

Hazard Resilience Strategies

Hydrological Hazards (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, Sea Ice and Ice floes,
Lake Outbursts

In order to avoid repetition, resiliency factors that only apply to human-caused hazards are in italics.

Avalanche – Natural and Human Caused

- Ensure areas are forested or reforestation is in place in order to retain snow.
- Ensure community-based avalanche exercises have taken place in the community-at-large (e.g., table-top or full-scale functional exercises).
- Ensure most persons (residents and visitors) using mountains for snow related activities, outside ski resorts and privately monitored areas, frequently check with avalanche forecasting agencies such as [Canada Avalanche](#) or contact experts to get avalanche risk reports based on depth of snow, precipitation and temperature
- Ensure that persons using the mountains for snow-related activities incorporate Traditional Knowledge and practices related to avalanches.
- Ensure persons moving through mountainous areas by snowmobile, dog sled (qamutiq) or other form of transportation are prepared for and know how to protect themselves if their activities trigger an avalanche (e.g., carry a rescue beacon, a small shovel, avoid fresh accumulation and windblown snow which is less secure).
- Signs are clearly posted at entry points to mountainous areas used by skiers, snowboarders and snowmobilers to ask them to have basics in place such as a rescue beacon, a small shovel, a cell phone).

- Ensure plans and personnel are in place to implement appropriate strategies to reduce avalanche hazards by: triggering snow avalanches in a controlled environment; testing and promoting slope stability or similar strategy.
- Ensure plans are in place to identify areas with a high risk of experiencing an avalanche as off-bound areas for snowmobilers, skiers, and dog sleds (qamutiq) and there are the required personnel to mark and monitor use of this area.
- Ensure regulations prohibit development, limit land use, or require structural reinforcements for buildings that must remain in avalanche hazard areas, such as reinforced walls and roofs; ensure a plan is also developed for the equivalent update/upgrade of existing structures/developments.
- Ensure structures are in place in avalanche runout and catchment zones such as diverters, catching dams or basins, retarding mounds (structures to stop debris), snow fences, snow nets, snow sheds or tunnels which slow, divert or stop avalanche flows.
- Ensure the community has mapped and posted, in multiple languages, avalanche hazard zones and evacuation routes in areas of high risk.
- Ensure the community and mountain resorts have posted visible signs warning, in multiple languages, residents and visitors of avalanche hazards; warning signs are updated daily and shared on social media.
- Ensure there is a warning system in place to notify community residents and visitors of a potential avalanche and how to evacuate the threatened area and test the system regularly.
- Ensure there is a warning system in place to notify emergency response personnel of a potential avalanche.
- Ensure community members and organizations within the community (or nearby) have participated in and maintain Search and Rescue (SAR) training and certification.
- Ensure there is a warning system in place to notify Search and Rescue (SAR) volunteers of a potential or actual avalanche.
- Ensure wind baffles (deflectors) are in place to direct wind in order to erode snow cover.
- Ensure the community has a means for consulting with Traditional Knowledge holders and subject matter experts about historical avalanche protection measures and appropriate prevention/control and response.
- Ensure that the community has in place, or is in consultation with transportation officials, with established protocols for closing roads when the avalanche risk is too high.

Flash Floods – Natural

- Ensure community monitors check frequently with weather forecasting agencies such as Environment Canada and monitor conditions that may lead to flash flooding to inform the issuance of warnings and watches.
- Ensure community-based flash flood exercises have taken place in the community-at-large (e.g., table-top or full-scale exercises).
- Ensure there is a warning system to notify community residents of flash flood risk and to evacuate areas prone to flash flooding (e.g., river beds).
- Ensure the community has implemented structural measures to reduce the risk of flooding, such as building dams, dykes and floodwalls, creating reservoirs or making channel improvements and ensure these structures are regularly maintained.
- Ensure the community has mapped areas subject to flash flooding and maps are available to residents in multiple languages.

