

Hazard Risk Analysis

Hydrological (related to water and snow)

Avalanches - Natural and Human Caused
Flash Floods
Ice Jam Floods
Local Floods
Rain Storm Floods
Snow Melt Floods
Glaciers
Icebergs, Ice Islands, Sea Ice and Ice Floes
Lake Outbursts

Hydrological

This section discusses hazards that are related to water or snow. This includes: Avalanches, Drought, Flash Floods, Local Floods, Rain Storm Floods, Ice Jam Floods, Snow Melt Floods, Glaciers, Ice floes, Icebergs, Ice Islands and Sea Ice, and Lake Outbursts. Here are eleven hydro-meteorological hazards (weather, wind and snow related) and many of them are both naturally caused and caused by humans. When you come developing resilience strategies for these hazards it is important to understand where the primary cause for the hazard lies.

Avalanches

Definition

An avalanche is a movement of snow and ice in response to the force of gravity down a hillside or slope.

Discussion

Avalanches can be divided into three zones. The starting zone is defined as the area from which avalanche release is initiated. The second component, the avalanche track, is the portion of the path between the bottom of the starting zone and the top of the runout zone. The runout zone is the area at the bottom of the path in which avalanches usually stop and is sometimes referred to as the 'area of deposit', where all the snow piles up. Avalanches are rated from small (less than 0.3 metres deposited) to climax (greater than 3.0 metres deposited over 150 metre wide track).

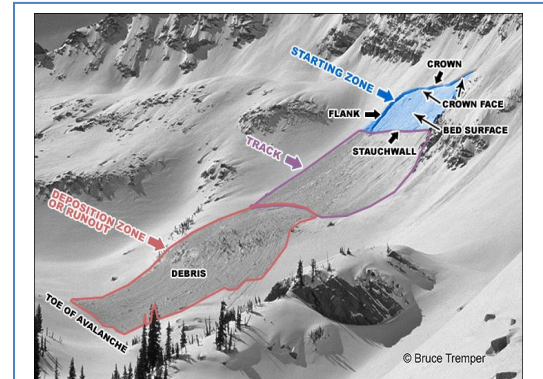


Figure 1 Avalanche Zones

Factors such as the type of snow (wet or dry), outdoor temperature and wind conditions are critical in determining avalanche conditions. For example, dense, wet snow falling on dry, loosely packed snow may give rise to an avalanche. Internal icy layers (or 'depth hoars') can also form weak layers within a snowpack and may give way suddenly, or through the added weight of fresh snowfall, a skier or snowmobiler. Depth hoars form by re-freezing of the upper (wetter) snow layer, which is then buried by new snowfall.

It Happened Here...

On January 31, 2016 five men from Alberta, all snowmobilers, were killed in an apparent human-triggered avalanche near McBride, B.C.

On March 13, 2010, two people were killed and hundreds were trapped when an avalanche hit a snowmobile drag race even in Revelstoke, B.C. A massive avalanche came down on a group of snowmobilers in the Monashee Mountains, apparently triggered by three daredevil sledders who unleashed a deadly wall of snow on up to 200 people below.

In December 2008, eight snowmobilers from the small mining town of Sparwood, B.C. were killed in an avalanche in nearby Fernie. More than 2,000 people attended the public funeral.

On February 2, 2003, seven teens on a high-school ski excursion on Mount Cheops, in B.C. died when a half-kilometre-wide avalanche roared down from a mountainside and engulfed their group.

On January 1, 1999, an avalanche crashed into a school gym in the remote northern Quebec Inuit community of Kangiqsualujjuaq (population 650). The event led to 9 deaths, 25 injuries and exposed approximately 400 people to 100 km/h winds and -20°C weather.

In December 1996 Following a heavy snowfall, the Fraser Canyon was hit with over 500 avalanches between Boston Bar (population 478) and Yale. Hundreds of people were stranded and many communities were cut-off from supplies. The Provincial Emergency Program airlifted food to the affected communities.

Avalanche - Natural

Hazard Rating				High Risk	<input type="checkbox"/>	Low Risk	<input type="checkbox"/>	Need More Info	<input type="checkbox"/>	Not Applicable	<input type="checkbox"/>
Yes	No	Need More Info	Not Applicable	FACTORS							
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Avalanches generally occur in the same place year after year. Have avalanches previously occurred in or near to your community?							
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Avalanches occur in mountainous terrain, generally on slopes with an incline between 25° and 55° degrees. Is your community located near avalanche-prone slopes?							
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Avalanches occur in areas with deep snow cover. Does your community receive large amounts of snow in the winter?							
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Increased snowmelt caused by rain or rapid warming can increase the likelihood of avalanche. Is your community in mountainous terrain and does your region receive rain-on-snow events or periods of rapid warming in the winter?							
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	If your community is located in or near to avalanche terrain, is there a lack of avalanche control measures?							
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Do Traditional Knowledge holders have oral history of where avalanches have occurred in the past, in or near by your community?							

