case Study - Southern Ontario Windstorm 2009

The day of August 9, 2009 began with high humidity and thunderstorms across southern Ontario. A severe line of thunderstorms with high winds developed just before noon. Wind gusts peaked close to 100 km/h through Orangeville-Caledon-Barrie-Coldwater-Cookstown and Aurora. Tree and hydro poles were knocked down by the wind which left more than 40,000 Hydro One customers without power. The winds were powerful enough to rip the roof off a house in Hamilton and a television antenna off of another house. Winds speeds of 96 km/h were recorded at Pearson International Airport. The high winds combined with hail and a brief power outage resulted in dozens of flights being delayed or cancelled. A woman seeking shelter under a dinghy at Port Franks was struck and killed by lightning.

(Environment Canada, 2010)

Technological Hazards

Technological hazards are hazards which arise ‘from the manufacture, transportation, and use of such substances as radioactive materials, chemicals, explosives, flammables,
Building/Structural Collapse

Definition

*The loss of structural integrity in a building or structure that results in the structure losing shape, caving in, flattened or reduced to debris.*

Description

Buildings and other structures such as bridges and transmission towers fully or partially collapse if the load-carrying capacity within the structure or of the structure as a whole is exceeded. The load-carrying capacity is exceeded when the building material is stressed beyond its limit. Collapse usually begins with fractures and deformations of the building or structure but may occur quickly so that these are not noticeable in time to evacuate. Buildings and structures may experience a complete or partial collapse. The collapse may be sudden or delayed.

Buildings and structures may exceed their load-carrying capacity due to the stresses of different causes:

- Fire
- Explosion
- Snow
- Ice
- High Wind
- Earthquake
- Material Flaws
- Design and Construction Flaws
- Deterioration

Building codes help to prevent building and structural collapses. The lack of strict building codes and the availability of proper construction materials is why building/structural collapses are more common in developing countries. While building collapses do infrequently occur in Canada, The Canadian Building Digest (CBD-147) states that while the risk of personal death or injury from this hazard does exist, it is less than the threat posed by building fires, automobile travel or smoking (EMO, 2005). Multiple sources have also stated that the risk of a building or structural collapse is greatest during construction or renovations.

Provincial Risk Statement

The Ontario Building Code was established in 1975 to provide standards for the design and construction of buildings. These standards have helped to reduce the risk of a building/structural collapse and in doing so, protect the public (MAH, 2002). The Ontario Building Code is applicable when the building is built and the standards are rarely applied retroactively (however, the Fire Code is retroactive). Since the Building Code...
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Evolves over time, there is no guarantee that a building will remain in compliance throughout its lifespan.

Ontario does experience high winds, freezing rain and heavy snow loads from time to time due to its geographic location. Most of these events do not result in a collapse. However, extreme events could exceed the threshold defined in the Building Code. However, the majority of building/structural collapses have been the result of errors in design or construction, rather than the exceedance of the loads (EMO, 2005). Building inspectors can require that repairs be made to buildings that are found to be unsafe; however, Ontario has many aging buildings that may not be immediately identifiable as being unsafe.

Other structures, such as bridges, are also vulnerable to damage and deterioration. Increases in the volume and weight of traffic can increase the rate of deterioration and subsequently, the risk of a collapse. Not all structures that risk collapse are large. Many smaller structures such as communications towers and utility poles can also collapse due to carrying-capacity exceedance. During the 1998 Ice Storm, many of these types of structures collapsed due to the weight of the ice that accumulated on them.

The vulnerability of the population to building/structural collapse depends on several factors:

- Type and use of the structure.
- Size of the structure
- Amount of time required to rescue trapped people

A building with a high occupancy rate or a busy bridge would result in many more casualties than a communications tower should it collapse. Time is another factor that can contribute to the number of fatalities. According to HUSAR (2010) “the rate of survival for person rescued from a collapsed building drops dramatically day by day over the first four to five days, after which the prospects of survival are extremely unlikely”. A Heavy Urban Search and Rescue Team (HUSAR), specializes in building collapses in order to provide rescue and to stabilize the structure to prevent further collapse. Their training and practices can assist in lower the response time and increasing the chances of survival of people trapped in rubble. Toronto is one of the four cities in Canada with a deployable HUSAR team. In the event of a fast collapse, no one population group is more vulnerable than another. For a slower collapse in which the signs show that a collapse is imminent, the physically disabled are most vulnerable.

A building/structural collapse is usually an isolated occurrence, unless it occurs as a secondary hazard due to an event such as an earthquake. The immediate building is affected, as well as any other structures that are within the collapse zone: the area that is likely to experience falling debris. Property damage is generally restricted to this area. Some infrastructure damage may occur if the collapse debris blocks a road or topples power lines; however, this damage is usually also local.
The environment is not vulnerable to building collapse in part because it is usually an isolated incident and generally occurs in areas that have a greater density of buildings. The business/financial impact depends on the type of building or structure that collapses. Since this is a localized incident, the impact is usually small.

**Case Study - Ottawa Bridge Collapse 1966**

In August 1966, the Heron road bridge that was undergoing construction collapsed without warning killing nine people and injuring 57 people. Welders had to use acetylene torches to cut through twisted steel cables and reinforcing rods in order to rescue three of the six workers who were still alive but trapped under debris. It was the worst construction accident up to that time in Ottawa's history. Other construction workers, police and members of the public worked together to free the survivors. The construction company accepted partial fault at the official inquest. The Ontario Safety Code was amended after this incident. (Canadian Disaster Database, 2005).

**Critical Infrastructure Failure**

**Definition**

*The disruption of any of the interdependent, interactive, interconnected networks of institutions, services, systems and processes that meet vital human needs, sustain the economy, protect public safety and security and maintain continuity of and confidence in government.*

**Description**

Infrastructures may be deemed to be critical if their failure or disruption may jeopardize the safety, security, and quality of life of the community or region affected.

Critical infrastructure includes:

- Electricity
- Water treatment and distribution
- Sewage treatment and disposal
- Communications systems
- Food production and distribution
- Transportation services
- Emergency Services
- Healthcare

In the complex, ‘just-in-time’ society of modern North America, people are extremely dependent on public and private infrastructure. Many essential goods and services are reliant on critical infrastructure and even a short down time can be disruptive. For example, most grocery stores do not keep a large supply of food to restock the shelves. Nowadays, they rely on ‘just-in-time’ deliveries in order to restock. If the delivery service...
was disrupted, stores would quickly run out of stock and be unable to supply food to the community.

Critical infrastructure may be independent, yet many are interdependent and require another form of critical infrastructure to function. When one system is disrupted, it can result in a cascading effect across other systems (Streips and Simpson, 2007). For example, a power outage will affect transportation by disrupting traffic lights, a disruption to refrigeration which would affect food services and can halt water and sewage treatment.

**Provincial Risk Statement**

The province of Ontario is heavily reliant on critical infrastructure to provide essential services. Few people keep sufficient stores of non-perishable food and water in their homes in case of emergency as many have grown accustomed to shopping as needed. In particular, people who are living in poverty or are homeless are not likely to be able to maintain this standard of personal preparedness. Many other people require electricity and refrigeration for medical reasons.

The climate of Ontario can contribute to the hazard. Ontario experiences a range of temperatures throughout the year. The severity of the impacts may depend on the season and the current temperature in which a critical infrastructure failure occurs. Failures of heat and power during a period of subzero temperature during winter could result in more severe social impacts, including fatalities and injuries, than if the failure had occurred during a period of milder temperatures. Secondary hazards may also increase due to the temperature during a critical infrastructure failure. In particular, the risk of accidental carbon monoxide poisoning caused by the use of heating devices in confined spaces increases during power outages in the winter.

During a critical infrastructure failure, many businesses are often forced to suspend their activities due to a lack of access to technology (many of a company’s functions are carried out by computers) or due to health and safety concerns (i.e. lack of access to water for sanitary purposes).

Attempts to reduce the vulnerability of Ontario to critical infrastructure failures are underway. Ontario has a Critical Infrastructure Assurance Program which identifies the province’s critical infrastructure, assesses its susceptibility to failure, and provides mitigation options based upon recommended practices to reduce their vulnerability.

**Case Study The 2003 Power Outage**

The second largest power outage in history affected an estimated 10 million people in Ontario and 45 million people in the Northeastern and Midwestern United States. All activities that require electricity that were not backed up by generators stopped. Traffic lights and some forms of public transit were out which affected millions of commuters trying to get home. Some areas lost water pressure due to the outage and there were
concerns about the contamination of the water supply. Cellular phones stopped working in many areas. Gasoline was not available since pumps require electricity. (Canadian Broadcasting Corporation, 2010).

**Dam Failure**

**Definition**

*The uncontrolled release of stored water due to the breaching or destruction of a dam or barrier intended to hold back water.*

**Description**

A dam is a barrier in a body of water (such as a river) that holds back water in order to create a reservoir, raise water levels, diverts water and/or controls flooding. The Ontario Ministry of Natural Resources also includes boat locks, mine tailing dams and weirs in its definition of a dam (MNR, 2010b).

Humans have built dams since approximately 4000 B.C. The earliest dams were used for irrigation and water supply (Stewart, 2008). Today they have several additional uses including flood and storm water management, low flow augmentation, fire protection, recreational activities, industrial purposes, a barrier for invasive species and as a local water supply (MNR, 2010a).

The main causes of dam failures are:

- Flooding from heavy runoff
- Flooding caused by upstream dam failure
- Earthquakes
- Landslides
- Technological or human error

(MNR, 2010)

Overtopping of the dam can be caused by extreme rainfall or snow melt. According to MNR (2010a) flooding is the primary cause of dam failure since it can result in water levels that exceed the carrying capacity of the dam. Ontario Power Generation (OPG) lists the key factors in dam failure as being “failure to follow operational plans; malfunctioning dam control structures; and/or underestimating flood magnitudes” (EMO, 2005). Human error can result in a dam failure in many ways: through design and construction deficiencies, supervision errors, sabotage, management and operational errors (Stewart, 2008).

A dam failure may result in the full or partial destruction of the dam (Stewart, 2008). Although in some cases, warning may be possible, in many cases the failure occurs with little or no advanced warning (EMO, 2005). The causes of dam failures have remained relatively constant throughout history. Human error plays a significant role in
contributing to the probability or failure or by magnifying some of the impacts in many instances of dam failure (Stewart, 2008).

**Provincial Risk Statement**

There are approximately 2,500 dams in Ontario that are greater than two meters in height and which each contain a minimum of 2 hectares in reservoir surface area (MNR, 2010a). In Ontario, dams can be either publicly or privately owned. The Ministry of Natural Resources provides safety standards and guidelines for dam owners, but it is ultimately the responsibility of the dam owners to ensure that their dams are safe (MNR, 2010a).

If a rural dam with a small storage capacity with no downstream inhabitants fails, the impacts is likely to be negligible. However, if a dam with a large storage capacity and a large downstream population fails, the impacts are likely to be much more severe.

Impacts of dam failure may include:

- Fatalities and injuries
- Property damage
- Damage to roads and bridges
- Damage to agriculture
- Loss of flood control capabilities
- Damage to aquatic habitats
- Loss of power generating capabilities
- Erosion

(Pierce County, 2002).

Aboelata et al (2003) devised three zones to estimate the potential for social losses from a dam failure. The area encompassed by each zone depending on the available shelter, local flood depths, flood velocities and debris:

- **Chance zones**: people are typically swept downstream or trapped underwater. Survival depends largely on chance; that is, finding floating debris that can be clung to, or otherwise finding safety. The historic rate of loss of life in these zones ranges from about 50 to 100%, with an average rate over 90%.
- **Compromised zones**: shelter has been severely damaged, increasing the exposure of people to floodwaters. The historical rate of life loss in these zones ranges from zero to 50%, with an average rate near 10%.
- **Safe zones**: are typically dry, or exposed to shallow flooding unlikely to sweep people off their feet. Life loss in safe zones is virtually zero.

**International Case Study - The Teton Dam Failure 1976**

The Teton Dam, a large earthen dam in eastern Idaho, failed during the initial filling of the reservoir on June 5, 1976. An estimated 300 million cubic meters of water headed down the Upper Snake River Valley. The towns in its path included Wilford, Sugar City,
Rexburg, and Roberts. More than 200 families were left homeless. The final toll was 14 dead and an estimated 400 million to one billion dollars in property damage. (Solava and Delatte, 2003)

Energy Supply Emergency

Definition
The disruption of the supply, production and transportation of electricity, natural gas, and/or oil severe enough to threaten public safety, business and the economy. If an energy supply emergency progresses to the point that there is a complete lack of electricity, natural gas, or oil then it may become a critical infrastructure failure emergency.

Description
An energy supply emergency refers to a disruption in the supply, refinement or transportation of electricity, natural gas, or oil. Many energy supply systems are interconnected or rely on the same delivery systems. Damage to the energy supply chain in one region may adversely affect energy supplies in other regions. The cause and/or effects of an energy emergency can occur at many different levels, be they local, national or international. Some energy supply emergencies may be foreseeable, while others may be sudden. The length of the energy supply emergency depends on the cause of the emergency and the area affected.

It is not possible to predict every possible cause of an energy emergency, especially since many factors and events on a global scale may influence it (California Energy Commission, 2006).

Some of the factors that have caused or contributed to energy emergencies in the past include:

- The disruption of transportation routes or vehicles.
- Constraints in production and refining capacity which increase the potential of supply not meeting demand.
- Uncertain climates (both political and natural) in some producer countries may hinder the exploration and development of resources.
- Geopolitical tensions and terrorism result in uncertainty as to the future availability of supply.
- Natural hazards can disrupt the supply or cause demand to increase. (International Energy Agency, 2007).
- Human error
- Technological failure
- Hoarding of fuel

There are many processes and facilities that if disrupted could result in an energy supply emergency. These include:
Oil and Natural Gas Fields: extraction of the fuel is reliant on computer, pumping and compressor systems, purification equipment and processes, storage and blending systems, oil-water separators and water treatment facilities.

Pipelines: the transportation of gas or oil through a pipeline will be halted if the structural integrity of the pipeline is compromised or destroyed. Although solid fuels such as coal and liquid fuels such as crude oil can be transported by trains, barges or trucks, there are almost no other methods of transportation other than pipelines for gases.

Terminals and Storage Facilities: computer, storage and loading systems are used to track and handle exportation of the fuel. Very few countries keep a significant reserve of fuels, so the loss of even one terminal or storage facility can have a serious impact on the market.

Refineries: are reliant on technology in order to refine feedstock, such as crude oil, into the final product. There are only 20 large refineries (with capacities of $\geq 400,000$ bbl/d of crude oil) in the world. These are located in 12 countries. Seven of these countries are considered to be politically unstable or have experienced a high number of terrorist incidents. An additional four large refineries are located in the United States and are currently operating at greater than 90% of their capacities. If production at even one of the U.S. refineries was disrupted, it would result in serious energy supply problems throughout North America. In a tight supply situation the loss of a refinery can result in a serious product shortage. Alternative supplies will be available, although at high cost. The situation can be aggravated if the energy supply emergency occurs in the winter and the option of bringing product into Ontario via the St. Lawrence Seaway is cut off due to the freezing of the Seaway, as it was during the 2007 Nanticoke outage. If Ontario is not in a tight supply situation, then alternative supplies are available from a large number of refineries. (Cooper, 2006)

Electricity: generation, transmission and/or distribution failures; loss of SCADA systems due to hostile cyber intrusions and technology failures in connected sectors e.g. telecommunications.

The predominant impact of an energy supply emergency is on the economy (International Energy Agency, 2007). If the energy supply is not sufficient to meet demand, then energy prices will rise (California Energy Commission, 2006). While negative economic impacts are likely to be the most common impact, an energy emergency could also result in transportation and communication disruptions which could put public safety and other services at risk. The climate of the area affected and the time of year can also increase the risk of public safety impacts since electricity and natural gas are used for heating and cooling.

**Provincial Risk Statement**
People in Ontario are especially reliant on energy sources in order to maintain their current quality of life. A large part of this reliance can be attributed to the demands of our climate, lifestyle and urban planning. Most people take energy sources for granted.
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Until there is an interruption. For example, electricity is a necessity for Ontarians; the majority of residents and businesses rely on natural gas for heating; and first responders and utilities require fuel for their vehicles. As a result, the effects of an energy emergency are likely to be far reaching across the province.

There is interdependency between the energy sectors and with other critical infrastructure sectors (CIs) which can compound the risk. All energy sectors are highly dependent on telecommunications for their operations. The electricity and natural gas sectors rely on fuel for their service vehicles. The oil sector is heavily dependent on electricity for its refineries, pipelines, distribution and retail operations, and on the trucking sector for the delivery of petroleum products.

There have been terrorist threats against the energy sector, especially oil infrastructure. The Royal Canadian Mounted Police’s National Security Criminal Investigations Unit is providing briefing and alerts to CI owners and operators of possible threats.

Cyber attacks may pose serious threats against energy sector operations, since such attacks have occurred in other jurisdictions.

**Oil Sector**

All Ontarians rely on gasoline and diesel fuel for transportation and some rely on Heating oil. In addition, the economy relies on air travel so distribution of aviation fuel to airports needs to be protected. An extended disruption of oil product supply could affect the health and safety of citizens. All critical infrastructure sectors rely on fuel for their continuous operations.

The four refineries in Ontario manufacture only about two-thirds of the Province’s fuel product needs, while the balance of the demand is met through imports into Ontario, primarily from Quebec and offshore. This can create vulnerability in the supply chain.

One of three main crude oil pipelines into Ontario ruptured in July 2010. This incident significantly reduced the amount of crude oil delivered to Ontario refineries from Western Canada. Oil companies had to make alternative arrangements to secure other sources of supply at a higher cost. The pipeline rupture occurred in Michigan and spilled millions of litres of crude into local streams and significantly impacted the environment. The pipeline was allowed to reopen after two months after satisfying conditions imposed by U.S. regulators.

A major fire at the Nanticoke oil refinery in February 2007 caused significant fuel shortages at service stations for a number of weeks. This situation was aggravated because it occurred in the winter and the option of bringing product into Ontario via the St. Lawrence Seaway was not available due to freezing of the Seaway. The Government directed the oil companies to supply northern communities, which are more vulnerable because of their fewer service stations. The Government also provided temporary
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waivers that provided oil companies with flexibility to increase fuel supply and ease the shortage.