- Ensure the community has posted signs warning of areas subject to flash flooding (e.g., roads near waterways).
- Ensure the community has regulations that prohibit development, limit land use, or require specific building codes for developments within flood hazard areas, such as elevating structures above maximum flood levels, requiring waterproof materials and anchoring buildings to prevent floatation; ensure a plan is also developed for the equivalent update/upgrade of existing structures/developments.
- Ensure the community has retained or re-established natural ecosystems in floodplains that provide flood control, such as vegetation cover which provides soil stability and absorption, wetlands and estuaries (a partly enclosed coastal body of water with one or more rivers or streams flowing into it and a free connection to the sea) which assist with water retention and absorption, and natural stream flows and riparian areas (areas situated on the bank of a river or other body of water) which slow water runoff velocity, reduce bank erosion and reduce the introduction of sediment and debris in watercourses – consultation with Traditional Knowledge holders and community members is encouraged in the planning of these actions.
- Ensure there is a warning system in place to notify community residents of a potential flash flood and to prohibit entry into areas subject to flash flooding or other appropriate responses, such as moving to safe space in home where flood waters will not affect you, evacuation to higher ground etc.
- Ensure there is a warning system in place to notify emergency response personnel of a potential flash flood.
- Ensure community members and organizations within the community (or nearby) have participated in and maintain Search and Rescue (SAR) training and certification.
- Ensure there is a warning system in place to notify Search and Rescue (SAR) personnel of a potential flash flood.
- Ensure the community has a means for consultation with Traditional Knowledge holders and subject matter experts about historical flood protection measures and appropriate prevention/control and response.
- Every location within a floodplain, regardless of the presence or absence of a levee, berm or other structure, is subject to some level of risk. Ensure that those responsible for activity in the floodplain (public officials, investors, and those relying on activities in the floodplain, etc.) have actively taken steps to ensure that those in the floodplain understand the nature of the risks they face and the steps that may be taken to reduce this risk.

Ice Jam Floods – Natural

- Ensure community officials check frequently with weather forecasting agencies such as Environment Canada and monitor conditions that may lead to ice-jam flooding and share warnings.
- Ensure community-based ice-jam flood training exercises have taken place in the community-at-large (e.g., table-top or full-scale exercises).
- Ensure community volunteers and personnel have received training regarding sand-bagging.
- Ensure dredging has taken place to avert potential ice jam floods and/or dredging activities are monitored and assessed for their potential to cause submarine slides.
- Ensure the community has implemented structural measures to reduce the risk of ice-jam flooding, such as building dams, dykes and floodwalls, creating reservoirs or making channel improvements.

- Ensure the community has a means for consulting Traditional Knowledge holders and subject matter experts about appropriate prevention and responses to ice jams and also regarding possible impacts of structural response measures on wildlife and ecosystems.
- Ensure the community has mapped areas subject to ice-jam flooding and shared maps with residents in multiple languages.
- Ensure the community has posted signs warning of areas subject to ice jam flooding (e.g., roads, railroad lines near waterways).
- Ensure the community has ready access to stockpiles of sandbags.
- Ensure the community has regulations that prohibit development, limit land use, or require specific building codes for developments within ice-jam flood hazard areas, such as elevating structures above maximum flood levels, requiring waterproof materials and anchoring buildings to prevent floatation; ensure a plan is also developed for the equivalent update/upgrade of existing structures/developments.
- Ensure the community has retained or re-established natural ecosystems in floodplains that provide flood control, such as vegetation cover which provides soil stability and absorption, wetlands and estuaries (a partly enclosed coastal body of water with one or more rivers or streams flowing into it and a free connection to the sea) which assist with water retention and absorption of spring rainwater and melt waters.
- Encourage consultation with Traditional Knowledge holders and subject matter experts to find locations prone to ice jams in order to inform land use and development planning and reduce risk of flooding to property.
- Ensure there is a warning system in place to notify community residents of a potential ice jam flood and to evacuate areas prone to ice-jam flooding (e.g., areas near bridges, below steep rapids or in river bends).
- Ensure there is a warning system in place to notify emergency response personnel of a potential ice jam flood and to prohibit entry into areas subject to ice jam flooding.
- Ensure community members and organizations within the community (or nearby) have participated in and maintain Search and Rescue (SAR) training and certification.
- Ensure there is a warning system in place to notify Search and Rescue (SAR) personnel of a potential ice jam flood.
- Ensure the community has plans in place for implementing artificial breakup if needed.
- Every location within a floodplain, regardless of the presence or absence of a levee, berm or other structure, is subject to some level of risk. Ensure that those responsible for activity in the floodplain (public officials, investors, and those relying on activities in the floodplain, etc.) have actively taken steps to ensure that those in the floodplain understand the nature of the risks they face and the steps that may be taken to reduce this risk.