Avalanche - Human-caused

Hazard Rating		High Risk	<input type="checkbox"/>	Low Risk	<input type="checkbox"/>	Need More Info	<input type="checkbox"/>	Not Applicable	<input type="checkbox"/>
Yes	No	Need More Info	Not Applicable	FACTORS					
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Avalanches generally occur in the same place year after year. Have avalanches caused by humans previously occurred in or near to your community?					
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Avalanches occur in mountainous terrain, generally on slopes with an incline between 25° and 55° degrees. Is your community located near avalanche-prone slopes?					
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	If your community is located in or near to avalanche terrain, do you lack effective avalanche control measures or avalanche inspections?					
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Backcountry skiers and snowmobilers are at risk of causing avalanches. Are these activities popular in or around your community (high-marking especially poses an increased risk, as snowmobilers travel up steep, possibly instable slopes)?					
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Scientists note there are changes to winter snowfalls amounts. Rapid warming followed by refreezing can occur more often. Has your community experienced such changes?					

Flash Floods

Definition

A flash flood is a flood caused by heavy or excessive rainfall in a short period of time, generally less than 6 hours. Topography, soil conditions, and ground cover are also factors that contribute to the likelihood of a flash flood. A flash flood rises rapidly, often with little or no warning. Flash floods may occur in rural or urban settings. Flash floods can occur in mountainous areas (posing a threat to campers along rivers or lakes), as well as in flat areas (where city culverts and storm drains may be unable to quickly drain the waters).

Discussion

Many things can cause a flash flood. Generally they are the result of heavy rainfall concentrated over one area. Most flash flooding is caused by slow-moving thunderstorms, thunderstorms that repeatedly move over the same area, or heavy rains from hurricanes and tropical storms. Flash floods can result in moving boulders, uprooted trees and destroy buildings and bridges.

Flash flooding can occur in water-carved gullies or normally dry creek beds and these can rapidly fill with rain water. They can occur as a result of heavy rains and water rapidly collecting from parking lot runoffs, or along various streets heading down hill and then levelling out.

It Happened Here...

On July 8, 2020 Thousands of people were without power and flash flooding was reported across Toronto after severe weather slammed the city. A heavy thunderstorm passed through the city for about an hour, swelling waterways, downing trees and flooding basements. According to the Toronto and Region Conservation Authority, the storm dropped about 65 millimetres of rain on some areas of the city within about half an hour.

On December 11, 2018, flash flooding caused severe traffic problems in the south-western British Columbia. Roads and highways were submerged. Local news reports said that emergency crews responded to at least 30 calls for vehicles in flood-related emergencies. The heavy rainfall also caused issues for transit services on the Expo Line TransLink) service after tunnels were flooded. Port Mellon, situated around 35 km North West of Vancouver, recorded 77mm of rain in 24 hours.

On May 30, 1961, a severe rainstorm dropped up to 10inches (254 mm) of precipitation in less than one hour over a small area near Buffalo Gap, Saskatchewan. In terms of high-intensity short-duration rainfall, it is the greatest flash flood on record in Canadian history.

Another example of flash flooding includes the flooding of Kamloops, British Columbia on July 24, 2014 as the result of a severe thunderstorm. The storm that hit Toronto, Ontario on July 8, 2013, which left cars, busses and trains submerged in water, and many in the city without power is yet another example.

Flash Floods Natural

Hazard Rating				
High Risk		<input type="checkbox"/>	Low Risk	<input type="checkbox"/>
Need More Info		<input type="checkbox"/>	Not Applicable	
FACTORS				
Yes	No	Need More Info	Not Applicable	
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Are there areas in your community with a water basin prone to quick runoff (small capacity, narrow shape, steep slope, lack of vegetation on surrounding land, and surrounding surfaces do not absorb water)?
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Are there areas in your community near a body of water with a high average annual flow rate?
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Are there areas in your community that can experience heavy rainfall (especially if in short periods of time)?
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	**Are there areas in your community on or near flood plains (low lying, flat ground) that have received and intense periods of rainfall in the past?
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Are there areas in your community with riverbank erosion or on an area prone to landslides? (see the section on Landslides)
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Are there areas in your community that experience heavy rains where there is parking lot run-off that feeds into sloping streets?
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Are there areas in your community with gullies, or normally dry riverbeds, in areas that are subject to large amounts of rainfall?
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Have there been flash floods in the past?
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Is climate change contributing to rainstorms of increased intensity in your community?
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Do Traditional Knowledge holders have oral history of where flash floods have occurred in the past, in or near by your community?
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Densely populated areas are at a high risk for flash floods. The construction of buildings, highways, driveways, and parking lots increases runoff by reducing the amount of rain absorbed by the ground. Are there areas in your community where there has been recent development and increased population?

Ice Jam Floods

Definition

Ice jams occur during freeze-up of rivers in winter or the break-up of winter ice cover in early spring. During the cold months, a layer of ice develops on river surfaces, leaving water to flow beneath. This ice cover can be thin because of spring melting or due to a warm winter. If enough water is supplied to the river (e.g., from snowmelt or rainfall), pressure from underneath the ice may be sufficient to break the ice cover. If so, the ice pack then flows downstream.

Discussion

Ice jam formations along a river is promoted by the presence of local sections of intact ice cover during break-up, and/or local channel characteristics (e.g., channel shoaling, variation in channel width, channel splitting by islands or bars, and sharp bends). However, ice jams can also form behind bridges and other structures that constrict a channel.