The Ministry of Energy together with Emergency Management Ontario (EMO) has developed a fuel distribution plan in the event of a declared Provincial emergency with a fuel shortage. EMO and the Ministry of Energy received assistance from the Ontario Division of the Canadian Petroleum Products Institute (CPPI), and on an individual basis from the four major oil companies (Imperial Oil, Shell, Suncor, and Ultramar) operating in Ontario that CPPI represents, as well as other oil companies.

The plan outlines how communities and designated critical infrastructure (CI) sectors will secure prioritized fuel distribution in the event of a shortage in a declared Provincial emergency. This Plan was conceived after the 2003 major electricity outage when the oil sector was impacted and some CIs were unable to locate fuel.

Electricity Sector
Ontario’s installed electricity generation capacity:
- Nuclear - 33%
- Hydroelectric - 23%
- Coal - 13%
- Natural Gas (for generating electricity) - 27%
- Wind and Other – 4%

The Government set a policy to phase out coal-fired generation in Ontario and replace it with cleaner sources in the earliest practical time frame in a way that ensures adequate capacity and electricity system reliability. The elimination of coal may increase vulnerability because there is less diversification. Electricity from wind power tends to be less reliable on hot summer days when demand peaks due to air conditioning loads.

A significant contribution of Ontario’s electricity supply mix is fuelled by natural gas. This percentage will increase with the number of natural gas fired generating stations currently being built.

Ontario is also promoting energy conservation and energy efficiency in addition to renewable energy. This policy will decrease Ontario’s reliance on fossil fuels, increase its energy security, reduce its environmental footprint and create economic opportunities

Since the 2003 blackout, the electricity sector has strengthened the transmission grid system and made it more resilient. The electricity sector also recognizes that oil sector critical facilities, along with the health care and water sectors, are to receive electricity restoration priority in the event of a disruption, in accordance with the Independent
Electricity infrastructure is aging and periodically equipment malfunction causes temporary outages. The entire system from generating facilities to transmission and distribution lines is being upgraded.

The 1998 major ice storm in Eastern Ontario and Western Quebec downed power lines which caused a chain of energy dependency impacts. This knocked out oil refineries in Montreal which normally supply fuel to Eastern Ontario. The electricity outage also impact heating, since most furnaces and boilers require electricity to operate. Thus, most homes and businesses were without heat and light. Houses that have wood fireplace were more resilient.

Ontario’s electricity sector is going through a process of renewal – with the replacement of aging infrastructure and the transition to a more sustainable energy supply mix.

The Independent Electricity System Operator’s (IESO) Ontario Reliability Outlook identifies a number of new projects in various stages of development to address this need. The latest forecast points to a positive outlook for Ontario’s longer-term reliability picture, but indicates that going forward, the focus will need to shift to ensuring that both generation and transmission projects are implemented in time to meet needs. The IESO will be working with the Ontario Power Authority to address the integration and operational challenges of a complex and changing generation mix.

**Natural Gas Sector**

Ontario has some reserves of natural gas but they are insufficient to meet demand. The majority of Ontario’s natural gas supply is imported from Saskatchewan, Alberta and British Columbia via pipelines (EMO, 2005).

Consumers cannot store natural gas and it must be delivered to homes and businesses as needed. Throughout the year, gas transmission pipelines try to run at close to full capacity and any excess supply of natural gas delivered to Ontario is pumped into underground storage facilities near Sarnia. During the winter months, gas from long distance pipelines is insufficient to meet Ontario’s demand, and delivery is augmented by gas withdrawn from underground storage.

Most Ontarians rely on natural gas for home heating and are vulnerable to a supply disruption in the winter. Most homes do not have supplementary sources of heat. Businesses, schools and public buildings heated with natural gas may have to be closed during a prolonged outage.

Utilities respond to hundreds of emergency calls per year because of ruptured distribution pipelines caused mostly by contractors and homeowners not locating buried pipelines before digging. Sometimes evacuations are required depending on the severity
There are two main transmission pipelines from western Canada that serve the province and beyond. One of the pipelines comes through northern Ontario and the other one near Sarnia. A major transmission pipeline ruptured in northern Ontario in February 2011. Supplies to interruptible industrial customers were curtailed for a number of days, while firm customers in the residential, institutional and commercial sectors were not impacted.

The National Energy Board regulates inter-provincial and international natural gas and oil pipelines. The NEB shares responsibility with the Transportation Safety Board (TSB) for incident investigation. The NEB investigates pipeline incidents to determine whether its regulations have been followed. The TSB investigates the cause and contributing factors.

The two major gas distribution companies operating in Ontario, Enbridge Gas Distribution and Union Gas have load shedding plans which will impact industrial customers first and residential customers last. There is mutual aid assistance arrangement between the two utilities in the event of a significant emergency. Such aid had been utilized a few times in the past.

**International Case Study - United Kingdom Fuel Protests 2000**

The 2000 fuel protests were a series of protest over the price of petrol and diesel in the United Kingdom. The first protest was primarily led by transport drivers and farmers and resulted in the blockades of oil facilities which led to a widespread disruption of the supply of petroleum products. The 2000 fuel protests led to the hoarding of petrol and diesel and had a negative impact on the government which resulted in a reduction in the government’s popularity.

(British Broadcasting Corporation, 2002)

**Explosion/Fire**

**Definition**

**Explosion:** The sudden conversion of potential energy into kinetic energy resulting in a sudden, violent release of gas/es under pressure.

**Fire:** Uncontrolled and/or potentially destructive burning caused by the ignition of a fuel or material, combined with oxygen, which gives off heat and light, with or without an open flame.

**Description**

Fires and explosions require three elements in order to propagate, a fuel source (e.g. bedding, wood), oxygen and a source of ignition. Sources of ignition include: heat, static, electricity and chemical reactions (IRP, 2006). The persistent and spread of a fire, and the strength and size of an explosion depends on:
• The type of fuel source
• The amount of fuel source
• The source, type and location of initial ignition
• The size and layout of the building/surroundings
• Air turbulence caused by the interaction of fire and/or burning gases with obstacles
• The type of vents and their locations
• Additional fuel sources
• The presence of prevention and mitigation systems.

(FABIG, 2008).

Explosions and fires can occur outdoors or within structures such as houses. This section includes fires that occur in relatively populated areas. For more information on forest/wildland fires, please refer to that section. The most common type of fire is outdoor fires. However, structure fires are responsible for the majority of fatalities, injuries and property loss (FEMA, 1999). Structure fires can have one of several causes including: heating/cooling, cooking, cigarette/lighters, faulty wiring and electricity and arson. Different types of buildings are more likely to experience fires resulting from different causes. Fires in rural areas are often caused by heating since fireplaces and woodstoves are more common in these areas. Fires in urban areas, especially in apartment buildings are more commonly caused by cooking accidents. The reason for the decrease in the prevalence of heating fires in urban areas is that more buildings (in particular apartment buildings) use central heating which is less of a fire risk. Communities with a population of greater than 100,000 tend to experience more fires related to arson. (FEMA, 1999)

Provincial Risk Statement
Structure fires and explosions can result in fatalities, injuries and significant property damage. Fatalities can be listed as being due to fire if they meet one of the criteria below and if death occurs as a result of fire injuries within a year and one day of the fire. Fire fatalities include:
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- People who died as a direct result of the fire (e.g. burns)
- People who died due to secondary complications from fire injuries (e.g. pulmonary edema)
- People who died as a result of damage caused by the fire (e.g. roof collapse)
- People who died as a result of being involved in fire control (e.g. a rescue attempt) (Wilson, 2009).

Large scale and high fatality fires have decreased due to advances in fire prevention and suppression since the 1970s, when smoke alarms became widely available. Other significant advances include: fire resistant building materials, sprinkler systems, fire extinguishers and improvement in fire fighting technology (Bruck and Thomas, 2010). Fires ignited due to tobacco products, such as cigarettes have declined due to the decreasing popularity of cigarettes, public awareness campaigns and the introduction of mandated ignition performance standards for cigarettes in Canada (Alpert et. al., 2010). Explosion suppression systems and improvements in the labelling of materials that could result in explosions have assisted in decreasing the incidence of explosions, In Ontario; the Building Code provides fire safety provisions for the construction of new buildings and renovations. Existing buildings are subject to the requirements of the Ontario Fire Code (EMO, 2005).

According to the Ontario Fire Marshal (2009), the most common ignition sources in Ontario structure fires are: cooking, heating/cooling, electrical wiring/outlets, cigarettes and appliances. The Ontario Fire Marshal classifies a fire as being a ‘loss fire’ if it results in a fatality, injury or an estimated monetary loss. As shown by the chart below, structure fires made up the greatest number of loss fires in Ontario. These fires were also associated with the greatest number of fatalities, injuries and property damage.

### 2008: Fire Incidents in Ontario

<table>
<thead>
<tr>
<th>Property Type</th>
<th>Number of loss fires</th>
<th>Fire Injuries</th>
<th>Fire fatalities</th>
<th>Estimated $ loss in millions</th>
<th>No loss fires</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structure</td>
<td>8,250</td>
<td>602</td>
<td>87</td>
<td>528.1</td>
<td>3,119</td>
</tr>
<tr>
<td>Property/Outdoor Storage</td>
<td>1,619</td>
<td>23</td>
<td>3</td>
<td>12.7</td>
<td>3,880</td>
</tr>
<tr>
<td>Vehicle</td>
<td>3,656</td>
<td>24</td>
<td>7</td>
<td>46.1</td>
<td>583</td>
</tr>
<tr>
<td>Total</td>
<td>13,525</td>
<td>649</td>
<td>97</td>
<td>586.9</td>
<td>7,582</td>
</tr>
</tbody>
</table>

Table 5. Table provided by the Ontario Fire Marshal (2009).

The situations under which fire fatalities occur may differ according to the age of the person at the time of their death. The chart below displays information collected by the Ontario Fire Marshal on the condition of the person during the fire incident and the fire situation.
<table>
<thead>
<tr>
<th>Fire Fatality Information</th>
<th>Age 65+</th>
<th>Ages 15 - 64</th>
<th>Ages 0 - 14</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average Fatalities</strong></td>
<td>25 per year</td>
<td>50 per year</td>
<td>10 per year</td>
</tr>
<tr>
<td><strong>Time of Day</strong></td>
<td>12:00am – 8am = 41%</td>
<td>12am – 8am = 55%</td>
<td>12am – 8am = 41%</td>
</tr>
<tr>
<td></td>
<td>8am – 4pm = 31%</td>
<td>4pm – 12pm = 23%</td>
<td>8am – 4pm = 31%</td>
</tr>
<tr>
<td></td>
<td>4pm – 12pm = 28%</td>
<td>8am – 4pm = 22%</td>
<td>4pm – 12pm = 28%</td>
</tr>
<tr>
<td><strong>Areas of Origin</strong></td>
<td>Living area = 38%</td>
<td>Living area = 37%</td>
<td>Living area = 52%</td>
</tr>
<tr>
<td></td>
<td>Sleeping area = 16%</td>
<td>Sleeping area = 19%</td>
<td>Sleeping area = 20%</td>
</tr>
<tr>
<td></td>
<td>Kitchen = 14%</td>
<td>Kitchen = 14%</td>
<td></td>
</tr>
<tr>
<td><strong>Ignition Source</strong></td>
<td>Cigarette = 22%</td>
<td>Cigarette = 17%</td>
<td>Matches/Lighters = 17%</td>
</tr>
<tr>
<td></td>
<td>Cooking = 12%</td>
<td>Arson = 15%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Matches/Lighters = 7%</td>
<td>Cooking = 7%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cigarettes = 8%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Candles = 7%</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Physical Condition</strong></td>
<td>Disability = 26%</td>
<td>Impaired = 27%</td>
<td>Asleep = 37%</td>
</tr>
<tr>
<td></td>
<td>Healthy = 25%</td>
<td>Healthy = 17%</td>
<td>Too young to act = 20%</td>
</tr>
<tr>
<td></td>
<td>Asleep = 17%</td>
<td>Disability = 11%</td>
<td>Healthy = 23%</td>
</tr>
<tr>
<td></td>
<td>Impaired = 7%</td>
<td>Asleep = 10%</td>
<td>Left unattended = 7%</td>
</tr>
</tbody>
</table>

Table 6. Fire fatality information.

Healthy = there is no known reason why the person would have not been able to respond and escape. Impaired = drugs or alcohol. OFM, 2009.

**Case Study - Mississauga Nursing Home Fire 1980**

A fire that rapidly spread through the top floor of a nursing home on July 15th, 1980 that housed 198 people, resulted in 21 deaths, 35 injuries and the evacuation of the residents. In addition to the 35 injured, seven firemen and several police officers were overcome by smoke while responding to the blaze. The majority of the victims died of smoke inhalation and extreme heat. The timely evacuation of the residents was hindered despite working smoke detectors since the affected floor housed most of the chronically ill residents. Many of the residents were bedridden or in wheelchairs. Dozens of elderly residents were rescued by firefighters who lowered them from balconies on stretchers attached to ropes. One patient was carried down an aerial ladder in his wheelchair.

(Canadian Disaster Database, 2005).
Hazardous Materials Incident

Definitions

**Hazardous Materials Incident**: the unintentional release of a material that is considered to be hazardous to humans, animals, plants or the environment due to its explosive, flammable, combustible, corrosive, oxidizing, toxic, infectious or radioactive properties.

**Fixed Site Incident**: one is which the release occurs at a location in which the hazardous material is stored, produced or utilized.

**Transportation Incident**: A transportation incident is one in which the release occurs during the transport (by means of road, rail, air or marine) of a hazardous material.

Description

Many potentially hazardous materials are used daily for a variety of purposes. When properly contained and stored, hazardous materials are fairly stable and safe. Every community has at least one facility that stores, produces or utilizes a hazardous material. These facilities include: water treatment plants, textiles manufactures, dry cleaners, chemical manufactures and even schools. Depending on the type of hazardous material, it can become a threat when their container is ruptured, exposed to extreme heat/cold, exposed to fire, water or another substance that when combined produces a reaction.

A hazardous materials incident at a fixed site or during transport can be caused by a human error or a technological malfunction. Traffic accidents can result in a hazardous materials transportation incident if one or both of the vehicles is carrying a hazardous material. Infrequently, a release can be caused by a natural hazard such as a flood.

Classification applies primarily to transportation and is regulated by the Transportation of Dangerous Goods Act. Hazardous materials can be classified as falling into one of nine classes:

- Class 1 Explosives
- Class 2 Gasses
- Class 3 Flammable liquids
- Class 4 Flammable solids, spontaneously combustibles, substances that, on contact with water, emit flammable gases
- Class 5 Oxidizing substances, organic peroxides
- Class 6 Poisonous (toxic), infectious substances
- Class 7 Radioactive materials
- Class 8 Corrosives
- Class 9 Miscellaneous products or substances, Miscellaneous identified dangerous goods certain specified goods considered dangerous to the environment, dangerous wastes (EMO, 2005).
Factors that can influence the impact of a hazardous materials incident include: changes in the manufacturing or storage process, equipment changes, aging technology and distribution systems, the population density of the surrounding area, the topography, traffic volume, weather conditions and the type of hazardous material being transported or located at a site.

The concentration, dispersal and range of materials which are hazardous in a gaseous form depend on atmospheric conditions. Depending on the amount and type of material released and the presence of an atmospheric cap, a high wind speed could either disperse the gas so that it no longer poses a threat or it could increase the affected area. A fire that occurs in a location in which hazardous materials are stored may result in toxic smoke which could hinder the extinguishing of the fire. A fire could also result in the release of toxic gas.

Hazardous materials can have a variety of negative impacts depending on the type of material. Some materials may have immediate or long-term impacts. Immediate impacts could be caused by the flammability or the corrosivity of the material while long-term impacts may arise from the accumulation of toxins in the bones or bloodstream or the persistence of the material in the environment (Carter, 2007). Hazardous materials can enter the human body through absorption (usually through the eyes or skin), ingestion (through swallowing) or inhalation (breathing in a material which is then absorbed by the lungs) (University of Toronto, 2010). Different types of hazardous materials can be dangerous in their solid, liquid or gaseous states or possibly in all three. Not all hazardous materials are detectable by humans in their gaseous state. Some are colourless and odourless. This type of hazardous material is generally dangerous to humans through inhalation. Many types of hazardous gases (e.g., chlorine) are heavier than air and therefore, accumulate in low lying areas.

Hazardous materials in a liquid state may seep into the ground or into porous building materials such as concrete. If enough material is released and has a low enough viscosity, it may be able to travel through the ground and contaminate groundwater and well water, possibly triggering a water quality emergency. Hazardous materials can also enter the water supply through overland flow and contaminate streams, rivers, ponds and lakes. Flammable materials that are either less dense than water which have been released into a body of water may still ignite. There have been recorded instances in which hazardous materials in a liquid state have entered sewer systems and ignited resulting in underground fires.

Materials that are hazardous in their solid state often are hazardous through contact or ingestion. In most situations, their range of impact is usually much smaller than that of a liquid or gas. However, solid materials may react with fire, water or other substances to result in an explosion or another less than desirable outcome depending on the type of material.
Provincial Risk Statement

Hazardous materials are used for many processes common in day to day life. Many different types are used, manufactured, generated as by-products, imported and exported in Ontario on a daily basis. Ontario has the largest chemical industry of any province in Canada. Chemicals are the third largest manufacturing industry in Ontario, with greater than 41,000 employees and more than $21.5 billion in revenues. Products include plastics, basic organic and inorganic chemicals, synthetic resins, fertilizers, pharmaceuticals and many others.

The City of Sarnia has the largest cluster of facilities that produce or use large quantities of chemicals in Canada. There are forty-six facilities that are listed in the National Pollutant Release Inventory within 25 km of Sarnia, with more on the United States side of the border. Two other areas which have been identified by the Ontario Government (2008) as having a large concentration of chemical companies are the Greater Toronto Area and Eastern Ontario.

Heavily industrialized areas such as Sarnia, experience a greater risk of a Hazardous Materials Incident than other locations (OFM, 2010). However, almost every community in Ontario has at least one facility that stores, produces or utilizes a hazardous material. Propane installations are located across the provinces and their presence increases the risk of an incident (OFM, 2010). The Ministry of the Environment (MOE), Spills Action Centre which ‘handles reports of spills, adverse drinking water results and other urgent environmental concerns’ and receives approximately 4,000 reports of spills every year. The majority of hazardous materials releases are relatively minor with no serious or long-term impacts, and can be usually handled by the organization responsible or the municipality. There are several programs for companies participating in the chemical industry that aim to improve preparedness and response to hazardous materials incidents; however, participation in these programs is voluntary. For those companies that are subject to Municipal Industrial Strategy for Abatement (MISA) regulations under the Environmental Protection Act, MOE may require that the regulated community develop and implement spill prevention and contingency plans.