Local Floods – Human-Caused

- Ensure the community public works department has developed and implemented measures to reduce the risk of local flooding, such as ensuring that storm sewage drains and systems are well maintained and free from blockages caused by ice, mud or other debris/garbage.
- Ensure the community monitors and maintains pumps and pump stations.
- Ensure the community has ready access to stockpiles of sandbags.
- Ensure community officials check frequently with weather forecasting agencies such as Environment Canada and monitor conditions that may lead to local flooding.

- Ensure community volunteers and personnel have received training regarding sand-bagging.
- Ensure community-based local flood exercises have taken place in the community-at-large (e.g., table-top or full-scale exercises).
- Ensure the community has a warning system to notify community residents and businesses of potential local flooding risk and to evacuate areas prone to local flooding.
- Ensure there is a warning system in place to notify Emergency Response Personnel of potential local flooding and to prohibit entry into areas subject to ice jam flooding.
- Ensure the community has a means to consult with Traditional Knowledge holders and subject matter experts regarding local flooding and history of development as it relates to flooding occurrence.
- Ensure that flood risk is assessed not only based on flood plain mapping but includes the exposure of people, property and infrastructure as well as their vulnerabilities to the flooding hazard.

Rain Storm Floods – Natural

- Ensure community officials check frequently with weather forecasting agencies such as Environment Canada and monitor conditions that may lead to rain storm flooding.
- Ensure community volunteers and personnel have received training regarding sand-bagging.
- Ensure community-based rain storm flood exercises have taken place in the community-at-large (e.g., table-top or full-scale exercises).
- Ensure dredging has taken place to avert potential ice jam floods and/or dredging activities are monitored and assessed for their potential to cause submarine slides.
- Ensure the community has implemented structural measures to reduce the risk of rain storm flooding, such as building dams, dykes and floodwalls, creating reservoirs or making channel improvements.
- Ensure the community has a means for consulting Traditional Knowledge holders and subject matter experts about appropriate prevention and responses to rainstorm floods and also regarding possible impacts of structural response measures on wildlife and ecosystems.
- Ensure the community has mapped areas subject to rain storm flooding (e.g., established flood plain areas at the 100- and 200-year level) and shared this information with residents.
- Ensure the community has posted signs in multiple languages warning of areas subject to rain storm flooding (e.g., roads, railroad lines near waterways).
- Ensure the community has ready access to stockpiles of sandbags.
- Ensure the community has regulations that prohibit development, limit land use, or require specific building codes for developments within flood plains, such as elevating structures above maximum flood levels (e.g., 100- or 200-year levels), requiring waterproof materials and anchoring buildings to prevent floatation; and that there is a plan for the equivalent update/upgrade of existing structures/developments.
- Ensure the community has retained or re-established natural ecosystems in floodplains that provide flood control, such as vegetation cover which provides soil stability and absorption, wetlands and estuaries (a partly enclosed coastal body of water with one or more rivers or streams flowing into it and a free connection to the sea) which assist with water retention and absorption, and natural stream flows and riparian areas (areas