The magnitude of ice jam floods is a function of the amount of water flowing through the river and the size of the ice jam obstruction. Flooding from ice jams tends to be localized since it is dependent directly on the formation of an ice jam. The tendency for an ice jam to form at any given location along a river is variable.

Chunks of ice may become lodged where the flow is constricted, obstructed or slowed. They may converge at channel bends and bridge piers, where rivers split in two around islands, or where the river becomes more shallow and less steep. When large amounts of ice build-up, they may block the flow of water. As water collects in the newly formed reservoir behind the jam, areas upstream may begin to flood. If the icejam breaks under the pressure of the upstream water, large volumes of water may flood downstream locations.

It Happened Here...

On April 29, 2020, up to 15,000 people in Alberta have been told to flee their homes after an ice-jam caused by a rapid spring thaw caused rivers in Alberta to flood. The mandatory evacuation order was issued Monday in Fort McMurray after the city became threatened by fast-moving waters from an ice-jam in the Athabasca River that broke loose. Officials said the ice created a blockage of almost 15.5 miles long as it jammed along the Athabasca and Clearwater rivers, sending water into nearby communities.

A large section of ice floating on the Bow River, Alberta, early April 2014 caused flooding in the First Nation community of Siksika. Cabins and roadways were flooded, and about 35 people were affected.

On January 18, 2006, a 6km long ice jam rose water levels in the Saint John River of New Brunswick, threatening to lift a historic 105-year-old wooden bridge off its piers in the small town of Hartland (population 947); no deaths or injuries were reported.

In January 2005, an ice jam in a river near Keremeos, resulted in water spilling over the dikes and flooding homes. Some people have had to be plucked from rooftops by rescue helicopters. About 100 residents were forced to flee the area.

The town of Badger (population 813) was evacuated February 15, 2003 after ice-jams in the Exploits, Red Indian and Badger Rivers caused flooding. The flood waters reached levels marked as within the predicted 100-year flood on flood hazard maps. Property damage was estimated as being in the millions of dollars; 1200 people were evacuated.

Ice Jam Floods - Natural

Hazard Rating				High Risk	<input type="checkbox"/>	Low Risk	<input type="checkbox"/>	Need More Info	<input type="checkbox"/>	Not Applicable	<input type="checkbox"/>
				FACTORS							
Yes	No	Need More Info	Not Applicable								
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Are there areas in your community near a river that freeze over with thick, strong ice during the winter?							
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Are there areas in your community with a large amount of rapid runoff as well as typically sunny weather in the spring?							
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Are there areas in your community in which the spring following a long, cold winter has mild average temperatures and moderate rain? Rain falling on a heavy snowpack increases the risk of ice jams.							
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Do Traditional Knowledge holders have oral history of where ice jam floods have occurred in the past, in or near by your community?							
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Have there been ice jam floods in the past?							

Local Floods

Definition

This type of flooding may or may not be linked with an extreme hydrologic event, but is caused by poor or blocked drainage. In many cases it is an annual event which occurs on agricultural land and has no major consequences, in other cases it can cause hardship.

Discussion

If either urban or rural areas are dependent upon pumps and pump stations to provide drainage assistance, local flooding can occur when the pumps are not able to deal with the amount of water. As well, storm drains, drainage ditches or natural drainage channels can become blocked by sediment, debris or ice; thus resulting in local flooding. Flooding can also occur as a result of water main breaks.

It Happened Here...

On October 17, 2018, an underground condo building garage near Toronto's Distillery District was flooded overnight following a water main break.

On August 7, 2018, firefighters in Big White, B.C. had their hands full with flooding for a few hours Monday morning. It appears a water main pipe broke uphill from the Big White Fire Department, causing water to come roaring down the hill and through the main floor of the fire hall.

On March 29, 2009, twenty million litres of water surged from a broken water main and shut down Nunavut's capital. Schools, the hospital, workplaces and government offices in Iqaluit were closed. The problem started with a break in a pipe leading to the local high school that had been clogged with ice and it froze and managed to break and while they were trying to repair it 20 million litres of water came out in just 20 minutes. And the emergency valve that they would have used to shut it down was faulty.

In late April 2008, the Albany River flooded, affecting the small, rural First Nations communities of Kashechewan and Fort Albany in Ontario. Kashechewan (population 1,200) was evacuated, for the fourth time in four years due to flooding. Flooding damaged homes, the airport and hospital.

From July 19-20, 1996, the Saguenay-Lac-Saint-Jean region of Quebec was affected by massive floods, due to both human and natural causes. The key human-related cause was poor maintenance of the region's dikes and dams. Damages totaled \$1.5M. There were 10 fatalities and more than 16,000 evacuated. The community of Mashteuiatsh (population 1,749) was among the many communities affected.