Hundreds of thousands of hazardous materials shipments move through Ontario annually. These shipments can occur at anytime, day or night and by means of road, rail, air and water and often through areas of high traffic volume, urbanized routes. Municipalities on corridors for hazmat transport such as the 400 series highways and the TransCanada highway are at greater risk of hazmat incidents (OFM, 2010). A study by Verter and Kara (2001) found that gasoline, fuel oil, petroleum, coal tar and alcohol that were transported on highways in Ontario and Quebec made up 56% of all hazardous materials transported on the Canadian highway system.

Hazardous materials are also commonly shipped by rail. The rail lines often run through populated areas. In 1979, the derailment of a train in Mississauga carrying propane, styrene, toluene, caustic soda and chlorine resulted in the largest evacuation in North America, second only to that of New Orleans in 2005. A large explosion and fire
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combined with the leaking chemicals from the rail cars hampered response efforts. In Ontario, from 2003-2008, there was on average 106.6 railway accidents that released hazardous materials per year in Ontario (Transport Canada, 2009).

Additional hazardous material shipments are made by boat. The Great Lakes, the St. Clair River and the St. Lawrence Seaway are all marine transportation routes. A release into one of these could contaminate the water supply of a large proportion of Ontarians and result in significant environmental damage depending on the type and the amount of material released.

Case Study Mississauga Train Derailment 1979
On November 10, 1979 a Canadian Pacific Railway train derailed near a populated area in Mississauga. Part of the train caught on fire which resulted in a large explosion. The cargo of the train included propane and chlorine. The proximity of the tank cars containing propane to those containing chlorine were a major cause of concern. If the propane tank cars near the chlorine tank cars had exploded, an extremely toxic cloud of chlorine could have been released. The evacuation of 225,000 people, the largest peacetime evacuation at that point in history was ordered as a precaution. (Canadian Disaster Database, 2005)

Human-Made Space Object Crash

Definition
An Earth orbiting human-made object (such as a satellite) which survives atmospheric reentry to impact Earth.

Description
The number of human made objects in space has been increasing since the launch of Sputnik 1 in 1957 (ESA, 2007). These objects include functioning and derelict satellites and space craft, rocket bodies and the upper stages of launch vehicles. Non-functioning human-made objects are referred to as space debris. The amount of each types of item that can be classified as space debris is:

- Operational spacecraft – (6%)
- Old spacecraft – (15%)
- Rocket bodies – (11%)
- Mission-related objects – (11%)
- Miscellaneous fragments – (56%)

(ESA, 2007).

Functioning and non-functioning space objects are tracked by many countries, including the United States, Germany, France and the United Kingdom. These countries have catalogued approximately 16,000 objects that are larger than 10 cm (NASA, 2009). Another 6000 objects have been discovered but not yet catalogued. Most human made space objects are small. These pose a significant threat to orbiting space craft and satellites but are not able to survive re-entry into the Earth’s atmosphere.
Many satellites are slowly drawn back to Earth due to the pull of gravity and the presence of the atmosphere. The atmosphere becomes increasingly thinner as altitude increases. There is actually still atmosphere several hundred kilometres above the Earth where some satellites orbit. The low density of the atmosphere where satellites orbit affects the length of time that it may take for them to impact Earth, if any part of them survives re-entry. Objects with degrading orbits that are hundreds of kilometres above the Earth (low Earth orbit) may take tens of years to fall to Earth. Objects that are even higher may stay in a degrading orbit for hundreds or thousands of years (Aerospace, 2006).

As the object gets lower, the density of the surrounding atmosphere increases. An object such as a satellite can be moving at a speed up to 29,000 km/hr. As it reaches areas of denser atmosphere below 100 km, the speed of the object begins to decrease. The increasing atmospheric density it passes through as it descends results in a high level of friction. The load on the object can exceed ten times the acceleration of gravity. The load and the heat generated from the friction can melt or vaporize parts or the entire object (Aerospace, 2006). The majority of objects that go through re-entry into Earth's atmosphere do not survive the heat.

The minority of objects that do survive re-entry have certain physical properties that enabled them to survive. Materials that re-radiate heat effectively or that have high melting temperatures are more likely to survive the heat of re-entry. The shape of the object can also play a role in its survival. Spherical objects are more likely to survive re-entry to impact Earth (Millard and Acon-Chen, 2010).

Since large human-made space objects are tracked, it is possible to predict the time that re-entry into the atmosphere will begin to within 10% of the actual time (Aerospace, 2006). However, it is more difficult to calculate where any surviving pieces of the object may land due to the high speed at which it is falling. If the object has propulsive capacity, the descent may be controlled so that it lands in an uninhabited area such as the ocean.

**Provincial Risk Statement**
Due to the larger number of objects in high inclination orbits and the fact that such objects spend more time at higher latitudes, Ontario does have a higher risk than a similarly sized region near the equator. Despite this, the chance of a space object actually hitting a populated area is small. Approximately 70% of the surface of the Earth is covered by oceans. Much of the remaining 30% is sparsely inhabited. In the last 40 years, more than 18,000 known objects have re-entered the atmosphere. Despite the high number of re-entries no fatalities have been reported from space object crashes. Only one case in which a person was struck by a piece of a re-entering satellite is known, and that person was not injured. The odds of someone (anyone) in the world being injured from a re-entering object (especially spacecraft or rocket body) can easily exceed 1 in 10,000 (Johnson, 2010).
Hazard Identification and Risk Assessment for the Province of Ontario

The impact of the object is not the only hazard associated with a human-made space object crash. There is also the possibility of chemical or radiological contamination (UN, 1999). It is very unlikely for propellants (fuel and oxidizer) to survive re-entry and reach the ground. Other hazardous materials, such as radioactive materials, can survive to the surface of the Earth (Johnson, 2010). These materials could be hazardous to people or the environment if they are exposed.

The size and severity of property damage depends on the size, material and inclination of the space object. The majority of space objects that are of a size that could pose a threat to public safety if they survive re-entry, are usually not large enough to damage a large area. In the very unlikely case of a large space object impact, severe damage is likely to be confined to a few buildings at the most, although this depends on the size of the object and whether pieces break off it and cause additional damage.

Case Study - COSMOS 954 1978
A Soviet nuclear-powered satellite, COSMOS 954 crashed in Northern Canada. There were concerns about the nuclear reactor aboard which sparked Operation Morning Light, the code name for the joint Canada-US operation to locate and clean up the radioactive debris associated with the re-entry and destruction of the satellite. Fortunately, the satellite fell in a fairly unpopulated area.
(Health Canada, 2008)

Mine Emergency

Definition
An unplanned event that jeopardizes the structural integrity and/or normal conditions of a mine site that presents a risk to the safety of mine workers, people near the mine, the property of the mine, the environment and/or the economy.

Description
Mining is a process that includes any work or undertaking for the purpose of opening up, proving, removing or extracting any metallic or non-metallic mineral or mineral-bearing substance, rock, earth, clay, sand or gravel; (“mine” OHSA).

It is an occupation that has long been recognized as being associated with exposure to hazards. The mining process consists of exploration, mine development, operation, decommissioning and land rehabilitation (Donoghue, 2004). The main two types of mines are surface mines (above ground and underground mines. The locations of metal and mineral deposits, as well as, advances in mining technology such as mechanized mining allow mines to have a complex, expanding network of tunnels. The farthest workings may be a considerable distance from the surface and involve a substantial amount of time to reach that involve different modes of transportation such as rail and mobile equipment.

Some possible causes or contributors to a mine emergency include:
The accumulation of lethal gases (e.g. methane, carbon monoxide, carbon dioxide and hydrogen sulphide).

- Malfunctioning or misuse of explosives
- Water inrush/flooding
- Ground instability and collapse of mine openings
- Fires and explosions that can result in creation of lethal gases
- Power outage

Abandoned mines, in addition to operating mines, can also pose a threat to the safety of a person who intentionally or unintentionally enters the mine. The term “abandoned mine” describes sites where advanced exploration, mining or mine production has ceased without rehabilitation being completed. Some of the dangers of abandoned mines are:

- Active explosives that have been left behind.
- Aging and/or unstable structures which may collapse.
- Bad air
- At the surface, shafts may be unprotected, hidden by vegetation or covered by rotting boards.
- Rotting timbers and unstable rock formations make cave-ins a real danger.
- Darkness and debris add to the hazards making escapes and rescues more difficult.
- Mine subsidence.
- Vertical cliffs in open pit mines and quarries can be prone to collapse.
- Water-filled quarries and pits may hide rock ledges, old machinery and other hazards. The water can be deceptively deep and dangerously cold. Steep, slippery walls can make exiting these swimming holes extremely difficult.
- Maps of the mine may no longer exist or may not include updated features which could hinder a rescue operation.

### Lethal Gases

The accumulation of lethal gases is a hazard particularly in underground mines where the enclosed spaces can quickly be filled with gases. Mechanical ventilation has significantly reduced the number of incidents involving gases but it still remains a significant risk to miners. Some of the gases commonly found in mines, and the type of risk they pose to humans are listed in the table below:

<table>
<thead>
<tr>
<th>Gas</th>
<th>Health effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>Flammable, explosive; asphyxiation (the deprivation of oxygen)</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>Chemical asphyxiation</td>
</tr>
<tr>
<td>Hydrogen sulphide</td>
<td>Eye, nose, throat irritation; acute respiratory depression (a decrease in the rate or depth of respiration)</td>
</tr>
<tr>
<td>Oxygen deficiency</td>
<td>Anoxia (absence of oxygen in the blood)</td>
</tr>
<tr>
<td>Blasting by-products</td>
<td>Respiratory irritants</td>
</tr>
</tbody>
</table>
Diesel engine exhaust  Respiratory irritant; lung cancer

Table 7. Gases commonly found in mines. (Weeks, 2010)

Other gases and chemicals, including those used in the extraction and purification processes may also present a health and safety risk to people who come in contact with them.

Explosives
The risk of explosions in mine has decreased due to advances in explosive technology. In particular, nitro-glycerin based explosives have been replaced with water gel explosives. However, forgotten or abandoned nitro-glycerin based explosives may still pose a risk if people re-enter an abandoned mine (EMO, 2005). As well, explosives detonation has become more technical and sophisticated, bringing with it the need for greater understanding in order to use them safely.

Water Inrush/Flooding
There have been a number of water inrush/flooding emergencies in mines on an international scale. Water can cause a range of stability, safety and operational problems depending on the water volume, the location of the leak, the layout of the mine and the speed at which it enters the mine. There are three categories of inrush/flooding:

<table>
<thead>
<tr>
<th>Category of Inrush/Flooding</th>
<th>Cause</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Event Controlled</td>
<td>Mining-Induced</td>
<td>Associated with mines below an aquifer or surface water body. The water inflow rate is suddenly increased and is then reduced to the background level over a period of time.</td>
</tr>
<tr>
<td>Accidental</td>
<td>Mining-Induced</td>
<td>A surface water body, a large pool of water in an upper seam or flooding the adjacent old mine workings, if suddenly released to the lower active workings could result in flooding.</td>
</tr>
<tr>
<td>Spontaneous</td>
<td>Natural</td>
<td>A natural phenomenon associated with mining in the vicinity of karst aquifers</td>
</tr>
</tbody>
</table>

Table 8. Water inrush/flooding in mines.

Structural Instability and Collapse
Structural instability and collapse can have many different causes. Among the more common:
- Errors in mining practices.
- Rock bursts
Advances in technology and the understanding of geology have decreased instances of structural collapse due to errors in mining practices. However, this still presents a risk in abandoned mines.

A rockburst/bump is “an instantaneous failure of rock causing an expulsion of material at the surface of an opening or a seismic disturbance to a surface or underground mine’ – Ontario Ministry of Labour, 1983. A large rockburst can displace more than 50 tonnes of rock and collapse tunnels. Damage may be severe but it is usually confined to a relatively small area. Scientific studies have identified the following conditions as being conducive to rockbursts: high stresses, narrow veins, high extraction ratios and strong brittle rocks in a complex geologic environment. On the surface, a large rockburst may sound like a sonic boom and shaking similar to a small, nearby earthquake may be felt (Blake and Hedley, 2003).

Fire and Explosion
Explosions and fires can have many causes including methane gas, coal dust, chemical used in the extraction and purification processes and equipment. Many explosions have been caused by the ignition of methane gas or coal dust. Most explosions in coal mines were caused by the ignition of methane gas (Weeks, 2010). A secondary explosion may occur if the force from the primary explosion suspended coal dust into the air. Ontario does not have any coal mines, surface or underground.

Power outage
On August 14, 2003, parts of the North-eastern and Southeastern Canada experienced widespread power blackouts. It was the second most widespread electrical blackout in history. Approximately 50 million people were affected by the outage including many mining operations that were faced with workers stranded underground. About 140 miners were stranded underground in Sudbury when the power went out. Mine officials said that they were safe and could be evacuated if necessary, but were not being evacuated due to the risks of doing so with no power. They were safely evacuated by the following morning when power was restored.

Provincial Risk Statement
Ontario has a significant and developed mining industry. The province produces approximately 34% of Canada’s nickel and 55% of Canada’s gold, 25% of Canada’s copper and 64% of Canada’s platinum group metals. Ontario is the leading producer of salt, clay products, cement, lime and stone in Canada. We are the second leading producer of sand and gravel as well as the only producer of indium, phosphate and nepheline syenite. Internationally Ontario ranks 3rd in platinum, 4th in nickel, 7th in cobalt, 14th in gold, 15th in copper, 15th in zinc and 16th in silver production. (Ministry of Northern Development and Mines, 2010) Information was updated.

Operating Mines
Mining in Ontario is a well-developed industry with safety standards that are in place. Emergency preparedness plans formulated by companies has lessened the risk of a mine
Hazard Identification and Risk Assessment for the Province of Ontario

Emergency is significantly. Advanced technology and requirements to provide ventilation systems, has decreased the risk of lethal gases accumulation. The switch from nitro-glycerin based explosives to less dangerous forms has decreased the risk of unintended explosions. A better understanding of geology and the factors that may contribute to mine disasters has also decreased the risk. However, some amount of risk is inherent in mining and although the risk of hazards has decreased significantly, an emergency may still occur in the future.

In Ontario the mines at Kirkland Lake and in the Sudbury Basin experienced rockbursting in the 1930s. In the 1960s, rockbursting occurred at the mines at Red Lake. A classification system was developed in Ontario to record rockbursts. Some types of rockbursts that have occurred in Ontario have involved hundreds or thousands of tonnes of rock and are capable of causing damage over multiple levels of the mine. (Blake and Hedley, 2003). The build-up of lethal gases is still a risk in Ontario, although mines are required to have sufficient ventilation systems and other safety measures in place. The presence of many large water bodies and aquifers in Ontario means that inrush/flooding will always present some degree of risk to miners in Ontario, although that risk has been decreased due to monitoring and advances in technology. Additionally all mines in Ontario are required to have refuge stations under Ontario R.R.O.1990, Reg.854 s 26 Regulations for Mines and Mining Plants. (DJF Consulting Limited, 2004). That provides a safe place and provisions for miners to take shelter until the situation is no longer dangerous or they are rescued.

Mine emergencies can result in fatalities, injuries or miners being trapped. Should a mine emergency occur in Ontario and miners subsequently become trapped, equipment and trained personnel are available to respond. Regulations require each underground mine to have trained rescue personnel and equipment under Ontario R.R.O.1990, Reg.854 s 17 Regulations for Mines and Mining Plants. The Ontario Mine Rescue Organization was created after the Hollinger Mine Fire in 1928 (Workplace Safety North, 2010).

Abandoned Mines
In 1991 the Mining Act was amended to require that mining companies submit closure plans and financial assurance to return lands to their natural or other acceptable state upon completion of exploration and mining activities. After various stages of production, surface structures are removed, underground stability is assessed, tailings areas are assessed for both physical and chemical stability, and appropriate areas are re-vegetated to make the land available for other uses.

There are abandoned mine sites in Ontario are over a century old, and standards for safety and closure were not comparable to current requirements. Some of the mining companies closed out due to business failure or receivership which resulted in some of these mines not having been properly rehabilitated. The age of some of the abandoned mines and the differences in rehabilitation and safety standards at the times they were closed result in these being mines dangerous to enter (even mines closed out to today’s...
standards are not safe to enter once closure is complete). Videos and photographs posted on the internet have shown that some members of the public have been intentionally entering abandoned mines for recreational purposes.

**Case Study - Kirkland Lake Mine Collapse 1993**
In 1993, a rockburst approximately two kilometers below the surface collapsed part of a mine in Kirkland Lake and trapped two miners. Attempts to rescue the miners were unsuccessful and it was not possible to recover the bodies. (Canadian Disaster Database, 2005)

**Nuclear Facility Emergency**

**Definition**

‘An actual or potential hazard to public health and property or the environment from ionizing radiation whose source is a major nuclear installation within or immediately adjacent to Ontario.’ (EMO, 2009).

**Description**

Nuclear generating stations such as the Pickering and Darlington stations in Ontario produce electricity created by nuclear fission. Nuclear fission generates heat which is used to boil water to produce steam which can then be used to power turbines which generates electricity (OPG, 2010).

A nuclear facility emergency could occur if a substantial amount of radioactive material is released into the environment. Advances in technology and safety procedures have decreased the probability of a nuclear facility emergency significantly.

A nuclear facility emergency could be triggered by:

- Fire or explosion
- Technological malfunction
- Intentional or unintentional human activity (EMO, 2005).

Reactivity excursions were once considered to be a potential cause of nuclear facility emergencies, have now been reduced to being very improbable due to safety advances.
The release of radioactive materials depends on the characteristics of an event and the type and response of the containment system. These systems are designed to prevent the release of radioactive materials in the event of an accident. Sudden releases (i.e. within a few hours) can only occur if the system malfunctions or it is bypassed (EMO, 2009).

In the extremely unlikely event of a nuclear facility emergency that results in the release of high levels of radioactive material, the most likely ways in which people can be exposed to radiation are:

- External Contamination – The contamination of the skin and/or clothing
- Direct Exposure – Exposure to the source of the radiation
- Internal Contamination – the inhalation of radioactive material or the ingestion of contaminated food or water. (EMO, 2009)

Exposure and contamination can be minimized in the event of a nuclear facility emergency through the use of specific protective measures. These protective measures work by minimizing or preventing exposure and/or contamination. The type of protective measures that should be used depends on the type of radioactive material, the amount released, the size of the affected area, land use and the population:

- Entry Control – restricting access to the affected area to essential personnel.
- Using Protective Equipment
- Ingestion of Potassium Iodide (KI) – this blocks radioactive iodine from entering the thyroid. It is only useful in an emergency involve the release (or potential release of iodine-131).
- Shelter-in-Place – Remaining indoors, with windows and doors closed and external ventilation systems turned off.
- Evacuation
- Decontamination
- Food Chain Protection – preventing radioactive material from entering the food chain.
Food and Water Control – preventing the consumption of contaminated food and water. (EMO, 2009)

Provincial Risk Statement
Ontario has used nuclear power as a source of electricity since the 1960s. It currently provides more than half of the province’s electricity (Ministry of Energy and Infrastructure, 2010). Many medical and university facilities have reactors; however, they do not have sufficient amounts of radioactive material to pose a large threat to the public. Ontario currently has three nuclear power plants with 16 reactors in operation and the Chalk River Laboratories which do have significant amounts of radioactive materials:

- Pickering Generating Station (six reactors in operation)
- Darlington Generating Station (four reactors in operation)
- Bruce Power (six reactors in operation)
- Chalk River Laboratories

In addition, the Fermi-2 reactor in Monroe, Michigan in the extremely unlikely event of a nuclear facility emergency could result in the contamination of extreme south-western Ontario.

Risk assessments of nuclear facility emergencies have shown that there is generally an inverse relationship between the likelihood of an emergency occurring and the severity of its likely impacts. Based on these risk assessments, and the different causes and impacts of a nuclear facility emergency in Ontario, the most likely scenario for a nuclear facility emergency would include:

- Warning time.
- External and inhalation exposure of radionuclides as the main public safety hazard.
- Low doses of radiation.
- Very low level environmental contamination which could continue for days or weeks.
- Affected area is likely just the area around the nuclear facility. (EMO, 2009)

A severe event is even more unlikely than the scenario listed above due to the types of containment systems (in particular CANDU reactors which prevent releases, even if impaired) used in Ontario. This would include one or more of the following effects:

- Very short time between the accident and the release of radioactivity.
- High doses of radiation.
- Radioiodines and particulates could be a part of the emission.
- Significant environmental contamination.
- A larger area is impacted. (EMO, 2009).

The impact of a nuclear facility emergency depends on the level of radiation released. Long-term exposures to low doses of radiation have been associated with increased risks of cancer. These cancers do not normally manifest for 4 – 20 years (EMO, 2009).
nuclear facility emergency in which high doses are released would be much more severe. Large numbers of people may be required to evacuate or even permanently resettled if the dose is high enough. This would also result in a significant economic loss to the province. However, the likelihood of a nuclear facility emergency of this magnitude is estimated at less than one in 10 million (EMO, 2005). Even though the probability of such an event is so low, Ontario has the Provincial Nuclear Emergency Response Plan and other procedures in case this emergency occurs.

Nuclear facility emergencies have been associated with negative psychosocial impacts in the past (e.g. Three Mile Island). The fear of radiation that the public has is a result of past international incidents (e.g. Chernobyl) and misinformation about the likelihood of such an event and the advances in safety and technology. In the event of an incident at a nuclear facility, it is possible that some people may self-evacuate regardless of the actual risk.

Chalk River Laboratories produces a significant amount of Ontario’s medical isotopes, failure at this facility would have specific and significant impacts on the ability of the health system to continue to provide health services that rely upon medical isotopes (e.g., diagnostic services).

International Case Study - Three Mile Island 1979
The accident at the Three Mile Island nuclear power plant near Middletown, Pennsylvania on March 28, 1979, was the most serious in U.S. commercial nuclear power plant operating history, even though it led to no deaths or injuries. The sequence of events involving equipment malfunctions, design-related problems and worker errors – led to a partial meltdown of the reactor core but only very small off-site releases of radioactivity. Authorities were caught off guard. The uncertainty surrounding the condition of the plant and the perception of the risk by the public resulted in a public relations nightmare. As a precaution, the members of society most vulnerable to the effects of radiation, pregnant women and young children within a five mile radius of the plant were advised to self evacuate.

Detailed studies of the radiological consequences of the accident have estimated that the average dose of radiation to approximately two million people in the surrounding area was only about one millirem. The exposure to radiation from a chest x-ray is approximately six millirem. (United States Nuclear Regulatory Commission, 2009)

Oil/Natural Gas Emergency
Definition
An event that poses a threat to public safety, property, the environment, critical infrastructure or the economy from the uncontrolled release of oil and/or natural gas from: 1) a pipeline; 2) oil/natural gas wells; 3) storage facilities and/or distribution systems.
Hazard Identification and Risk Assessment for the Province of Ontario  UNCLASSIFIED

Description
Oil and natural gas are natural resources that were produced from the carbon and hydrogen molecules of decayed organic matter. Decayed organic matter built up in layers over millions of years within geological formations. Over time, heat, pressure and anaerobic bacteria altered the organic matter into oil and gas. Oil and natural gas can be found in many different geologic formations (Canadian Association of Petroleum Producers (CAPP), 2010). They can be retrieved by drilling wells to the deposit.

Oil and natural gas have many uses:
- Oil – gasoline, diesel fuel, synthetic rubber and fibres, plastic, pesticides
- Natural gas – heating, plastics, fertilizers

Natural Gas
The term ‘natural gas’ refers to primarily methane and other gas types such as ethane, propane, butane, pentanes and heavier hydrocarbons. It does not naturally have an odour, so the odorant, mercaptan is added in order to give it a distinct smell. This can help to minimize the risk of a natural gas emergency since it can be detected easier. This is usually done during processing.

Some of the hazards associated with natural gas are:
- Asphyxiation – natural gas is lighter than air. If it is released in a large, open area, it will dissipate and not pose a threat to human health. However, if it is released in an enclosed space, it may displace air. Even though it is non-toxic, a person can be asphyxiated from the lack of air.
- Ignition – natural gas can ignite if it is presence in small concentrations. If the concentration of natural gas is too high, it is unable to ignite since fire and/or explosions require oxygen. Ignition can occur due to a number of sources, such as matches, electricity and pilot lights. The ignition point of natural is between 593°C and 649°C (Transport Canada, 2008). Natural gas burns at very high temperature and as a result, produces a high radiant heat which can ignite other materials nearby.
- Explosion – if natural gas is present in small concentrations and in an enclosed space with a source of ignition, it may result in an explosion. In addition, natural gas may result in a special type of explosion referred to as ‘Boiling Liquid Expanding Vapour Explosion’ (EMO, 2005). This can occur if a container holding pressurized liquid natural gas is ruptured.
- Hydrogen Sulphide – hydrogen sulphide may exist as an impurity within reservoirs of natural gas. Natural gas containing high levels of hydrogen sulphide is referred to as ‘sour gas’. Hydrogen sulphide is very toxic to humans.

Oil
Oil or liquid petroleum is made up of a mixture of liquid hydrocarbons. The viscosity of oil can range from being as thin as water to as thick as tar. It is referred to as ‘crude oil’ if it has not been refined.
Crude oil can be divided into four types:

- **Class A**: Light, Volatile Oils – These are highly fluid and very toxic to humans. Examples of this type of oil are gasoline and jet fuel.
- **Class B**: Non-Sticky Oils – These are waxy and are less toxic to humans. Examples of this type of oil are light crude oil and diesel fuel.
- **Class C**: Heavy, Sticky Oils – These are dark in colour (brown or black) and are sticky or tarry. These are not considered to be very toxic but can severely impact wildlife. Examples of this type of oil are the majority of crude oils.
- **Class D**: Non-Fluid Oils – These are non-toxic but can severely impact wildlife. Examples of this type of oil are heavy crude oils.

(National Library of Medicine, 2010).

Some of the hazards associated with oil are:

- Spills – spilled oil can be extremely difficult to clean up. It can contaminate land and enter waterways. It can have severe impacts on wildlife and natural ecosystems.
- Fire – oil fires in oil wells, pipeline or storage facilities can be extremely difficult to extinguish due to the abundance of fuel. The smoke produced by these fires may contain many chemicals and particulates that are harmful to human health if proper safety precautions are not taken.

Oil/natural gas emergencies can be divided into three groups depending on at what stage in the extraction/production/transport process the emergency occurs:

1. **Oil/Natural Gas Wells**
   1. Pipelines
   2. Storage/Distribution Systems

**Oil/Natural Gas Wells**

Oil and natural gas wells may pose a threat to public safety whether they are in operation or abandoned. Operating wells can pose a threat if they are not operated or maintained properly and abandoned wells may pose a threat if they were not properly capped or if activities, such as construction, occur in the immediate vicinity of an unknown well.

Some of the hazards associated with oil and natural gas wells are:

- Loss of well control (due to human error or equipment malfunction)
- Fire - fires in wells can be extremely difficult to extinguish due to the abundance of fuel. The smoke produced by these fires may contain many chemicals and particulates that are harmful to human health if proper safety precautions are not taken.
- Spills – oil or natural gas may be released into the surrounding environment. Natural gas dissipates in open areas.
- Release of hydrogen sulphide (sour gas) – hydrogen sulphide is toxic to humans and other forms of life.
Pipelines
Pipelines can be grouped into four categories:

- **Gathering Lines**
  - Transport raw oil and gas from wells to processing plants and transmission facilities.
  - Transport storage gas from wells to compressor stations.

- **Trunk Lines**
  - Transport crude oil, natural gas liquids and refined petroleum products to refineries, petrochemical plants, consumer areas.

- **Gas Transmission Systems**
  - Transport natural gas at a high pressure to consumer areas.

- **Local Distribution**
  - Companies deliver natural gas at low pressures to consumers. (EMO, 2005)

Hazards associated with pipelines include:

- **Release of oil/gas** – The rupture of a pipeline can result in the release of its contents which may be under high pressure. Oil spills can result in significant damage to the environment and are difficult to clean. If an underground pipeline transporting natural gas is ruptured, frost or paved surface may result in the gas following utility ditches or conduits into buildings (Transport Canada, 2008).

- **Blast Effects** – The pressure of the contents at the time of the pipeline rupture can result in projectiles (often pieces of the pipeline itself) being thrown into the air at high speeds.

- **Fire and Explosion** – In the vast majority of pipeline accidents, ignition has not occurred.

- **Noise** – The release of natural gas under high pressures is very loud and can result in hearing loss and disorientation in people close to the ruptured section of the pipeline.

(Suffolk County Council, 2002).

Storage/Distribution Systems
Oil is stored at refineries and product terminals until it can be refined and the finished product can be distributed to consumers. A certain quantity of natural gas is stored, particularly during the warmer months, in order to meet the expected peak demand in the colder months for heating. Many facilities that store natural gas used underground storage tanks in order to minimize the risk of an explosion or a release affecting the public.

Hazards associated with storage/distribution systems include:

- **Explosion** – the presence of filled storage tanks increases the risk of a strong explosion due to the amount of available fuel. Some storage sites are located close to existing large commercial and residential areas, while others that were
once buffered by a more rural landscape are now being encroached upon by development. Fires that involve stored propane can result in a very powerful explosion known as boiling liquid expanding vapour explosion.

- Spills – if the storage tanks or distribution system is ruptured or corroded.

**Provincial Risk Statement**

**Oil/Natural Gas Wells**

Ontario has approximately 3,000 oil and natural gas wells in operation. These wells are located on land and offshore under Lake Erie. Every year, approximately 100 new wells are drilled in Southern Ontario and approximately 600 wells are suspended (MNR, 2010).

A well emergency may result in fatalities or injuries if it is ignited and an explosion results. However, this is fairly uncommon. Perhaps the greatest risk is environmental contamination. Oil can travel through fractures in the rock layers that are pre-existing or caused by incorrect operation or maintenance practices. This may pose a risk to ground water. The presence of abandoned wells that may have been improperly capped can pose a threat if ruptured due to construction if existing land owners do not know that they exist.

**Pipelines**

While Ontario does have some natural reserves of oil and natural gas, the majority needs to be imported from the other provinces. As a result, Ontario has many hundreds of kilometres of pipelines. The Canadian Standards Association (CSA) has established standards for pipelines in Canada, many of which have been incorporated into federal and provincial regulations. As a result, poor design is rarely a cause of pipeline failures in Canada. The risk of a pipeline emergency is further reduced through federal and provincial requirements that utilities that own/operate pipelines must conduct leak surveys in order to detect leaks and pipeline corrosion before they result in an emergency situation. However, aging infrastructure and an extensive pipeline network increases the potential for a leak to occur anywhere in the province. Should an emergency situation occur, many sections of pipelines can be remotely shut down to isolate sections of pipeline.
A pipeline emergency can result in fatalities, injuries, property damage, critical infrastructure failure and environmental damage. Most of the pipeline infrastructure in Ontario is located in remote, sparsely populated areas where only environmental damage is likely to occur, however, increasingly development has been infringing on these areas. In urban areas, pipeline accidents are often caused by construction or other human activities that involve digging. In the unlikely event of a pipeline emergency, the impacts depend on the location of the rupture, the population, environmental sensitivity, the pressure of the oil/natural, the size of the pipeline and whether it ignites.

**Storage/Distribution Systems**

Many facilities that store natural gas and oil in Ontario used underground storage tanks in order to minimize the risk of an explosion or a release affecting the public. No major
events that threaten public safety have been reported in Ontario. Companies are required to have safety procedures and plans in place in order to prevent and mitigate emergency situations.

A storage/distribution system emergency can result in fatalities, injuries, property damage (in case of an explosion), environmental contamination and a significant business/financial interruption to the company responsible for the facility. The severity of the impacts depends on the amount of oil/natural gas being stored, the size and proximity of the surrounding population and the trigger of the emergency (i.e. rupture, explosion).

**Case Study - Sunrise Propane Explosion 2008**

On August 10, 2008 a series of explosions occurred at Sunrise Propane in Toronto. As a precaution, thousands of people were temporarily evacuated. Two fatalities were associated with this event. A District Chief of Toronto Fire Services died of a heart attack and deceased person was found at the scene. The deceased person was later identified as an employee of Sunrise Propane. Damage to the Sunrise Propane site and the surrounding area was extensive, resulting in substantial clean up costs estimated to be $1.8 billion.

The cause was later identified as a propane leak that resulted from a hose failure during a “tank-to-tank” transfer from one cargo truck to another. The ignition source is still unknown. (Office of the Fire Marshal, 2010)

**Radiological Emergency**

**Definition**

A radiological emergency occurs when radiation from radioactive material is unintentionally emitted outside of protective spaces, at levels high enough that it presents a threat (real or perceived) to people or the environment.

**Description**

Radiation can be divided into two groups:

- Non-ionizing radiation
- Ionizing radiation

Non-ionizing radiation can vibrate atoms in a molecule but does not have enough energy to remove electrons. Ionizing radiation has enough energy to remove electrons and to break chemical bonds. Very-high energy radiation is capable of breaking up a nucleus (EPA, 2010). A radiological emergency is one which involves ionizing radiation.

There are three basic types of ionizing radiation:

- Alpha particles
- Beta particles
- Gamma rays
A device that contains radioactive material and could result in exposure is referred to as a ‘source’. Radiation sources are commonly used in universities, industry and government facilities. A source can be classified as being dangerous if uncontrolled exposure could result in severe health effects. A source may be considered to be uncontrolled if it is abandoned, lost, stolen or otherwise outside of regulatory control. These may also be referred to as ‘orphan sources’ (IAEA, 2006). Radiological emergencies may also arise from the misuse or malfunctioning of industrial and medical sources, human-made space objects, and transportation accidents carrying radioactive materials and from unknown origins. While radiological incidents may occur from time to time, (these are usually small and are cleaned up very quickly without any negative effects) radiological emergencies are rare. Due to their rarity, first responders may not be familiar with this hazard.

There are several different ways in which people and animals can be exposed to radiation:

- Direct exposure (being near or in contact with an uncontrolled source)
- Inhalation of radioactive particles
- Ingestion of foods or liquids contaminated with radiation.

The severity of exposure depends on the:

- Type of radiation: different types may damage different tissues
- How the person was exposed: direct, inhalation and/or ingestion
- Amount of time spent near the radiation source
- Proximity to the radiation source: exposure increases the closer you are to the source
- Presence and type of shielding: depending on the type of radiation effective shielding ranges from a piece of paper to a lead-lined wall (EPA, 2010).

**In a radiological emergency, it may be necessary to establish a safety perimeter around the source in order to prevent any further exposure to the public and responders. The table below displays the International Atomic Energy Association’s (2006) recommendations for the appropriate sizes and locations of the safety perimeter for different radiological emergencies. The table also notes that the size of the perimeter may be required to expand (but never decreased) if ambient dose rate readings are high.**
### Table 9. Safety perimeters for a radiation emergency (IAEA, 2006).

<table>
<thead>
<tr>
<th>Situation</th>
<th>Safety Perimeter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unshielded or damaged potentially dangerous source</td>
<td>30 m around19</td>
</tr>
<tr>
<td>Major spill from a potentially dangerous source</td>
<td>100 m around19</td>
</tr>
<tr>
<td>Fire, explosion or fumes involving a potentially dangerous source</td>
<td>300 m radius 19</td>
</tr>
<tr>
<td>Suspected bomb (potential RDD), exploded or Unexploded</td>
<td>400 m radius or more to protect against explosion20</td>
</tr>
</tbody>
</table>

#### Initial determination - outside

<table>
<thead>
<tr>
<th>Situation</th>
<th>Safety Perimeter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Damage, loss of shielding or spill involving a potentially dangerous source</td>
<td>Affected and adjacent areas (including floors above and below)</td>
</tr>
<tr>
<td>Fire or other event involving a potentially dangerous source that can spread materials throughout the building (e.g. through the ventilation system)</td>
<td>Entire building and appropriate outside distance as indicated above</td>
</tr>
</tbody>
</table>

#### Initial determination - inside a building

<table>
<thead>
<tr>
<th>Situation</th>
<th>Safety Perimeter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient dose rate of 100 mean Sv/h22</td>
<td>Wherever these levels are measured.</td>
</tr>
</tbody>
</table>

#### Expansion based on radiological monitoring

Table 9. Safety perimeters for a radiation emergency (IAEA, 2006).