Local Floods Human-caused

Hazard Rating				High Risk	<input type="checkbox"/>	Low Risk	<input type="checkbox"/>	Need More Info	<input type="checkbox"/>	Not Applicable	<input type="checkbox"/>
Yes	No	Need More Info	Not Applicable	FACTORS							
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Are there areas in your community that experience fast runoff due to road grids directing the water flow to a limited storm sewer capacity?							
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Are there areas in your community where streams or rivers have been diverted from their original direction?							
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Are there areas in your community near a dam where the infrastructure is aging and not kept repaired and/or where the intensity of water flow exceeds the capacity of the dam?							
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Are there areas in your community that are dependent upon pumps and pump stations to provide drainage assistance?							
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Are there areas in your community where storm drains, drainage ditches or natural drainage channels are next to or downhill from areas of soil, sediment or forest debris (leaves, small branches) that can wash over and block these drainage systems?							
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Are there areas in your community that experience freezing temperatures in winter and where storm drains, drainage ditches or natural drainage channels can become blocked by ice?							
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Scientists have observed that with climate change there are communities which are experiencing higher amounts of rainfall and thus increasing the likelihood of flooding. Is your community experiencing increased rainfall?							

Rain Storm Floods

Definition

The basic cause of most river floods is excessive rainfall which can cause major rises in river levels. The effect of elevated water levels is the flooding of low lying river floodplain areas.

Discussion

Storms of intense rainfall or rain-on-snow events, where a warming trend and rainfall follow a shallow snowfall (typically in the late summer or early fall), tend to cause quicker floods. The

majority of flood disasters in Canada (65%) are caused by snowmelt, rainfall or a combination of the two. Damage caused by flooding is related to factors such as:

- the depth of the water;
- how long the flooding lasts;
- the velocity of flood waters over flooded land;
- how quickly the water rises
- how often flooding occurs;
- and the timing of floods.

There have been several billion dollars of insured damages due to flood disasters in Canada—the most expensive of which was the 1950 Red River valley flood in southern Manitoba, costing \$1,093 million.

It Happened Here...

On January 31, 2020, the Cowichan Valley Regional District on the southern part of Vancouver Island declared a local state of emergency after flooding shut down roads and prompted the evacuation of around 30 residents. British Columbia Emergency Info reported evacuation orders in the District of Kent as a result of a mudslide, and in Sunshine Coast Regional District as a result of flooding.

Rain flooding, along with snowmelt flooding, began on April 19, 2019 in communities in Ontario, Quebec and New Brunswick are coping with heightened water levels that have forced authorities to pile sandbags and homeowners to move their possessions to higher ground to avoid them being damaged by the flooding. Residents have found themselves taking transport by canoe on the streets amid flooding that has inundated communities in three provinces. Flooding was severe in Minden Hills and Bracebridge, Ontario. Over 2,000 troops were deployed to affected areas to help with evacuations and to shore up flood defences.

Canadian Armed Forces were also been deployed to parts of New Brunswick, including Island View, Fredericton, Oromocto, Grand Lake, Gagetown, and Grand Bay, to assist with the flood situation caused by the rising water levels of the Saint John river. New Brunswick Emergency Measures Organization (NBEMO) said that satellite imagery collected by Service New Brunswick on 25 April showed that 16,155 properties had been touched by floodwater, although not all buildings on those properties were affected.

Between April 5-7 2017, there was major flooding in Southern Quebec and wind damage across parts of Ontario and Quebec. Roads, homes, and businesses were flooded in Quebec as rivers overflowed and sewers backed up. And along with the rains, there were strong winds that downed trees and power lines in both areas. This spring system caused over \$106 million in insured damage, and \$225 million in total damages. Between May 5-6, 2017 as a result significant rainfall, there was severe flooding in Ontario and Quebec with nearly \$117 million in insured damage.

In June 2016, High levels of rain caused major flooding in the Peace River Regional District in northeastern British Columbia. Dawson Creek and Chetwynd, around 100km west, were two of the worst hit areas. Evacuations were carried out and flooding caused severe damage to roads and infrastructure. However, no injuries or fatalities have occurred. A state of local emergency was declared within District of Chetwynd boundaries as a result of the floods. In Dawson Creek, 60 residences were evacuated due to flooding from the creek that cuts through the centre of the city.

From July 21 to 22, 2008, a tropical rain storm drenched Nova Scotia, including the small town of Clark's Harbour (population 860). The amount of rain received in the 24-hour period equaled approximately the amount usually received in an entire month.

On January 26, 2005 in the small community of Willow Creek, BC seven homes were damaged by flooding and 6 more were threatened along Arnett Road.

In early June 2010 Maple Creek, in southwestern Saskatchewan, experienced very heavy rains which flooded basements and collapsed a portion of the Trans-Canada Highway.

A four-day heavy rainfall-on-snow event started on October 15, 2003 and led to the worst recorded flooding of the Lillooet River, British Columbia. The First Nations community of Mount Currie and the Village of Pemberton were cut off from the rest of the region, as highway 99 and the railway connection toward Whistler were washed out, and landslides blocked the highway east-ward between Mount Currie and Lillooet. The runway of the Pemberton Airport was submerged, thus the only transportation to the valley was by helicopter. About 500 people of the Mount Currie were evacuated, as well as 250 residents of nearby Pemberton. Five people were killed as their vehicles plummeted into Rutherford Creek after the bridge washed out. Damage related to the floods is estimated between \$20 and 30 million.