**Provincial Risk Statement**

There are tens of thousands of radiation sources in Ontario in research facilities, universities, industry and medical buildings. Ontario has more radiation sources than all of the other Canadian provinces combined (EMO, 2005). Increasing demand for radiation sources and materials has resulted in increasing amounts of these items being transported throughout the province. Many of these shipments travel through populated areas and along busy highways.

Human and animal living tissue can be damaged by ionizing radiation. Health effects may not appear for days, weeks or even years depending on the length, type of
radioactive material and form of exposure. Negative health effects can be divided into two categories: chronic and acute.

Chronic health effects are related to long-term exposure to radiation. The energy level of the radioactive material is not sufficient to cause immediate health effects. Negative health effects may not show up until months or years after exposure. According to the U.S. Environmental Protection Agency (2010) increased levels of exposure to radiation make chronic negative health effects more likely to occur, but it does not influence the severity of the effect. The primary chronic health effect related to radiation exposure is cancer. Teratogenic mutations of foetuses are also possible if pregnant women are exposed to radiation sources over the long-term (EPA, 2010).

Acute health effects are caused by exposure to high levels of radiation. These effects may appear quickly, within a matter of hours or days. Symptoms can become more severe as the level of exposure increases. The principle acute health effect is radiation sickness. Radiation sickness can induce symptoms such as weakness, hair loss, nausea, damage to the organs and skin burns. If the dose of radiation received from exposure is high enough, radiation sickness can be lethal with death usually occurring within two months of exposure (EPA, 2010).

Past emergencies, incidents and misinformation have created an exaggerated fear of radiation in the minds of the public. Oftentimes, the fear generated by the perceived threat, rather than the reality of the situation has been the most severe consequence of many past radiological emergencies that have occurred in areas around the world (IAEA, 2006). Fear of exposure can cause significant impacts on the health system.

Another potential negative effect of a radiological emergency involving a dangerous source could be ground contamination. Depending on the level of contamination, clean up of the site may be necessary. If the contamination is severe, any inhabitants of that site may require relocation.

According to the IAEA (2006) it is unlikely that a public water supply could be contaminated by radiation to a level that would result in severe health effects but that it may be possible to have contamination levels that exceed international safety standards. International safety standards are reflect levels below those that would result in severe health effects if the contaminated water was drank for a year. The IAEA states that water contaminated at levels higher than the international safety standard could possibly be ingested for months without any severe health effects, even in vulnerable populations.

**International Case Study - Radiological Accident in Thailand**

In January 2000, an unregistered teletherapy device (use for the treatment of some cancers) in Thailand was bought by several people who intended to sell it as scrap metal. The device displayed a warning label that indicated that it contained radioactive material; however, the people did not understand the language it was written in or the form of radioactive material.
meaning of the symbol. The brought the device to one of their homes where others assisted in trying to dismantle it further. On February 1st, 2000, two of the people took the device to a junkyard in Samut Prakam. A junkyard worker disassembled the device further using a torch. While he was doing this, the source fell out of its housing unnoticed.

Soon after their exposure to the device and its source, the people exposed began to feel the effects of radiation sickness and sought medical attention. Doctors at a local hospital recognized the signs and symptoms and reported their suspicions to the regulatory authority. The regulatory authority was able to trace the origin of their illness back to the junkyard where high radiation levels were detected. The area was secured and the source recovered. No environmental contamination had occurred. Of the people exposed, three died and seven experienced radiation sickness. (International Atomic Energy Agency, 2002)

**Transportation Emergency**

**Definition**

A crash, collision or incident, of large scale, involving an air, land (road), rail or marine mode of transportation that excludes hazardous materials incidents.

**Description**

The Transportation Safety Board (TSB) of Canada investigates and records transportation accidents ‘that have a reasonable potential to result in safety action or that generate a high degree of concern over transportation safety. Investigation of recreational boating, inter-provincial trucking, bus, and industrial accidents is outside the scope of the TSB’s mandate’.

**Air**

Transportation emergencies involving aircraft may arise from the circumstances below:

- An aircraft colliding with another aircraft in the air.
- An aircraft crashing or being in imminent danger due to mechanical problems, or human error.
- An aircraft crashing while in the takeoff, cruising or landing phases of a flight.
- An aircraft colliding with an object on the ground or at any stage during the flight.
- Two or more aircraft colliding on the ground during staging or taxi operations.

A transportation emergency involving aircraft may result in secondary hazards such as fires and explosions. If a structure is impacted, it may result in building/structural collapse.

An average of 262 accidents involving Canadian registered aircraft (excluding ultra lights) occurs in Canada every year occurring to Transport Canada. Aircraft accidents result in approximately 49 fatalities a year in Canada (Transport Canada, 2009).
Marine
Transportation emergencies involving marine vehicles may arise from the circumstances below:
The main types of marine accidents include:

- A collision with another marine vehicle or object
- The marine vehicle capsizing, floundering, sinking.
- A marine vehicle encounters severe weather which causes damage or flooding.
- A fire and/or explosion aboard the marine vehicle.
- The marine vehicle striking land, ice or rocks and becoming damaged or grounded.
- A marine vehicle suffers structural damage that compromises its safety.
- The flooding of a marine vehicle.

Marine emergencies have become less frequent in recent years due to advancements in weather forecasting, technology and safety. Transport Canada (2009) reports that an average of 390 marine accidents occur annually with an average of 21 fatalities.

Rail
Transportation emergencies involving railways may arise from the circumstances below:

- A train derails for any reason.
- A train collides with another train or another object.
- Track related - track buckle, broken rail and track geometry problems;
- Equipment related - broken wheels, bearing and axel failures, and component failures.
- Train operations related - operating violations, technological and human error.

Transport Canada (2009) reports that an average of 1300 reported rail accidents per year with an average of 91 fatalities annually.

Road
Transportation emergencies involving road transportation may arise from the circumstances below:

- Crashes involving objects.
- Crashes involving other motor vehicles.
- Poor road conditions.
- Human and technological error.
- Driver impairment.

Thousands of small-scale road accidents occur annually, although, large-scale road transportation emergencies are uncommon. Few are severe enough that they exceed the local emergency response capacity and require provincial assistance.
Provincial Risk Statement

Air

Thousands of airplanes fly into and out of airports in Ontario every day. Despite the high volume of air traffic, serious air transportation incidents involving large numbers of people are fairly rare. However, when they do occur, they can result in a large number of injuries and even fatalities. The number of people affected depends on the size of the aircraft, the number of passengers and crew, the speed at which it is travelling and the area (and the population) in which the incident occurs. Serious property damage can occur if the incident occurs in an area with a large amount of building and/or structures. Damage can be very severe, resulting in the complete destruction of the building/structure. Critical infrastructure may also be damaged. However, due to the size of aircraft and the amount of fuel aboard, air transportation incidents are usually localized.

Canadian Air Occurrence Statistics indicate that the flight phase is very critical to the level of accident risk. For airplanes, accidents during the landing phase account for 35% of total accidents. Approximately 24% of aeroplane accidents occur during the takeoff phase.
Since the take-off and landing phase account for a high percentage of airline crashes, developed areas adjacent to major airports and in airport flight paths are more vulnerable to this hazard. (EMO, 2005)

Road transportation incidents have become a routine occurrence on many of Ontario’s heavily travelled roadways. However, rarely do incidents occur that are severe enough that they exceed the local emergency response capacity.

Roads are an essential component of the critical infrastructure, vulnerable to closure due to major accidents, spills, severe weather, landslides, earthquakes and even bridge failures. Serious incidents on Ontario’s northern remote roads would pose emergency response challenges. Roads are essential to public welfare, especially in remote communities dependent on transport of food, water, and other vital medical supplies. They also serve as public evacuation routes where this is required.

Of the 231,548 Highway Traffic Act reportable collisions that occurred in Ontario in 2004, only 1% resulted in fatalities, 27% resulted in injuries and 73% involved only property damage (MTO, 2007).
Ontario has a highly regulated rail industry and a safety record that shows a decline in accidents and fatalities. Major rail derailments involving passenger trains are relatively rare, and few have resulted in passenger deaths. The severity of a rail transportation incident varies depending on the number of people aboard the train, the speed, whether it occurs in a populated area, the number of rail cars affected, and the type of cargo the train is carrying, whether there is any property or infrastructure damage and whether an evacuation occurs. Communities with major rail infrastructure and commuter train service are at increased risk of a passenger rail event.

Passenger related train events have a shock value with the public when they do occur, as they result in multiple casualties/injuries and property damage. Many factors have contributed to the overall decrease in Canadian main track derailments including, improvements in technology and operating methods, and rigorous safety regulatory enforcement and inspection programs (EMO, 2005).
Ontario’s history of marine events is extensive, many with large-scale casualties. Fortunately, the extremely high marine hazards of the 19th and 20th century have been reduced through improvements in navigation technology, shipbuilding, safety equipment and better accuracy of marine weather forecasts etc. Also, Canada’s marine safety is regulated through measures concerning employee training, operator qualifications, inspections, security, substandard vessels and non-compliance with regulations.

Ontario shares critically important waterways with other provincial and US jurisdictions and the infrastructure accommodates a growing industry of large lake/ocean cargo vessels, as well international cruise ships. The severity of any potential marine emergency disaster would vary on the number of passengers/crew on board, the specifics of the cargo, and the capability to respond to the emergency. Factors of human error (and negligence) must be considered as a high risk factor with increased marine traffic (EMO, 2005).

**Case Study - Brantford Train Derailment 2002**

On November 16th, 2002, a train collided with a van in Brantford. The driver of the van was killed. The force of the collision derailed eight train cars which rolled down an
embankment that adjoined a neighbourhood. Since the cars contained a residue of butylenes and butane, 120 people from the immediate area were evacuated as a precaution for two days. (Canadian Disaster Database, 2005).

Human-Caused Hazards

Human-caused hazards are hazards which result from direct human action or inaction, either intentional or unintentional. This includes hazards that arise from problems within organizational structure of a company, government etc.

Civil Disorder

Definition

A group or groups of people intentionally not observing a law, regulation or rule in order to disrupt a business, organization or community to bring attention to their cause, concern or agenda.

Description

Large scale civil disorder emergencies are rare. Some of their potential causes include:

- Resource shortages.
- High profile/controversial meetings.
- A victory or defeat of a sports team.
- Hostile labour disputes.
- Local, national or international events.
- The implementation of controversial laws polices or court rulings.
- Disagreements between special interest groups over a particular issue or cause.

Civil disorder can take many forms including:

- Small or large groups that cause the disruption of normal public services and activities.
- Groups that intentionally block or impede access to buildings, roads or other sites.
- Assaults on public figures, police or security personnel.
- A riot in which property is destroyed and the public threatened.

A group warranting concerns of civil disorder are generally made up of three categories of people: non-violent spectators/participants, onlookers and a small but active, potentially violent subgroup. The number of people in the potentially violent subgroup is significantly less than those in the broader group (EMO, 2005). While very few people in a crowd usually intend from the outset to participate in violent activities, violent tendencies can spread throughout the group through a psychological phenomenon called ‘crowd personality’. Collective groups of people can accentuate emotions ranging from happiness to anger in individuals within the crowd. It is possible for this crowd personality to be manipulated and influenced by a small number of people with the intent to incite violence (Cocks, 1999).
Civil disorder can be static or dynamic. A civil disorder can be considered to static if the group of people involved stays within a particular area. In this case, some public safety measures can be taken, such as designating first aid facilities, rerouting transportation routes and planning evacuation routes (Cocks, 1999). A dynamic civil disorder is one in which the group may move locations on either a predictable or unpredictable route. If the route is not predictable, then it may not be possible to activate certain public safety measures.

The number of groups involved in the protest and their relationships to each other can also be significant. Some acts of civil disorder involve only one group. Others may involve two or more groups with a hostile relationship. An additional group is added if the police are required to intervene to separate the groups.

**Provincial Risk Statement**

Ontario has experienced a large number of civil disorder events. Most of the large-scale events occur in cities with large populations, such as Ottawa or Toronto. Ottawa has an average of 700 demonstrations annually and Toronto has several hundred, the majority of these events are held with peaceful intentions and do not pose a significant threat to public safety (EMO, 2005). For smaller communities, the threat of a civil disorder emergency is much lower. Civil disorders, unlike most other hazards, need to be handled in a cautious manner in order to find a balance between public safety and the preservation of individual rights and freedoms as guaranteed under the Charter of Rights and Freedoms. Civil disorder events may not be triggered only by events that occur at a local or national level. In an increasingly interconnected world, international incidents may trigger events.

Civil disorder can result in injuries to the participants, police and security forces, bystanders and anyone else in the immediate area. The types of injuries depend on the degree of escalation of the civil disorder. A relatively peaceful event may result in no injuries. An event with a degree of violent may result in injuries such as lacerations and contusions if members of the crowd begin to throw items that they have picked up from the surrounding area, such as bottles and paving stones. A civil disorder reaches a higher degree of escalation if the participants bring objects with them to intentionally cause damage and/or injury. These objects may include wooden clubs, spears and machetes. The injuries may include deep wounds. The civil disorder can escalate even further if items are brought that are intended to be used as chemical weapons (e.g. battery acid, ammonia) or as incendiary devices, such as Molotov cocktails. Riot control agents may also result in injuries and pose a risk of contamination for healthcare providers as they may be transferred during medical assistance.

Property damage, especially to businesses, is likely the most common impact of civil disorder. Depending on the cause or motivation for the civil disorder, particular businesses may be targeted. Many of these are often internationally owned and operated large chain businesses that may be perceived to have unscrupulous business practices.
or manufacturing practices. Certain facilities or areas may be more at risk of civil disorder incidents than others, depending on the cause or motivation for the civil disorder. Municipal, provincial and federal government buildings, landmarks, universities, detention facilities etc. all experience an increased risk due to their activities.

Civil disorder incidents can have significant impacts on the health sector. Hospitals and clinics may be inaccessible if the civil disorder incident is nearby or they may be overwhelmed by a sudden increase in people requiring medical care. As a result, the health sector requires significant contingency planning for civil disorder.

**Case Study - G20 Protests 2010**
The 2010 G20 summit was held in downtown Toronto. While the majority of the protests were peaceful, an extremely small minority engaged in civil disorder. These individuals used black bloc tactics to cause damage and attempt to incite violence. The windows and store fronts of businesses including banks, retail stores and fast food chains were damaged and several police cruisers were set on fire. Four major hospitals, several hotels and a major shopping centre located close to the violence were put under lockdown. Public transit services were suspended or diverted. (EMO, 2010).

**Cyber Attack**

**Definition**

‘A criminal offence involving a computer as the object of the crime, or the tool used to commit a material component of the offence’ (Canadian Police College, 2010).

**Description**
Cyber attacks are a fairly new hazard. As society’s dependence on technology and computer systems have increased, so have the risk of cyber attacks. Computer technology is used for a variety of important functions, from functions in water treatment plants to business transactions to the energy supply grid.

Cyber attacks can be divided into two very general categories depending on how computers, networks and programs are used:

1. The computer as the tool of the crime
   1. The computer as the object of the crime
(Kowalski, 2002).

The first category includes traditional crimes, such as fraud, which have been adapted to use computer technology. The second category contains emerging crimes, such as the spreading of computer viruses.

Some examples of cyber attacks are:
Hazard Identification and Risk Assessment for the Province of Ontario

- Hacking or the unauthorized use of computer systems and networks (including critical infrastructure)
- Computer viruses and spyware
- Using a computer to steal information
- Fraud (including identity theft and stealing banking information)
- Harassment
- Defacing, altering or removing websites
- Obtaining sensitive documents

(Kowalski, 2002).

Cyber attacks have become an increasing national and international concern. While data on the number of events that occur annually is not available and many attacks are not reported, it is believed that they are increasing. Attacks may not be reported because the victim may be unaware that they were targeted, the information taken was of a sensitive nature, many law enforcement agencies around the world are not yet set up to handle cyber attacks and other reasons. Cyber attacks can be committed by individuals, groups, organizations and even governments.

One of the major difficulties in preventing and prosecuting the people behind cyber attacks is that due to the proliferation of the internet and computer technology knowledge, the internet can now be access in more than 200 countries (Kowalski, 2002). A person can commit a cyber attack targeting computers, networks and systems internationally from a single location, almost any location that has telephone service. Identifying the person or persons responsible can also be extremely difficult since the attack can be routed through many different countries and it is not difficult for them to use false identities.

**Provincial Risk Statement**

Many of Ontario’s critical infrastructure networks and businesses are heavily reliant on computer technology. The severity of the impact depends on the type of cyber attack and the type of target. A cyber attack could have significant financial repercussions for a business or organization. An attack on the stock market could have large scale financial repercussions, while an attack on critical infrastructure could disable that infrastructure and leave thousands without access to that infrastructure. The human intelligence behind a cyber attack could serve to prolong the duration of the incident or maximize the impacts.

Canada as a whole has been an active participant in the development of information technology and in efforts to counteract cyber attacks. Canada is also one of the first countries to develop laws against cyber attacks.

**International Case Study - Stuxnet 2009**

Stuxnet is a computer worm which targets specific industrial systems and appears to have been written to specifically target Supervisory Control And Data Acquisition.
Hazard Identification and Risk Assessment for the Province of Ontario

systems. It is the first computer worm to be found that is capable of providing information on and reprogramming industrial systems. It is also the first to include a programmable logic controller root kit. Stuxnet is also considered notable in that it appears to have been developed ‘with nation-state support’ (Kaspersky Labs, 2010).

It is believed that the intended target may have been Iran’s nuclear facilities, in particular the uranium enrichment facility at Natanz. Although reports initially stated that Stuxnet had not caused any damage, on November 29th, Iran confirmed that its nuclear program had been damaged by the worm. (Symantec, 2010)

Sabotage

Definition

The act of damaging, destroying, interfering, impairing or obstructive public or private property, machinery, businesses or the environment with the intention to cause harm.

Description

Acts of sabotage may include:

- The damage or destruction of property, resources or machinery
- The use of force or threats
- Hate crime (ethnic, religious or gender intimidation)
- Product or process tampering
- The release of sensitive, confidential information

Sabotage can be an internal or external threat within the community, company, organization or government that is targeted. Internal threats include sabotage by employees or other people who have routine access (while the access of the general public is controlled) to the targeted facility, site or object. External threats arise from people who do not have routine access to the targeted facility, site or object (Baybutt and Ready, 2003).

The motives of people who commit sabotage include:

- Criminal intent
- To gain publicity for a cause
- Organizational and/or ideological recognition
- Revenge for perceived injustices
- Political, religious or ideological causes
- Business disruption

(EMO, 2005).

Internal acts of sabotage are more likely to be motivated by perceived injustices to the individual(s) and labour disputes. External acts of sabotage are more likely to be motivated by political, religious or ideological agendas (Baybutt and Ready, 2003).
Provincial Risk Statement
Sabotage is cited under the Canadian Security Intelligence Service (CSIS) Act (1984). Government facilities, critical infrastructure, businesses and organizations may be targeted. Sabotage is of greater concern in highly populated industrial communities. This is in part because there is the potential for more people to be affected, the greater presence of media and the location of the target. Industrial sabotage is of particular concern to locations that manufacture, store or use hazardous materials and the industries such as energy and water (EMO, 2005).

Sabotage can result in fatalities, injuries, property damage and economic damage. They may also result in disruptions of the target business, infrastructure, organization or government. It can also result in a public loss of confidence of the government and safety and security services. Rarely, an extreme act of sabotage may have the potential to result in a threat to national security or to negatively impact the government’s political and/or social agenda. However, the majority of sabotage acts do not present a threat to public safety and do not result in serious consequences.

International Case Study - Communications Sabotage in Santa Clara County, United States 2009
In 2009, Santa Clara County in the United States was forced to declare a state of emergency due to the interruption of fiber optic lines by sabotage. The fiber optic lines were severed at four different locations and law enforcement officials claimed that the work could only have been done by some one with expertise in fiber optic lines. The severing of the lines resulted in interrupted telephone and internet service for tens of thousands of customers.

The loss of telephone communication required a change in strategy for first responders since 911 was no longer available. Parts of the system were re-routed; first responders used two-way radios and were strategically placed in affected communities.

The outage also had a significant impact on businesses since credit and debit card payments were not available unless their devices were connected by satellite. Many banks were forced to close and ATMs were out of service. Schools were placed on high alert since they would be unable to contact parents or emergency responders in case of an emergency.
(Santa Clara Sentinel, 2010).

Special Event
Definition
A non-routine, lawful activity that is usually planned and that attracts large numbers of people. These events include, but are not limited to, the attendance of prominent public officials, national/international dignitaries, concerts and public events.
Description
Hundreds of events are held successfully with few or no problems or threats to public safety. However, occasionally an event may be considered a hazard if it:

- Is non-routine.
- Places a strain on community resources.
- Involved a large number of people.
- Requires additional planning, preparation, and mitigation.

(FEMA, 2010).

Special events may present a greater risk for incidents and provide criminals and terrorists with opportunities for crime due to the large numbers of people attending, media attention and any prominent political or cultural figures that may be in attendance. Depending on the type and size of a special event, it may require assistant from law enforcement, public works, public health and the health care system, and others.

Special events can range from festive to those arranged due to political and/or global concerns.

Examples of special events include:

- Air events (e.g. air shows, hot air balloon festivals)
- Aquatic events (e.g. watercraft races, surfing competitions)
- Concerts
- Conventions
- Festivals (e.g. music festivals, art festivals)
- Motorized events (e.g. car races, motorcycle demonstrations)
- Political rallies (e.g. protests, VIP visits)
- Sporting events (e.g. marathons, World Cup)
- Spontaneous events – unplanned events (e.g. celebrations following a sporting championship, demonstrations after controversial court decisions).

Some of the common factors of special events are that they may include:

- The convergence of thousands of people (sometimes including vulnerable groups, such as children) to a central location
- Increased requirement for security
- Non-routine provisions in order to ensure transportation and health and safety requirements.
- Large media presence.
- Most are planned months or even years in advance.

(EMO, 2010)

Special events can threaten public safety in several ways:

- The influx of people can exceed the capability of the infrastructure- requiring additional public health services, sanitation needs, water, food, lodging,
The unpredictable dynamics of crowd management;
- Severe weather factors can create additional risks; many outdoor special events offer little shelter;
- Provides an environment where crimes of opportunity can occur between person(s) or groups.
- Attraction of persons with violent agendas.
- Increased concentration of people can created increased risk of the transmission of communicable diseases and outbreaks.

(EMO, 2005 and MOH, 2010)

Provincial Risk Statement
Many special events are held every year in various communities throughout Ontario. The vast majority of these take place without any major problems or threats to public safety. Since special events are usually planned for months, even years in advance of the event itself, emergency plans and contingency places are often developed prior to the event and the necessary resources are obtained.

Some factors/actions may induce panics or crazes within the crowd. A panic is the flight of a group of people from a real or perceived threat. A craze is the temporary, short-lived competitive rush by a group of people toward some desired object or person (FEMA, 2010).

- Operational (e.g. cancellations of performances)
- Event activities (e.g. noise, smoke)
- Performance Actions (e.g. violent lyrics)
- Spectator Factors (e.g. alcohol and drugs)
- Security Factors (e.g. excessive force)
- Social Factors (e.g. team rivalries)
- Weather (e.g. thunderstorm)
- Natural Disaster (e.g. earthquake)
- Human-caused Disaster (e.g. structural failure)

(FEMA, 2010)

A panic or a craze may result in people being unable to move out of the way in time to avoid being pushed and/or trampled. This may lead to injuries (mainly crushing or blunt force trauma injuries) or even in fatalities. The very young, the elderly, people with disabilities and people with small frames are more likely to be injured if this occurs. The presence of a large group of people may encourage theft or vandalism since the criminal can quickly rejoin the crowd to avoid capture.

Case Study - 2010 Winter Olympics
The 2010 Winter Olympics were a major international multi-sport event that was held from February 12 to 28th, 2010 in Vancouver. Prior to the event, the Olympics Torch
Relay, a 106 day run across Canada was held with an estimated 12,000 torchbearers including many celebrities. An estimated 5,000 athletes and officials, 10,000 media members, 14,000 volunteers and 2.3 million spectators attended the Olympics. The large number of people required significant planning and preparedness measures, improvements to infrastructure and security arrangements. (Vancouver Organizing Committee for the 2010 Olympic and Paralympics Winter Games, 2010).

**Terrorism/CBRNE**

**Definition**

Chemical, biological, radiological, nuclear and explosive (CBRNE) materials that are intentionally released with the intent to cause harm to humans, property, business or the environment. These materials can be weaponized or non-weaponized.

**Description**

CBRNE incidents and hazardous materials incidents are terms which are sometimes used to describe any incident which involves the release or the potential release of hazardous materials. For the purposes of this document, the two terms have been separated. Hazardous materials incidents refer to unintended releases of a hazardous material; while CBRNE incidents refer to those caused by intended actions. The human element behind CBRNE incidents can result in an incident that may be more complex and unpredictable than a hazardous materials incident.

CBRNE incidents include events such as:

- Acts of terrorism
- The intentional poisoning, infecting or otherwise targeting through means such as planned explosions of an individual or small group for non-political reasons.
- Criminal acts such as the intended release of hazardous materials in order to avoid fines or regulatory requirements. (Stokes, 2010)

Different types of attacks include:

- Chemical
- Biological
- Radiological
- Nuclear (including EMP)
- Explosion

The impact of a CBRNE incident depends on:

- the type of material used
- amount of material used
- dispersal method
- number of different CBRNE materials used
- the location (open or closed in)
- the weather conditions
Hazard Identification and Risk Assessment for the Province of Ontario

- the population density
- the length of exposure
- the length of time in which symptoms appear
- the length of time in which the material is identified

(CDC, 2010)

CBRNE incidents may involve:
- Negative psychosocial impacts
- The risk of mass casualties or fatalities and illness
- Chronic health impacts
- The creation of a hazardous environment
- Uncertainty in ascertaining what type of material was used
- The potential use of a combination of CBRNE materials with identical or different release times
- The immediate need for medical response, decontamination systems and specialized pharmaceuticals
- The need for detection equipment

(The Centre for Excellence in Emergency Preparedness, 2010)

Provincial Risk Statement
The most likely type of CBRNE incident is explosive. Instructions for building explosive devices can be found on the internet. Explosive devices do not have to be particularly sophisticated in order to cause a significant amount of damage. Many ingredients for an explosive device have common, daily uses and are easy to obtain. High volume purchases of these ingredients may raise suspicion, however, numerous purchases at different locations and over a period of time may go undetected.

Chemical and biological weapons can be difficult to disperse in an effective manner if the goal is to expose as many people as possible. The dispersal of either of these weapons can be greatly influenced by wind direction and speed, and the duration of the substance in the open environment. However, if a chemical and/or biological weapon were to be released in an enclosed space with a large number of people, it could result in a large number of fatalities and injuries depending on the type and amount of agent used. However, this type of incident would likely involve more planning, time and sophistication than an explosive device which has a greater potential to cause injuries and fatalities. A chemical or biological incident is a covert form of attack and increases the odds that the attacker could escape detection.

The least likely type of CBRNE incident is a nuclear one. A sophisticated nuclear device, such as those used by militaries, would require a large amount of nuclear material and a less sophisticated device would require even more to work. Countries and nuclear facilities track their usage of nuclear materials and any loss is likely to be noticed and reported. However, it is not impossible to obtain nuclear material.
Eighteen of 175 known cases of nuclear materials trafficking documented by the Atomic Energy Agency (IAEA) involved small amounts of highly enriched uranium and plutonium. In 1992, an attempt was made to steal 1.5 kg of highly enriched uranium from the Luch Scientific Institute in Russia (Gottemoeller, 2010).

As of May, 2010 there has only been one intentional CBRNE incidents that have been successful in Ontario (OFM, 2010). In 1942, a plant in Toronto that was manufacturing components for cruise missiles was bombed by the Direct Action Group. Ten people were injured. However, it has become public knowledge that attacks have been planned in the past. For example, in 2006, a group dubbed the 'Toronto 18' planned to attack the Toronto Stock Exchange; the Front St. offices of Canada's spy agency; and a military base off Highway 401 between Toronto and Ottawa using explosives. They were arrested by police before they were able to achieve their goal.

It is possible that Ontario faces a greater risk of intentional CBRNE incidents than the other provinces and territories. The risk may be higher since Ontario contains Ottawa, the national capital, and Toronto, which is Canada’s economic capital. Landmarks and infrastructure such as the CN tower and public transit could also be targeted. Border communities also face an increased risk of intentional CBRNE incidents. There are nine border communities in Ontario.

Cities with a high volume and high reliance on public transportation may also have their transportation infrastructure at risk. An attack against a public transportation system which a large number of the local population relies on for transit may paralyze a city. The London bombing on July 7 2005 were coordinated attacks on the public transit system during rush hour. Three of the explosions were detonated on the London Underground trains and one was detonated on a bus. Fifty-two people (not including the bombers) were killed and approximately 700 were injured. CBRNE attacks can have a greater toll if they involve large numbers of people in an enclosed space. Rail systems, in particular subways in larger cities have been selected for attack in recent years. In March, 2010 two suicide bombers detonated explosives at two subway stations in Moscow killing 35 people and injuring many others. While a successful attack on public transit has not occurred in North America, a plot to bomb three New York City subways in September of 2009 was prevented by police.

**Case Study - The Toronto 18 2006**

After lengthy investigations by Canada’s spy agency (CSIS) and the RCMP, a group of 14 adults and four youths were arrested in 2006. The investigation was capped by an elaborate sting operation. It ended with tactical units, armed with submachine guns making the first in a series of arrests.

The plan was to detonate fertilizer bombs in U-Haul trucks at targets such as the CN Tower, the Toronto Stock Exchange, the Toronto Offices of CSIS and a military base along Highway 401.

Emergency Management Ontario
2012
Approved
The case was the first homegrown cell in Canada charged under the anti-terrorism legislation. Four adults and three youths had charges against them stayed. The group had two ringleaders - Fahim Ahmad and Zakaria Amara. Seven adults pleaded guilty, including Ahmad and Amara. Of the remaining accused, all were convicted. (The Toronto Star, 2010)

**War/International or Provincial/Territorial Emergency**

**Definitions**

*International Emergency:* an emergency that affects Canada and at least one other country that requires joint management and response efforts between the countries.

* Provincial/Territorial Emergency:* an emergency that affects Ontario but that occurs in another province or territory and that requires joint management and response efforts between the countries.

*War Emergency:* a real or imminent war or other armed conflict that involves Canada or any of its allies that is of sufficient magnitude to be a national emergency.

**Description**

War/International emergencies are coordinated at the federal level since the authority for external action rests with the federal government. The province is expected to take the lead in managing those effects that are a sub set of the War or International emergency. An international emergency does not have to arise from armed conflict. It may involve an event that requires joint emergency management and response that occurs in all countries involved or in international waters.

A Provincial/Territorial emergency maybe coordinated at the provincial/territorial level. If the impact or the potential consequences are deemed to be particularly severe, it may be coordinated at the federal level.

**Provincial Risk Statement**

The political climate of the world is ever changing and the threat of war or international conflict is always present. A declaration of war anywhere in the world could have an effect on Canada and the Province of Ontario. The possible impacts vary significantly depending on the type of emergency from fatalities to business interruptions.

Notwithstanding the federal lead in these matters, it is possible that Canadian participation in War or International emergencies will have an impact in Canada and this could result in a public welfare or public order emergency. In the event of a war/international emergency, Ontario would be expected to manage sub-sets of the emergency that directly impact the provincial with direction from the federal government. Increasingly, the province has also been asked to send resources and support to affected areas such as health professionals, fire fighting and medical professionals.
Case Study - September 11, 2001

On September 11, 2001 al-Qaeda launched a series of coordinated suicide attacks on the United States. Nineteen terrorists hijacked four commercial passenger airplanes and intentionally crashed two of them into the towers of the World Trade Center in New York City and another into the Pentagon in Arlington, Virginia. The fourth airplane crashed into a field in rural Pennsylvania after the passengers and crew attempted to fight back. Everyone on board the planes was killed. Almost 3,000 people (including 343 firefighters and 60 police officers) died in the attacks on the World Trade Center and 184 people were killed in the attack on the Pentagon. The majority of casualties was civilians and included people from more than 70 countries, of which Canada was one. At least 24 Canadians were killed or are presumed to have been killed in the attacks.

Canada was impacted by the attacks. Border crossings were closed and airplanes were instructed to land in Canada instead of continuing over the United States. The Canadian government, volunteer organizations and civilians provided assistance and resources. (CBC, 2001)

Risk Assessment

4.1 Requirements

The revised Ontario Provincial Hazard Identification and Risk Assessment (HIRA) methodology was required to:

- be risk-based
- assess different types of hazards (natural, technological and human-caused);
- allow for the addition of currently unknown and evolving hazards in subsequent revisions;
- incorporate both qualitative and quantitative information;
- incorporate as much scientific information as possible;
- be applicable to a range of event consequences and frequencies;
- be scaleable so that it can be used at both a provincial and a municipal level;
- to serve the needs of Emergency Management Ontario in the coordination of the preparedness, prevention, mitigation, response and recovery activities;
- to consider the variety of consequences that may result from some hazards;
- be simple enough to be easily understood by a diverse group of people with different professional backgrounds.

4.2 Literature Review

In order to develop a methodology that reflected recommended practices and that is suitable for use at a provincial level, an extensive literature review was conducted. The sources of the documents that were reviewed include: scientific and peer-review journals, HIRAs from other provinces and international HIRAs that were developed in a
Hazard Identification and Risk Assessment for the Province of Ontario

The table below displays some of the methodologies that were examined in the literature review process.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Risk Assessment Equation</th>
<th>Definition of Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>World Health Organisation</td>
<td>$R = (x)(y)$</td>
<td>$x =$ Probability of an event occurring $y =$ Probability of various possible consequences</td>
</tr>
<tr>
<td>Zilinskas, 2005</td>
<td>$R = (H)(E)$</td>
<td>$H =$ Hazard (Impact) $E =$ Exposure or what population will be exposed to the agent, at what concentration, and for how long</td>
</tr>
<tr>
<td>Misra et al., 1991*</td>
<td>$R = (C)(T)(Cm)(S)$</td>
<td>$C =$ Chance (Probability) $T =$ Toxicity $Cm =$ Concentration $S =$ Time $*$For HazMat incidents only</td>
</tr>
<tr>
<td>Shook, 1997</td>
<td>$R = (H)(V)(P)$</td>
<td>$H =$ Threatening event that could cause loss of life or damage to property or the environment $V =$ Susceptibility of vulnerable elements, such as human populations $P =$ Level or degree of planning for and control of hazardous events and vulnerable elements</td>
</tr>
<tr>
<td>Arnold, 2002</td>
<td>$R = (H)(V)(M)$</td>
<td>$H =$ Hazard or phenomena that cause harm to human populations $V =$ Vulnerability or susceptibility of human populations to hazards</td>
</tr>
</tbody>
</table>
| Task Force on Quality Control of Disaster Management | \( P_D = f(H_N + H_M)(R_H)(V_N + a_1 + a_2 + b_1 + b_2) \) | \( P_D = \text{Probability that event will inflict damage on the society and/or the environment at risk} \)  
\( H_N = \text{Hazard dictated by nature} \)  
\( H_M = \text{Hazard dictated by man} \)  
\( R_H = \text{Probability that hazard will be converted into an event} \)  
\( V_N = \text{Resultant vulnerability as dictated by nature} \)  
\( a_1 = \text{Vulnerability augmentation} \)  
\( a_2 = \text{Vulnerability mitigation} \)  
\( b_1 = \text{Counter-productive disaster response} \)  
\( b_2 = \text{Productive disaster response} \) |
|---|---|---|
| Ferrier and Haque, 2003 | \( R = (p)(V)(n) \) | \( p = \text{probability of occurrence} \)  
\( V = \text{vulnerability} \)  
\( N = \text{social consequences} \) |
| Commonwealth of Massachusetts State Hazard Mitigation Plan | \( R = (F)(S) \) | \( F = \text{Frequency} \)  
\( S = \text{Severity (Consequence)} \) |
| British Columbia | \( R = (L)(C) \)  
\( C = I+V \) | \( L = \text{Likelihood (Frequency)} \)  
\( C = \text{Consequence} \)  
\( I = \text{Impact} \)  
\( V = \text{Vulnerability} \) |
| Manitoba Office of the Fire Commissioner | \( R = (I)(L) \) | \( I = \text{Impact} \)  
\( L = \text{Likelihood} \) |
| City of Redmond | \( R = (F)(V) \)  
\( V = \text{(Human + Built + Natural + Systems + Severity) / 5} \) | \( F = \text{Frequency} \)  
\( V = \text{Vulnerability} \) |
| State of Michigan | \( \text{Risk} = (P)(S) \) | \( P = \text{Probability} \)  
\( S = \text{Severity} \) |
| Regional District of Nanaimo | \( \text{Risk} = (I)(L) \) | \( I = \text{Impact} \)  
\( L = \text{Likelihood} \) |
| The Centre for Excellence in Emergency Preparedness | \( \text{Risk} = (P)(I) \) | \( P = \text{Probability} \)  
\( I = \text{Impact} \) |
| Lein, 2003 | \( P(A/B) = (p(A)*p(B/A))/(\sum p(B_n)*p(A/B_n)) \) | \( P = \text{conditional probability} \) |
A = probability of a consequence given that event (B) has occurred.