Rain Storm Floods Natural

Hazard Rating				High Risk	<input type="checkbox"/>	Low Risk	<input type="checkbox"/>	Need More Info	<input type="checkbox"/>	Not Applicable	<input type="checkbox"/>
Yes	No	Need More Info	Not Applicable	FACTORS							
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Are there areas in your community with frequent high winds?							
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Are there areas in your community with frequent storms that have a wide geographical range (as opposed to localized storms)? These areas are at greater risk from rain storms because the water basin will fill faster.							
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Are there areas in your community when there is constant rainfall? Areas where the soil is already saturated before a storm comes are more at risk.							
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Are there areas in your community that historically receive annual, long-duration storms and have small watersheds in relation to the rainfall received?							
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Are there areas in your community on or near flood plains (low lying, flat ground) that have received long and intense periods of rainfall in the past?							
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Have Traditional Knowledge holders noticed increases in the frequency, numbers and intensity of rain storms?							
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Do Traditional Knowledge holders have oral history of where rain storm floods have occurred in the past, in or near by your community?							
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Decisions about lakes' or rivers' water levels include minor adjustments so everything stays balanced or allows for greater outflows when weather events, such as heavy rainstorms continuing for days threaten water levels levels. Is there a lack of continual monitoring of water levels in lakes and rivers affecting your community?							

Snow Melt Floods

Definition

River floods can also be caused by snow melts (freshets) which cause a major rise in river levels. This has the same effect of causing flooding in low-lying areas.

Discussion

The size of the river catchment, as well as the temperature rise (how quick, how long, how warm), is critical in determining the character of flooding. Flooding caused by snow melt events tend to occur in the late spring and the effects of such flooding is tied directly to the amount of winter snow pack. The thicker the snowpack, the greater the risk of flooding in the spring. Floods occur throughout the year in Canada, but are concentrated (40%) in April and May, due to snowmelt.

However, climate change has changed the timing for potential snow melt floods. In some cases, snow melt floods can occur sooner than expected if warmer weather results in snow in the mountains melting earlier in the year. In other situations, heat waves can result in snow that would typically remain at high altitudes all year long start to rapidly melt and result in snow melt floods into early summer. Snow melt floods, in these circumstances may occur in parallel with rapid glacier melting.

Characteristics of snow melt floods are that the flood duration may last for days or weeks, especially in bigger river systems. In smaller rivers or coastal flooding from smaller river systems may last only a few hours. Snow melt floods are generally easier to monitor and forecast, as they are directly related to temperature.

It Happened Here...

On June 30, 2021, an unprecedented heat wave started to melt the snowpack at astounding rates of up to 100 mm of snow water equivalent each day. This was compounded by the melting of glaciers between Prince George, B.C. and Jasper, Alberta. Homes in the Robson Valley, BC were being evacuated and the Fraser River had already flooded in several areas. Additionally, widespread flooding was experienced along the Squamish Valley Road, B.C. with at least one car submerged.

On May 14, 2018, Heavy rainfall, warm weather and rapid snowmelt triggered flood warnings and evacuations in the Interior. More than 4,000 British Columbians have been forced from their homes, while thousands. Evacuation orders affecting over 2,700 people were issued in parts of Kootenay Boundary, from Christina Lake through the West Boundary, including areas of Grand Forks. Firefighters rescued around 30 people by boat in Grand Forks, located at the confluence of the Granby River and Kettle River and one of the hardest hit areas. The Emergency Info BC website listed evacuation orders or alerts in six other regional districts and eight First Nations around the province. Okanagan-Similkameen district has also been badly affected, with evacuation orders issued in Osoyoos after the level of Osoyoos Lake rose dramatically.

Rapid snowmelt at the end of April 2013 led to flooding in the reserves of Attawapiskat and Kashechewan, northern Ontario. The only hospital in Attawapiskat had to be evacuated and several schools had to be shut-down as the below-standard sewage system was unable to deal with the flood waters. The remote, northern communities experience the snowmelt-related flooding frequently, but in 2013 the snowmelt was rather sudden, and led to quickly rising river levels.

In May 2008, New Brunswick experienced severe spring flooding along the Saint John River. Many communities were affected, including the small town of Prince William (population 879). Numerous factors caused the flood: record-setting snow pack, which remained into the spring;

sudden warming and heavy rains. The flood was the most extensive in 35 years. It impacted 1,600 properties, causing over \$50M in damages. No deaths or injuries were reported.

In April 1999, the town of Melita, Manitoba (population 1,051) experienced major flooding as a result of rapid snow melt. The flooding of the Souris River washed out roads and damaged bridges in rural areas, and made 800,000 hectares of farmland unseedable.