Table 10. Risk assessment equations and their sources.

NOTE: In some cases, the primary variables are broken down into specific sub variables as explained below.

In order to determine which variables should be included within the Provincial HIRA, the literature review was taken a step further to examine the different variables used in each equation. Many variables in the equations above actually have sub variables, e.g. vulnerability may be determined by assessing the social, environment and business impacts. The table below displays the common variables and sub variables of the different methodologies:
Variables and Sub variables

<table>
<thead>
<tr>
<th>Source</th>
<th>Consequence</th>
<th>Frequency</th>
<th>Social</th>
<th>Property</th>
<th>History</th>
<th>CI</th>
<th>Business</th>
<th>Environmental</th>
<th>Preparedness</th>
<th>Response</th>
<th>Manageability</th>
<th>Growth</th>
<th>Extent</th>
<th>Urgency</th>
<th>Psychosocial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Department for International Development (UK)</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Emergency Management Australia</td>
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<td>X</td>
<td>X</td>
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</tr>
<tr>
<td>Federal Emergency Management Agency</td>
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<td>X</td>
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<td>X</td>
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<td>X</td>
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<tr>
<td>General Accounting Office (US)</td>
<td>X</td>
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<td>X</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Ferrier and Haque</td>
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<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Commonwealth of Massachusetts</td>
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<tr>
<td>British Columbia Emergency Program</td>
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<tr>
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<tr>
<td>Manitoba Office of the Fire Commissioner</td>
<td>X</td>
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<tr>
<td>State of Michigan</td>
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<td>Regional District of Nanaimo</td>
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<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 11. The variables and sub variables in some of the methodologies that were reviewed.

It was recommended that a variable for psychosocial impacts be included based on the results of the literature review. The inclusion of psychosocial impacts has been discussed in many different journals and articles (e.g. Morrissey and Reser, 2007 and Sundram et al., 2008). This is not reflected in the table above since few of the journals actually developed risk assessment equations. Their purpose was to merely suggest that...
4.3 Risk Equation

At the core of all risk assessments is the equation Risk = Frequency * Consequence. The suggested methodology in this document incorporated a third variable. This third variable, Changing Risk introduces projected changes in frequency and vulnerability into the equation. The resulting equation for the Ontario Provincial HIRA is:

**Risk = Frequency**\(\times\) **Consequence**\(\times\) **Changing Risk**

4.4 Calculation

4.4.1 Frequency

For the ease of calculation, the frequency of the hazards can be divided in six groups:

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Category</th>
<th>Percent Chance</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rare</td>
<td>Less than a 1% chance of occurrence in any year.</td>
<td>Hazards with return periods &gt;100 years.</td>
</tr>
<tr>
<td>2</td>
<td>Very Unlikely</td>
<td>Between a 1- 2% chance of occurrence in any year.</td>
<td>Occurs in the province every 50 – 100 years and includes hazards that have not occurred in the province but are reported to be more likely to occur in the near future.</td>
</tr>
<tr>
<td>3</td>
<td>Unlikely</td>
<td>Between a 2 – 10% chance of occurrence in any year.</td>
<td>Occurs in the province every 20 – 50 years.</td>
</tr>
<tr>
<td>4</td>
<td>Probable</td>
<td>Between a 10 – 50% chance of occurrence in any year.</td>
<td>Occurs in the province every 5 – 20 years.</td>
</tr>
<tr>
<td>5</td>
<td>Likely</td>
<td>Between a 50 – 100% chance of occurrence in any year.</td>
<td>Occurs in the province &gt;5 years.</td>
</tr>
<tr>
<td>6</td>
<td>Almost Certain</td>
<td>100% chance of occurrence in any year.</td>
<td>The hazard occurs annually.</td>
</tr>
</tbody>
</table>

Table 12. Frequency categories.

Frequency should be calculated whenever possible based on existing data from official and/or scientific sources. It should be remembered that some hazards do not have a long historical record and that their frequencies can be estimated based on the best sources available. Ideally, the frequency would be calculated based on the number of times that the event has occurred, rather than in years, however the differing lengths of the historical records in Ontario did not make this possible. Some hazards may not have occurred in Ontario (or have occurred before recorded history) to an extent that they meet the criteria. These would be classified as 1 or 2 in the Frequency Table depending on the information obtained from journals, case studies and other sources.
4.4.2 Consequence

In order to produce a HIRA that is a true depiction of the actual level of risk faced by a certain area, care must be taken to assure that the frequency and consequence of each hazard are well understood and are representative of possible occurrences of each hazard.

Many hazards rarely occur with sufficient intensity to result in an emergency situation. For example, according to Environment Canada (2010), Ontario experiences a minimum of 60 days with fog a year. Despite this, there have only been two events in which fog has resulted in harm to humans, property, critical infrastructure or the environment. The frequency of events exceeding the threshold for damage is often much lower than the frequency of all the events of all consequences. It should be noted that the HIRA is not intended to be a scientific assessment of the frequency of the different hazards, but is a risk assessment which must consider how likely it is that a hazard will occur with sufficient intensity to result in an emergency situation.

To ensure that the values for consequence were not skewed by non-damaging events, criteria were proposed to focus the research on damaging events. A hazardous event is considered to exceed the threshold for damage when any of the conditions below were met (Copas, 1999; Ferrier and Haque, 2003; Jonkman et al., 2003, Sharp, 2008; and others):

- Assistance was required from another province or country (if this is being used for a community, it would become ‘required assistance from another community or the province’).
- Multiple fatalities and/or injuries were reported resulting directly from the hazard or its immediate impact.
- Evacuations greater than 100 people from several buildings were reported.
- Severe damage to property or infrastructure was reported. This would include either the partial or complete destruction of at least one building or widespread, less severe damage.
- Environmental damage that was deemed to be severe enough to be reported on by official sources and which required a form of response or monitoring. In particular, damage was considered to be widespread, significantly affected wild species, damaged natural resources, significantly impacted critical infrastructure (e.g. low water levels which required significant changes to shipping practices.) or resulted in the significant business/financial loss to an industry.
- Critical infrastructure service disruptions/impacts were included if they affected more than 10,000 people (this could be scaled to an entire town if the population is less than 10,000), were widespread, resulted in multiple types of failures and/or were required to result in the complete failure of the critical infrastructure.
- The event resulted in a significant loss to business/finances that it was deemed worthy to be reported, was widespread, affected an entire/or a large portion of an industry.
In order to determine which past hazardous events within the Province of Ontario should be examined in order to improve the assessment of consequence, credible sources such as the ones listed below were used:

1. The Canadian Disaster Database
   1. Environment Canada
   2. Ontario Hazards
   3. The Provincial Emergency Operation Centre Reports
   4. The Ontario Fire Marshal
   5. Ministry Reports and Information

The information from this research was transferred into a spreadsheet and analyzed in order to determine the greatest consequence for each hazard that has been experienced in Ontario since records began, the average consequence of damaging events for each hazards, and whether any changes, such as mitigation measures have made the previous greatest consequence values unlikely to be reached again.

Following this, an extensive scientific literature review was conducted in order to determine whether it was possible for each hazard to occur at a consequence level that is significantly greater than the consequences of any events that have occurred in the past. This was done because some hazards have very long return periods (e.g. earthquakes); while others, such as cyber attacks are emerging hazards. The lack of occurrences can skew results for consequence. For example, a hazard with a very long recurrence time may have occurred a couple of times in the past, but resulted in very low consequence damage. An analysis based solely on the recorded historical record would come to the conclusion that the consequence of this hazard is very low. However, scientific studies may find evidence of occurrences which were at a much greater consequence but were before the near window of time encompassed by the historical record. If the scientific literature suggests that the hazard may occur at the same high consequence in the future, then the HIRA must take that information into consideration in order to prepare emergency managers for a severe event.

The variable for consequence was divided into six categories based on recommended practices for risk assessment (e.g. Copas, 1999; Ferrier and Haque, 2003 ;).

- **Social Impacts** - The direct negative consequences of the occurrence of a hazard on the physical health of people. This category is further broken down into three groups; fatalities, injuries or evacuations.
- **Property Damage** - The direct negative consequences of the occurrence of a hazard on buildings, structures and other forms of property, such as crops.
- **Critical Infrastructure Service Disruptions/Impact** - The negative consequences of the occurrence of a hazard on the interdependent, interactive, interconnected networks of institutions, services, systems and processes that meet vital human needs, sustain the economy, protect public safety and security, and maintain continuity of and confidence in government.
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- **Environmental Damage** - The negative consequences of the occurrence of a hazard on the environment, including the soil, water, air and/or plants and animals.
- **Business/Financial Impact** - The negative economic consequences of the occurrence of a hazard.
- **Psychosocial Impacts** - The negative response of community or a subset of the community to a hazard caused by their perception of risk. This includes human responses such as self-evacuation, mass hysteria, hoarding and other potential undesirable responses.

The consequence is determined by examining past events at which the hazard occurred at a level that met the criteria. The table below displays the different consequence sub variables. The total consequence value can be obtained by adding the values obtained from each of the sub variables. (Note: The social impacts sub variable was further divided into the fatality rate, injury rate and evacuation rate. Since human impacts are often the most ‘jarring’ result of an emergency and have an unquantifiable impact on the community, social impact was intentionally weighted higher than the other sub variables.)

The magnitude categories in this HIRA methodology are a scale of impact, rather than a prioritization. **The same value in two categories does not mean that the consequences of the two are equal and interchangeable.**

<table>
<thead>
<tr>
<th>Consequence</th>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>None</td>
<td>Not likely to result in fatalities within the province.</td>
</tr>
<tr>
<td>1</td>
<td>Minor</td>
<td>Could result in fewer than five fatalities within the province.</td>
</tr>
<tr>
<td>2</td>
<td>Moderate</td>
<td>Could result in 5 – 10 fatalities within the province.</td>
</tr>
<tr>
<td>3</td>
<td>Severe</td>
<td>Could result in 10 – 50 fatalities within the province.</td>
</tr>
<tr>
<td>4</td>
<td>Catastrophic</td>
<td>Could result in +50 fatalities within the province.</td>
</tr>
</tbody>
</table>

**Social Impact - Fatalities**

<table>
<thead>
<tr>
<th>Consequence</th>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>None</td>
<td>Not likely to result in injuries within the province.</td>
</tr>
<tr>
<td>1</td>
<td>Minor</td>
<td>Could injure fewer than 25 people within the province.</td>
</tr>
<tr>
<td>2</td>
<td>Moderate</td>
<td>Could injure 25 – 100 people within the province.</td>
</tr>
<tr>
<td>3</td>
<td>Severe</td>
<td>Could injure +100 people within the province.</td>
</tr>
</tbody>
</table>

**Social Impact – Injuries**
### Social Impact - Evacuation

<table>
<thead>
<tr>
<th>Consequence</th>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>None</td>
<td>Not likely to result in property damage within the province.</td>
</tr>
<tr>
<td>1</td>
<td>Minor</td>
<td>Could cause minor and mostly cosmetic damage.</td>
</tr>
<tr>
<td>2</td>
<td>Moderate</td>
<td>Localized severe damage (a few buildings destroyed).</td>
</tr>
<tr>
<td>3</td>
<td>Severe</td>
<td>Widespread severe damage (many buildings destroyed).</td>
</tr>
</tbody>
</table>

### Property Damage

<table>
<thead>
<tr>
<th>Consequence</th>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>None</td>
<td>Not likely to disrupt critical infrastructure services.</td>
</tr>
<tr>
<td>1</td>
<td>Minor</td>
<td>Could disrupt 1 critical infrastructure service.</td>
</tr>
<tr>
<td>2</td>
<td>Moderate</td>
<td>Could disrupt 2 – 3 critical infrastructure services.</td>
</tr>
<tr>
<td>3</td>
<td>Severe</td>
<td>Could disrupt more than 3 critical infrastructure services.</td>
</tr>
</tbody>
</table>

### Critical Infrastructure Service Impact

<table>
<thead>
<tr>
<th>Consequence</th>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>None</td>
<td>Not likely to result in environmental damage.</td>
</tr>
<tr>
<td>1</td>
<td>Minor</td>
<td>Could cause localized and reversible damage. Quick clean up possible.</td>
</tr>
<tr>
<td>2</td>
<td>Moderate</td>
<td>Could cause major but reversible damage. Full clean up difficult.</td>
</tr>
<tr>
<td>3</td>
<td>Severe</td>
<td>Could cause severe and irreversible environmental damage. Full clean up not possible.</td>
</tr>
</tbody>
</table>

### Environmental Damage

<table>
<thead>
<tr>
<th>Consequence</th>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>None</td>
<td>Not likely to disrupt business/financial activities.</td>
</tr>
<tr>
<td>1</td>
<td>Moderate</td>
<td>Could result in losses for a few businesses.</td>
</tr>
<tr>
<td>2</td>
<td>Severe</td>
<td>Could result in losses for an industry.</td>
</tr>
</tbody>
</table>
Consequence | Category  | Description |
------------|-----------|-------------|
0           | None      | Not likely to result in significant psychosocial impacts. |
1           | Moderate  | Significant psychosocial impacts including limited panic, hoarding, self evacuation and long-term psychosocial impacts. |
2           | Severe    | Widespread psychosocial impacts, e.g. mass panic, widespread hoarding and self-evacuation and long-term psychological impacts. |

### Psychosocial Impact

Table 13. Consequence variables.

The total for each hazard is then divided into one of six groups in order to have consequence and frequency play an equal role in the assessment of risk.

<table>
<thead>
<tr>
<th>Sub variable Total</th>
<th>Consequence</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 4</td>
<td>1</td>
<td>Minor</td>
</tr>
<tr>
<td>5 - 6</td>
<td>2</td>
<td>Slight</td>
</tr>
<tr>
<td>7 - 8</td>
<td>3</td>
<td>Moderate</td>
</tr>
<tr>
<td>9 - 10</td>
<td>4</td>
<td>Severe</td>
</tr>
<tr>
<td>11 - 12</td>
<td>5</td>
<td>Very Severe</td>
</tr>
<tr>
<td>+13</td>
<td>6</td>
<td>Catastrophic</td>
</tr>
</tbody>
</table>

Table 14. Consequence

The consequences of the hazards that have not occurred as reported events that have met the criteria were inferred from scientific studies and scenarios, case studies and risk assessments. Considerable effort was made to utilize estimates and studies that were based on likely emergency situations.

#### 4.4.3 Changing Risk

Hazards and their risks do not remain static over time. The frequency and consequence of future events can be affected by things like prevention and mitigation practices and climate change. While it is difficult to predict what policy and technological changes lie ahead, there is a substantial amount of scientific information on the possible impacts of future trends on the different hazards. The inclusion of this variable also leaves open the possibility of including other agents of change (e.g. new technology) in future revisions. Only scientific information on future changes to frequency and consequence from reliable sources was used. Since the information that provides a basis for this variable was based on scientific assessments of future trends and was not based on trends or impacts that have already been observed, the variable has a maximum value of four, rather than six like consequence and frequency since uncertainty still exists in most scientific projections and there could be a significant variation in the amount of time before actual trends are observed.
Changing Risk = Change in Frequency + Change in Vulnerability

Change in Frequency
1. Is the number of reported non-emergency occurrences of the hazard increasing?
   1. Is human activity (e.g. population expansion, altering of drainage flow patterns) likely to lead to more interaction with the hazard or an increase in frequency?
   2. Is there an environmental reason (e.g. climate change) why the frequency of this hazard may increase?
   3. Are human factors such as business, financial, international practices more likely to increase the risk?
If the answer is ‘yes’ to two or more, then the change in frequency = 2
If the answer is ‘yes’ to one or fewer then the change in frequency = 1

Change in Vulnerability
1. Is a large percentage of the population vulnerable to this hazard or is the number of people vulnerable (see vulnerable groups) to this hazard increasing?
   1. Does critical infrastructure reliance or our ‘just-on-time’ delivery system (e.g. stores not keeping a supply of food and relying on frequent shipments for restocking) make the population more vulnerable?
   2. Are response agencies not aware of, practiced and prepared to response to this hazard?
   3. Are no prevention/mitigation measures currently in use for this hazard?
If the answer is ‘yes’ to two or more, then the change in vulnerability = 2
If the answer is ‘yes’ to one or fewer then the change in vulnerability = 1

The scores from the change in frequency and the change in vulnerability should then be added together to get the Changing Risk.

Risk Analysis
History of Hazards in Ontario
Past occurrences of hazards can provide information on the frequency of the hazards and their possible consequences. The history of hazards in Ontario was examined using sources such as the Canadian Disaster Database, Environment Canada's Atmosphere Hazards webpage, Provincial Emergency Operations Centre summaries and reports and other government and scientific documents. The table below shows the length of the historical record of confirmed hazard events:

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Span of Record</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural and Food Emergency</td>
<td>&gt;50 years</td>
</tr>
<tr>
<td>Building/Structural Collapse</td>
<td>&gt;100 years</td>
</tr>
<tr>
<td>Civil Disorder</td>
<td>&gt;10 years</td>
</tr>
<tr>
<td>Hazard</td>
<td>Approximate Time Period</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>Critical Infrastructure Failure</td>
<td>&gt;10 years</td>
</tr>
<tr>
<td>Cyber Attack</td>
<td>&gt;5 years</td>
</tr>
<tr>
<td>Dam Failure</td>
<td>&gt;5 years</td>
</tr>
<tr>
<td>Drinking Water Emergency</td>
<td>&gt;10 years</td>
</tr>
<tr>
<td>Drought/Low Water</td>
<td>&gt;50 years</td>
</tr>
<tr>
<td>Earthquake</td>
<td>&gt;100 years</td>
</tr>
<tr>
<td>Energy Emergency (Supply)</td>
<td>&gt;5 years</td>
</tr>
<tr>
<td>Erosion</td>
<td>n/a</td>
</tr>
<tr>
<td>Explosion/Fire</td>
<td>&gt;100 years</td>
</tr>
<tr>
<td>Extreme Temperature</td>
<td>&gt;100 years</td>
</tr>
<tr>
<td>Flood</td>
<td>&gt;100 years</td>
</tr>
<tr>
<td>Fog</td>
<td>&gt;25 years</td>
</tr>
<tr>
<td>Forest/Wildland Fire</td>
<td>&gt;100 years</td>
</tr>
<tr>
<td>Freezing Rain</td>
<td>&gt;50 years</td>
</tr>
<tr>
<td>Geomagnetic Storm</td>
<td>&gt;50 years</td>
</tr>
<tr>
<td>Hail</td>
<td>&gt;50 years</td>
</tr>
<tr>
<td>Hazardous Material</td>
<td>&gt;50 years</td>
</tr>
<tr>
<td>Human Health Emergency</td>
<td>&gt;100 years</td>
</tr>
<tr>
<td>Human-Made Space Object Crash</td>
<td>&gt;25 years</td>
</tr>
<tr>
<td>Hurricane</td>
<td>&gt;100 years</td>
</tr>
<tr>
<td>Land Subsidence</td>
<td>&gt;10 years</td>
</tr>
<tr>
<td>Landslide</td>
<td>&gt;50 years</td>
</tr>
<tr>
<td>Lightning</td>
<td>&gt;50 years</td>
</tr>
<tr>
<td>Mine Emergency</td>
<td>&gt;10 years</td>
</tr>
<tr>
<td>Natural Space Object Crash</td>
<td>&gt;100 years</td>
</tr>
<tr>
<td>Nuclear Facility Emergency</td>
<td>&gt;50 years</td>
</tr>
<tr>
<td>Oil/Natural Gas Emergency</td>
<td>&gt;50 years</td>
</tr>
<tr>
<td>Radiological Emergency</td>
<td>n/a</td>
</tr>
<tr>
<td>Sabotage</td>
<td>&gt;50 years</td>
</tr>
<tr>
<td>Snowstorm/Blizzard</td>
<td>&gt;100 years</td>
</tr>
<tr>
<td>Special Event</td>
<td>&gt;10 years</td>
</tr>
<tr>
<td>Terrorism/CBRNE</td>
<td>&gt;25 years</td>
</tr>
<tr>
<td>Tornado</td>
<td>&gt;100 years</td>
</tr>
<tr>
<td>Transportation Emergency</td>
<td>&gt;100 years</td>
</tr>
<tr>
<td>War and International Emergency</td>
<td>&gt;5 years</td>
</tr>
<tr>
<td>Windstorm</td>
<td>&gt;100 years</td>
</tr>
</tbody>
</table>

Table 15. The approximate time period (from present) that confirmed records of hazard events are available.

A study of the consequences of each hazard was done in order to assess whether the historical maximum consequence level is the same as the maximum consequence level.
Hazard Identification and Risk Assessment for the Province of Ontario

Possible for each hazard. Extreme events are generally rare and may have occurred so far in the past that the consequences of them occurring today could be very different due to changes in population density, technology and building codes etc. Some hazards, such as natural space object crashes have been recorded within Ontario in modern times but did not cause damage since they occurred in remote areas and were relatively small in size. However, scientific studies and prehistoric events suggest that a damaging impact is still a possibility despite the rarity of these events. Even those hazards that have resulted in damage in the past may have not have occurred at their highest possible magnitude. An example would be tornadoes. According to the Ontario Tornado Database, Ontario has not experienced an F5 tornado (the highest level on the Fujita scale of tornado intensity); however, there is no known meteorological reason why an F5 would not occur in Ontario. It is very likely that Ontario has not experienced a confirmed F5 tornado only because of the rarity of F5s compared with other, lower tornado intensities. It is necessary for emergency managers to be aware of the potential severity of extreme events in order to be fully prepared, like the old saying: “prepare for the worst, but hope for the best”.

The Maximum Historical Consequence is displayed using the blue bars. The Maximum Possible Consequence is displayed using the black squares. Research showed that for some hazards, the maximum historical and the maximum possible consequence levels were the same. This is shown by using only the blue bar and no square.

As displayed in Figure 17, some of the hazards could result in more damage in the future than they have in the past due to different intensities and changes in vulnerability. Hazards, such as earthquakes, geomagnetic storms and natural space object crashes, were found to have possible consequence levels that were higher than that observed from past events. Earthquakes and natural space object crashes are hazards with
extremely long return periods. The length of time between the occurrences of these hazards can be so long that they have not occurred during the historic record but they still have the possibility of occurring in the future. Geomagnetic storms are an example of these hazards. Large geomagnetic storms may have occurred in the past but had minimal consequences since the technology that they damage was not as widespread at the time. As technology becomes more widespread and society’s dependence on it grows, the consequence and the risk associated with geomagnetic storms increases. For other hazards, the consequences have decreased since past events. For several hazards (drought/low water, extreme temperatures, hurricane, lightning) the maximum possible consequence level has decreased. The reason for the decline varies depending on the hazard. For example, better forecasting tools, warning systems and flood plain development regulations have reduced the risk of hurricanes since Hurricane Hazel in 1954. The widespread usage of residential air conditioners and heating systems has resulted in a lower possible consequence for extreme temperatures than that of historical events.

Like the example given above of Hurricane Hazel, prevention, preparedness, mitigation, response and recovery measures have lowered the potential consequence of explosions and fires. Two of the most significant contributions to this were the implementation of the Fire Code and the Building Code.

The human element of the human-caused hazards can suddenly and dramatically alter both the frequency and the consequence of these hazards. For example, a political event may result in a sudden increase in the frequency of civil disorders. The current literature review and the study of past events, and international case studies suggest that the consequences of human-caused hazards in the near-future in Ontario will be similar to that of past events. However, two human-caused hazards were identified as being possible exceptions to this. Cyber attacks and terrorism/CBRNE events have been identified as having a greater potential consequence than past occurrences.

Risk of Hazards in Ontario

There are many different methodologies that can be used for risk assessments. The methodology for this HIRA was selected only after an extensive literature review and consultation with risk assessment professionals and ministries. Frequency and consequence are two variables that are generally the core components of risk assessments. These can provide a snapshot of the past and current risk of a hazard. A third variable, changing risk was added to increase the ability of the HIRA to make projections of the risk in the near future rather than relying solely on the frequency and consequences of past events. It accounts for changes in vulnerability, climate change and other factors. For example, urban flooding events are expected to increase due to changes in drainage patterns (e.g. more ground paved over results in an increase in runoff), an aging drainage system and an increase in the frequency and intensity of rainfall events due in part to climate change (Sandink, 2009). Changing risk is intended to account for hazards such as urban flooding which are currently undergoing a change
in their frequency and/or consequences due to changes in their risk or changes in vulnerability. Since changing risk is a fairly new concept, the hazard analysis will present the findings for both frequency*consequence and the full frequency*consequence*changing risk.

**Risk Level of Hazards Using Consequence*Frequency (C*F) and Consequence*Frequency*Changing Risk (C*F*CR)**

<table>
<thead>
<tr>
<th>Hazard</th>
<th>C*F</th>
<th>C<em>F</em>CR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural and Food Emergency</td>
<td>Moderate</td>
<td>High</td>
</tr>
<tr>
<td>Building/Structural Collapse</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td>Civil Disorder</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>Critical Infrastructure Failure</td>
<td>Moderate</td>
<td>High</td>
</tr>
<tr>
<td>Cyber Attack</td>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td>Dam Failure</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td>Drinking Water Emergency</td>
<td>Very High</td>
<td>Very High</td>
</tr>
<tr>
<td>Drought/Low Water Emergency</td>
<td>Moderate</td>
<td>High</td>
</tr>
<tr>
<td>Earthquake</td>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td>Energy Emergency (Supply)</td>
<td>Very Low</td>
<td>Very Low</td>
</tr>
<tr>
<td>Erosion</td>
<td>Very Low</td>
<td>Very Low</td>
</tr>
<tr>
<td>Explosion/Fire</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Extreme Temperature</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td>Flood</td>
<td>Extreme</td>
<td>Extreme</td>
</tr>
<tr>
<td>Fog</td>
<td>Low</td>
<td>Very Low</td>
</tr>
<tr>
<td>Forest/Wildland Fire</td>
<td>Extreme</td>
<td>Extreme</td>
</tr>
<tr>
<td>Freezing Rain</td>
<td>Extreme</td>
<td>Extreme</td>
</tr>
<tr>
<td>Geomagnetic Storm</td>
<td>High</td>
<td>Very High</td>
</tr>
<tr>
<td>Hail</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Hazardous Materials Incident</td>
<td>Extreme</td>
<td>Extreme</td>
</tr>
<tr>
<td>Human Health Emergency</td>
<td>Very High</td>
<td>Extreme</td>
</tr>
<tr>
<td>Human-Made Space Object Crash</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>Hurricane</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td>Land Subsidence</td>
<td>Very Low</td>
<td>Very Low</td>
</tr>
<tr>
<td>Landslide</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>Lightning</td>
<td>Low</td>
<td>Very Low</td>
</tr>
<tr>
<td>Mine Emergency</td>
<td>Low</td>
<td>Very Low</td>
</tr>
</tbody>
</table>
### Table 16. Risk levels for the identified hazards

<table>
<thead>
<tr>
<th>Natural Space Object Crash</th>
<th>Low</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuclear Facility Emergency</td>
<td>Moderate</td>
<td>High</td>
</tr>
<tr>
<td>Oil/Natural Gas Emergency</td>
<td>Very High</td>
<td>Very High</td>
</tr>
<tr>
<td>Radiological Emergency</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Sabotage</td>
<td>Very Low</td>
<td>Very Low</td>
</tr>
<tr>
<td>Snowstorm/Blizzard</td>
<td>Extreme</td>
<td>Extreme</td>
</tr>
<tr>
<td>Special Event</td>
<td>Low</td>
<td>Very Low</td>
</tr>
<tr>
<td>Terrorism/CBRNE</td>
<td>Moderate</td>
<td>Very High</td>
</tr>
<tr>
<td>Tornado</td>
<td>Extreme</td>
<td>Extreme</td>
</tr>
<tr>
<td>Transportation Emergency</td>
<td>High</td>
<td>Moderate</td>
</tr>
<tr>
<td>War and International Emergency</td>
<td>Very Low</td>
<td>Very Low</td>
</tr>
<tr>
<td>Windstorm</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

As shown in the table above, 51% of the hazards were associated with the same risk level for both the traditional C*F and the new C*F*CR. Approximately twenty-three percent of the hazards experienced an increase in their risk level while 25% experienced a decrease in their risk level. The increased risk levels between the two methods for some of the hazards has a variety of causes such as an increased reliance on technology (e.g. geomagnetic storms) and a projected increase in frequency (e.g. cyber attacks). The decreased risk levels of some of the hazards are due to changes such as the implementation of the Building and Fire Codes (e.g. building/structural collapse, explosion/fire), advancements in forecasting (e.g. hurricane) and technology (decreased vulnerability to extreme temperatures due to the widespread use of air conditioners and heaters).
<table>
<thead>
<tr>
<th>Level of Risk</th>
<th>Description</th>
<th>Hazards</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;50</td>
<td>Extreme</td>
<td>Flood, Forest/Wildland Fire, Freezing Rain, Hazardous Materials Incident, Human Health Emergency, Snowstorm/Blizzard, Tornado</td>
</tr>
<tr>
<td>41 – 50</td>
<td>Very High</td>
<td>Drinking Water Emergency, Geomagnetic Storm, Oil/Natural Gas Emergency, Terrorism/CBRNE</td>
</tr>
<tr>
<td>31 – 40</td>
<td>High</td>
<td>Agricultural and Food Emergency, Critical Infrastructure Failure, Drought/Low Water, Nuclear Facility Emergency</td>
</tr>
<tr>
<td>21 – 30</td>
<td>Moderate</td>
<td>Civil Disorder, Cyber Attack, Earthquake, Human-Made Space Object Crash, Landslide, Transportation Emergency, Windstorm</td>
</tr>
<tr>
<td>11 – 20</td>
<td>Low</td>
<td>Building/Structural Collapse, Dam Failure, Explosion/Fire, Extreme Temperatures, Hurricane, Natural Space Object Crash, Radiological Emergency</td>
</tr>
</tbody>
</table>

**Risk Level of Hazard Using Frequency*Consequence*Changing Risk**

Risk assessments which use two variables, usually consequence and frequency, often plot their results in a risk matrix in order to create a visual representation of the risks of the hazards. The methodology in this document has a third variable, changing risk. To create a visual representation of risk, the bubble graph can be used. Consequence and frequency are each on an axis. The size of the ‘bubble’ represents the changing risk.
**Next Steps**
A HIRA program is an ongoing process in which the identified hazards are prioritized based on their levels of risk. The prioritization of hazards provided by the HIRA is presented for consideration by organizations such as the Order in Council Ministry leads, which participate in risk altering activities (e.g. prevention and mitigation activities). A HIRA identifies which hazards should be a priority for emergency management programs, but it is just one element of an emergency management program. The next step after a HIRA has been completed is for the organizations who are involved in risk altering activities to determine which steps should be taken to minimize the risk.

The hazards listed as posing an extreme risk are those that must be a very high priority for prevention, preparedness, and mitigation, response and recovery programs in Ontario. Attempts to minimize the risks of the hazards listed as having very a high and high level of risk should be a priority for mitigation programs. The hazards that are listed as moderate are those that should be addressed after the hazards with greater risk. The hazards listed as having low or very low risks are those that should be addressed only after the hazards with a greater risk have been considered for prevention, preparedness, and mitigation, response and recovery activities.

**Conclusion**
The province of Ontario has experienced significant impacts from natural hazards, technological hazards and human-caused hazards in the past and will continue to be impacted in the future. Hazard identification and risk assessment documents are an important factor in enhancing the focus of emergency management programs. An
Hazard Identification and Risk Assessment for the Province of Ontario

Emergency management program can use a HIRA to assist in determining prevention, preparedness, and mitigation, response and recovery activities based on risk. After the hazards which are identified as being priorities are addressed, a revision of the HIRA will be done since hazards and their risks may change significantly over time.

The Provincial HIRA is the first step in a comprehensive emergency management program that can assist in building a disaster resilient Ontario. Since hazards may vary depending on factors such as location, scale and topography, it is necessary for ministries and communities to develop their individual HIRAs that have been tailored to their own locations and needs. The principle objectives of the Ontario Provincial HIRA were to provide a broad overview and introduction to the hazards which can impact Ontario and to provide a basic methodology for risk assessment. This methodology can be adopted or modified by others for their individual HIRAs if they so choose.

Appendix I - Vulnerable Populations

During the hazard identification process, vulnerable groups were identified for each hazard. Vulnerable groups were defined as those which are more likely to suffer severe impacts due to the occurrence of a hazard beyond the threshold of tolerance disproportionate to the rest of the community (Ferrier and Haque, 2003). These groups may be more vulnerable to a hazard due to an inability to self-evacuate or to take the proper safety precautions, susceptible to a hazard due to their health, or a lack of access to warnings or other reasons that increase their vulnerability to a specific hazard. Not all people who identify themselves as belong to one of these groups may be at an increased risk during the occurrence of a hazard, it will depend on the individual’s specific situation. Many hazards were found to have several different vulnerable populations, as shown on the table below.

<table>
<thead>
<tr>
<th>Hazard Identification</th>
<th>Elderly</th>
<th>Children</th>
<th>People with physical or mental disabilities</th>
<th>Pregnant Women</th>
<th>Participants and bystanders</th>
<th>People who use medical devices and perishable medications</th>
<th>People with a small physical Do not speak the common</th>
<th>Do not live in the affected area</th>
<th>The homeless</th>
<th>People with compromised immune systems or medical The physically or socially isolated</th>
<th>People in a particular industry</th>
<th>Security personnel</th>
<th>Reliant on surface or well water</th>
<th>Low income households</th>
<th>People in high rise buildings</th>
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### Hazard Identification and Risk Assessment for the Province of Ontario

**Critical Infrastructure Failure**  
- Cyber Attack
- Dam Failure
- Drinking Water Emergency
- Drought/Low Water
- Earthquake
- Energy Emergency
- Erosion
- Explosion/Fire
- Extreme Temperatures
- Flood
- Fog
- Forest/Wildland Fire
- Freezing Rain
- Geomagnetic Storm
- Hail
- Hazardous Material
- Human Health Emergency
- Human-Made Space Object Crash
- Hurricane
- Land Subsidence
- Landslide
- Lightning
- Mine Emergency
- Natural Space Object Crash
- Nuclear Facility Emergency

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**Emergency Management Ontario**  
2012  
Approved
### Hazard Identification and Risk Assessment for the Province of Ontario

#### Vulnerable Populations

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#### Appendix II - The HIRA Development Process

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<th>Stage</th>
<th>Specific Action</th>
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| Hazard Identification      | • Literature review of hazards in Ontario.  
• Updating of the list of identified hazards in Ontario.  
• Review of the list of identified hazards in Ontario.  
• Final list of identified hazards.  
• Literature review of each of the identified hazards.  
• Development of hazard narratives.  
• Review of the hazard narratives.  
• Final hazard narratives. | • Emergency Management Ontario  
• Emergency Management Ontario  
• Ministry Emergency Management Coordinators and External Subject Matter Experts  
• Emergency Management Ontario  
• Emergency Management Ontario  
• Emergency Management Ontario  
• Ministry Emergency Management Coordinators and External Subject Matter Experts  
• Emergency Management Ontario |
### Risk Assessment

- Literature review of risk assessment methodologies.
- Collection of information on the risks associated with each hazard.
- Development of 1.0 draft methodology.
- Review of the HIRA methodology: Step 1.
- Review of the HIRA methodology: Step 2.
- Development of the final HIRA methodology.

### Risk Analysis

- Review of information collected on the risks associated with each hazard.
- Prioritization of the hazards through the methodology

### Monitor and Review

- Continuous monitoring of new and evolving hazards
- Review and update of HIRA

---

**The HIRA Development Process**

**Appendix III - Risk Assessment Values**

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**Risk Assessment Values**

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