Snow Melt Floods Natural and Human-caused

Hazard Rating				High Risk	<input type="checkbox"/>	Low Risk	<input type="checkbox"/>	Need More Info	<input type="checkbox"/>	Not Applicable	<input type="checkbox"/>
Yes	No	Need More Info	Not Applicable	FACTORS							
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Are there areas in your community near rivers fed by vast quantities of snowmelt in the spring? Thicker and dense snowpack, combined with a fast melt rate, increase risk.							
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Are there areas in your community with a water basin prone to runoff and surrounding surfaces do not absorb water?							
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Are there areas in your community with a large amount of rapid runoff as well as typically sunny weather in the spring?							
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	In the past, has your community experienced a long, cold winter with heavy snowfall, followed by a spring with mild average temperatures and moderate rain? Rain falling on a heavy snowpack increases the risk of ice jams.							
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Scientists have noted that with climate change there are changes in increased snowfalls and rainfalls during the winter over much of North America, which could result in increased runoff and river flows in winter and spring. Has your community experienced increased snow and rainfall amounts over the winter?							
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Is the community not maintaining regular contact with the organizations that provide streamflow forecast data that provide sufficient accuracy and precision to manage flooding?							
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Do Traditional Knowledge holders have oral history of where snow-melt floods have occurred in the past, in or near by your community?							
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Heat waves can contribute to sudden, rapid melting snow, often in combination with melting glaciers and can increase the likelihood of flooding at lower elevations. Have there been recent heat waves in the mountainous areas where there are snow packs?							

Glaciers

Definition

A glacier is a large body of ice that consists largely of re-crystallized snow and that shows evidence of downslope or outward movement due to its own weight. There are several types of glaciers including:

- alpine or mountain glaciers which are relatively small glaciers located at high elevations in mountains;
- cirque glaciers occupy bowl-shaped depressions (called “cirques”) on the sides of mountains. They are typically wider than they are long, but they can grow and spread into valleys and flow down the valleys as valley glaciers;

- valley glaciers are curbed by the walls of a valley. They can extend down to sea level and may carve a narrow valley into the coastline, in which case they are called fjord glaciers. If a valley glacier extends down a valley and then spreads out into a giant lobe, it is called a piedmont glacier; and
- ice sheets are the largest types of glaciers on Earth and cover large areas (over 50,000 square kilometers) of the land surface, they can cover mountain areas.

Discussion

In Canada, an estimated area of 200 000 square kilometers, or about 2% of the country's area is covered by glaciers and ice fields. A huge amount of freshwater is frozen in the polar ice caps and in high mountain glaciers. Glaciers and ice fields are found in western Canada and the mountains in the eastern Arctic.

Currently many Canadian glaciers are melting due to warming temperatures. Seasonal meltwater from glaciers is a resource of freshwater that is used in many different ways: hydroelectric power generation, the development of freshwater habitats, household water use, and irrigation. Glaciers act as water savings accounts, storing water during cool, wet climate and releasing it during warm, dry climate.

Heat waves can result in rapid melting of glaciers at high-altitudes and result in flooding, often combined with melting snow, in rivers and streams located at lower altitudes. Floods resulting from melting glaciers can occur in the spring and even early to late summer.

Over the short term, increased melting causes increased water levels in streams and rivers, but high levels of warming temperatures can result in glacial lake outbursts and rapid ice advances on to land or out to sea that can be dangerous and destructive. Over the long-term, high rates of melting and prolonged "mass wastage" will eventually exhaust the glacier resource and result in far-reaching consequences for communities that rely upon glacier meltwater for freshwater in the summer months.

It Happened Here...

On June 30, 2021, an unprecedented heat wave started to melt glaciers between Prince George, BC and Jasper, Alberta. As a result, and compounded by the melting snow pack, the Upper Fraser River and the Chilcotin River had exceeded their banks.

Damage still remains at the base of Mount Edith Cavell, one year after half of the Ghost Glacier fell on Aug. 10, 2012. Half of the Ghost Glacier fell off of the east side of Mount Edith Cavell, crashing into a pond at the base of the mountain in Jasper National Park. With a surface area estimated to be somewhere between 8,600 and 24,000 square metres, the Ghost Glacier's descent was the largest volume of snow and ice falling from a mountain in Jasper. Fortunately it occurred at approximately 5:30 a.m. as there were no visitors in the area.

Clearcut logging and a receding glacier were pinpointed Tuesday as probable contributors to a devastating flood which swept through the remote British Columbia First Nations community of Kingcome Inlet in September 2010. Helicopters provided the only way out for about 120 residents when water quickly rose up to four metres in parts of the village.

Glaciers Natural

Hazard Rating				High Risk	Low Risk	Need More Info	Not Applicable
				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
				FACTORS			
Yes	No	Need More Info	Not Applicable				
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Are there areas in your community on the coast or near sea level? Global climate change contributes to glaciers melting more than they are replenished each year, contributing to sea level rise.			
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Are there areas in your community that depend on glacier melt for drinking water, irrigation and/or hydroelectric power? These areas are at risk of such water sources running out due to climate change. The consequence of rapid glacier melting rates is often that underground water levels increase in the short term and decrease in the long term.)			
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Are there areas in your community located in the valleys below glaciers? These areas are at risk of large amounts of sediment being deposited in the valleys as the glaciers melt.			
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Scientists have noted that in many parts of Canada annual maximum winter and summer temperatures have been rising and thus glacier melting has increased. Is your community close to a glacier and have temperatures been rising over the past several years?			
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Do Traditional Knowledge holders have oral history of where glaciers and their boundaries existed in the past, near by your community?			
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Rapid melting glaciers, often in combination with snow-melt floods, can increase the likelihood of flooding at lower elevations. Have there been recent heat waves in the mountainous areas where there are glaciers?			

Icebergs, Ice Islands, Sea Ice and Ice Floes

Definition

Permanent and seasonal sea ice can be found near a significant portion of Canada’s coastlines—posing fishing, navigation and other marine hazards.

Icebergs are usually formed by large blocks of ice breaking off (or ‘calving’) the front of a glacier or ice shelf that drains into the ocean. Ice islands are large portions of ice (kilometers wide and long) that break off an ice shelf. One such ice island broke off Antarctica in November 2013, it measured 33 kilometers long and 21 kilometers wide.

Sea ice permanently covers the Arctic Ocean near the North Pole. In the winter this pack of sea ice grows and it can reach as far south as southeast Newfoundland. The extend of sea ice is monitored by Environment Canada to map where the sea ice is and where it may move to. Ice floes are large packs of floating ice, at sea it is also known as ‘drift ice’.

Ice shelves are sheets of ice floating on water and attached to land. Ice shelves form where a glacier meets the ocean. They may extend hundreds of kilometers from land and reach thicknesses of 1000 m.

Discussion

When seawater freezes, it is only the water that forms into ice crystals. The salt becomes trapped between the crystals in a concentrated brine. When the brine eventually leaches out, it leaves mostly pure ice floating on the surface, surrounded by sea water of increased salinity and density. Since the ice displaces its own weight in this denser water, it does not displace as much volume as it occupied before freezing. Because of this, freezing has an effect similar to that of evaporation - it lowers the water level and increases the surface salinity and density. Surface water must therefore flow toward a region of freezing, while the cold salty water that is formed must sink and flow away from the region.

It Happened Here...

In 2017, sea ice made life difficult for many who cross the waters along the coast. The sea ice was crowding Canada's so-called Iceberg Alley, forcing cargo ships to find new routes. The Canadian Coast Guard said they've been called to break vessels from the ice 85 times so far this year. There was a low-pressure system that moved south of Newfoundland, and it had sustained hurricane-force winds for a three-day period and in just a week it went from 37 icebergs in the shipping lane up to 455. Beyond the icebergs, the sheets of sea ice were crippling the fishing business and stranding large ferries.

In July 1981, a 900-tonne Canadian survey ship called the Arctic Explorer struck an iceberg. The accident occurred just off the coast of Newfoundland, near the small town of St. Anthony (population 2,476). Thirteen crewmen died; 19 survived by life raft; the ship sank in 20 minutes.

In 1997 a group of high school students together with three Elders, from the remote community of Pond Inlet, were studying whales off the edge of sea ice near the shore, when part of it broke off. The students were trapped on the ice floe for four days, during which the ice floe traveled 90 kilometers into the Lancaster Sound. Fortunately, the group had planned to spend a week camping on the ice, and as such had food, rifles, radios and camping gear available to them. The Elders had previous experience being trapped on the ice and knew how to keep the students safe on the thickest part of the ice floe (which was made up of older ice that had been floating in the ocean for more than one season). Helicopters were not able to rescue the students for four days because of high winds.

Icebergs, Ice Islands and Sea Ice Natural

Hazard Rating				High Risk	<input type="checkbox"/>	Low Risk	<input type="checkbox"/>	Need More Info	<input type="checkbox"/>	Not Applicable	<input type="checkbox"/>
				FACTORS							
Yes	No	Need More Info	Not Applicable								
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Are there areas in your community on the coast that experience long, cold, freezing winters and with frequent marine traffic? These areas are more at risk of marine accidents due to icebergs, ice islands or sea ice.							
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Are there areas in your community that have experienced hazards due to icebergs, ice islands or sea ice in the past?							
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Is your community on the Atlantic coast of Canada? Climate change is contributing to large icebergs breaking off and floating south (especially in the Atlantic).							
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Do Traditional Knowledge holders have oral history of where ice bergs and sea ice have occurred in the past near by your community?							
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Is your community located on the Labrador Current along Newfoundland’s coast or near shipping passages in the Northern Canada? These areas are at greatest risk.							

Lake Outburst

Definition

Rapid increase of water in glacial lakes can result in a sudden outburst of large volumes of water and debris, which can cause sudden floods downstream. Glacial lake outburst floods cause serious harm to life (injuries and deaths) and property downstream of the glacial lake. These floods can destruct valuable forests, farms and costly mountain infrastructure. Flood outbursts from glacier-dammed lakes are also called jökulhlaups.

Similar to lakes forming behind an ice lobe of a glacier, lakes can also form behind a glacier moraine (which is the mound of sediment, rock and debris the glacier pushed forward and is left in the landscape after the glacier has melted away). Outburst floods from these so-called “moraine-dammed lakes” happen when the moraine is eroded away by water, or becomes otherwise unstable.

Discussion

Lake outburst floods can result due to the faster rate of ice and snow melting, possibly caused by global warming, but can also occur when a landslide hits the glacier dammed lake and overtops the dam. As well, the lakes may drain through or underneath the ice, or over the ice. Glacier-dammed lakes may remain stable for some time and then release suddenly, or they may slowly fill and then release on a periodic basis.

Additionally, lake outbursts can be caused by earthquakes which compromise the stability of mountain slopes, glaciers and moraine dams.

Once an outburst flood ceases, the lake can refill if the glacier dam reforms. A reformed glacial lake can drain again at some time in the future. Although most jökulhlaups in Canada occur in

remote areas, they can pose a serious threat to infrastructure, forest lands and fish habitat far downstream

Lake dams can form in basins vacated by retreating glaciers, typically in cirques and steeped-walled valleys. Some of these dams are vulnerable to rapid erosion by waters flowing from the lake, which may lead to a catastrophic outburst flood. Since 1925, there have been at least ten outburst floods from moraine-dammed lakes in the western part of Canada taking up most of British Columbia, the Yukon, and cutting into the Rocky Mountains. Like jökulhlaups, floods from moraine-dam failures occur in remote areas, but they pose a serious threat to infrastructure, forest lands and fish habitat far downstream from the lake basin.

It Happened Here...

In November, 28 2020, a massive landslide, on the B.C. coast, about 110 km northeast of Campbell River propelled approximately 7.7 million cubic metres into an ocean inlet, reshaping the coastal landscape. The force of the event was equivalent to a magnitude 4.9 earthquake. Scientists say the initial slide happened when a steep slope let go and sent debris into a swollen glacial lake and caused an outburst flood that happened when the lake overflowed in a sudden wave down the mountain.

On October 9, 2019, the 2.2 sq km. lake in Kluane National Park in the Yukon, on the Donjek Glacier, was suddenly released. The ice dam at the terminus of the glacier broke, releasing the waters into the Donjek River.

In July 1994, an ice-dammed lake at Goddard Glacier in British Columbia suddenly drained and flooded the surrounding area. Near the community of Chilko Lake (population 62) the flood deposited sediment, destroyed large areas of forest and changed the Farrow Creek channel. It is thought that above average rainfall and snowmelt may have been the cause for the jökulhlaup.

In 1978, debris flows in Kicking Horse Pass were triggered by a lake outburst from Cathedral Glacier which destroyed three levels of the Canadian Pacific Railway track, derailling a freight train. Sections of the Trans-Canada Highway were also buried.

Lake Outburst Natural

Hazard Rating				High Risk <input type="checkbox"/>	Low Risk <input type="checkbox"/>	Need More Info <input type="checkbox"/>	Not Applicable <input type="checkbox"/>
Yes	No	Need More Info	Not Applicable	FACTORS			
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Are there areas in your community in high mountain valleys, just downhill or downstream from glacier-dammed or moraine-dammed lakes? These areas are at greater risk of an outburst flood from a glacier dam failure.			
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Is there a failure to implement regular aerial checks on glaciers to ensure that that there is no buildup of a glacial lake behind potentially unstable soil?			
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Are there regular checks to ensure that beavers have not created potential lake outbursts by creating a network of dams in mountainous glacial terrain?			
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Glacial lakes can drain and then reform. Have there been previous glacial dams in or near your community?			
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Glacial lakes can be destabilized by earthquakes. Are there glacial lakes in areas subject to earthquakes near your community?			
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Do Traditional Knowledge holders have oral history of where lake outburst floods have occurred in the past, in or near by your community?			
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Lake outburst floods can be triggered by increased numbers of rain storms and storms of higher intensity occurring over glacial lakes brought about by climate change. Is climate change having an impact on the amount of rain water falling into glacial lakes near or in your community?			

Risk Analysis Resources

Avalanches

Natural Resources Canada's "The Atlas of Canada" provides a lot of information about [major avalanches](#) in Canada.

Keywords: Atlas of Canada, avalanche

The [Canadian Avalanche Centre](#) provides timely information and warnings regarding avalanches and also includes an Avalanche Danger Scale.

Keywords: Canadian Avalanche Centre, avalanche, danger scale, avalanche rating.

Drought

The website of the [Climate Atlas of Canada](#) provides all kinds of information regarding drought management in Canada.

Keywords: Climate Atlas of Canada, Agriculture, Agri-food Canada, drought.

The [Canadian Drought Monitor](#) provides up-to-date information on drought.

Keywords: Canadian Drought Monitor, Agriculture, Agri-food Canada, drought.

Floods

Public Safety Canada provides useful information regarding [floods in Canada](#).

Keywords: Public Safety Canada, flood, natural hazards

Environment Canada also provides useful information regarding [floods](#) in Canada.

Keywords: Environment and Climate Change Canada, flood, natural hazards

Natural Resources Canada's "The Atlas of Canada" provides a lot of information on [water](#) and climate related information.

Keywords: Natural Resources Canada, Atlas of Canada, flood, natural hazards

The Institute for Catastrophic Loss Reduction (ICLR) has a lot of information about a number of natural hazards including [Floods](#).

Keywords: Institute for Catastrophic Loss Reduction, flood, natural hazards

Glacial Lake Outburst Floods

The United Nations Development Programme provides a lot of information on [glacial lake outburst floods](#).

Keywords: UNDP, glacial lake, outburst flood

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