- situated on the bank of a river or other body of water) which slow water runoff velocity, reduce bank erosion and reduce the introduction of sediment and debris in watercourses.
- Ensure there is a warning system in place to notify community residents of a potential rain storm floods and to evacuate areas prone to rain storm flooding (e.g., flood plains) or other appropriate responses when evacuation is high risk, such as moving to safe space in home where flood waters will not affect you.
 - Ensure there is a warning system in place to emergency response personnel of a potential rain storm flood and to prohibit entry into areas subject to flooding.
 - Ensure community members and organizations within the community (or nearby) have participated in and maintain Search and Rescue (SAR) training and certification.
 - Ensure there is a warning system in place to notify Search and Rescue (SAR) personnel of a potential rain storm flood.
 - Ensure consultations have taken place to consider floodwalls or sea walls.
 - Ensure evacuation routes for flood-prone areas have been identified and posted.
 - Ensure that plans are in place to offer property buyouts and/or permanent relocation in areas subject to repetitive flooding.
 - Review community eligibility to see if the community can apply for funding from the [National Disaster Mitigation Program](#).
 - Ensure that the community has taken steps to upgrade physical infrastructure such as roads and storm sewers in anticipation of the impacts of climate change on flooding.
 - Ensure that the community has undertaken improvements in building and housing to mitigate the impacts of climate change through promotion of natural infrastructure such as green roofs, stormwater wetlands and tree planning to offset runoff.
 - Ensure that flood risk is assessed not only based on flood plain mapping but includes the exposure of people, property and infrastructure as well as their vulnerabilities to the flooding hazard.

Snow Melt Floods

- Ensure community officials check frequently with weather forecasting agencies such as Environment Canada and monitor snow pack conditions that may lead to snow melt flooding; ensure warnings are issued as needed.
- Ensure community volunteers and personnel have received training regarding sand-bagging.
- Ensure community-based snow melt flood exercises have taken place in the community-at-large (e.g., table-top or full-scale exercises).
- Ensure dredging has taken place to avert potential ice jam floods and/or dredging activities are monitored and assessed for their potential to cause submarine slides (not to be done in spring while ice is still present).
- Ensure the community has implemented structural measures to reduce the risk of snow melt flooding, such as building dams, dykes and floodwalls, creating reservoirs or making channel improvements.
- If the community is protected by dams, dykes, levees or floodwalls ensure that these are inspected at least bi-annually prior to the flood season and when water is at its lowest.
- If the community is protected by dams, dykes, levees or floodwalls ensure that these have been built to accommodate flooding higher than the maximum flood levels (i.e., a

one or two percent annual chance flood (100-year flood/200-year flood) as the impacts of climate change are changing flooding intensities.

- Ensure the community has a means for consulting Traditional Knowledge holders and subject matter experts about appropriate prevention and responses to snow melt floods and also regarding possible impacts of structural response measures on wildlife and ecosystems.
- Ensure the community has mapped areas subject to snow melt flooding (e.g., established flood plain areas at the 100- and 200-year level and marked low-lying areas) and shared maps with the community.
- Ensure the community has ready access to stockpiles of sandbags.
- Ensure the community has regulations that prohibit development, limit land use, or require specific building codes for developments within flood plains, such as elevating structures above maximum flood levels (e.g., 100- or 200-year levels), requiring waterproof materials and anchoring buildings to prevent floatation; ensure a plan is also developed for the equivalent update/upgrade of existing structures/developments.
- Ensure the community has retained or re-established natural ecosystems in floodplains that provide flood control, such as vegetation cover which provides soil stability and absorption, wetlands and estuaries (a partly enclosed coastal body of water with one or more rivers or streams flowing into it and a free connection to the sea) which assist with water retention and absorption, and natural stream flows and riparian areas (areas situated on the bank of a river or other body of water) which slow water runoff velocity, reduce bank erosion and reduce the introduction of sediment and debris in watercourses.
- Ensure the community consults with Elders, Traditional Knowledge holders and subject matter experts regarding the ways Indigenous peoples have controlled or prevented floods in the past.
- Ensure there is an early warning system in place to notify farmers of potential snow melt floods and to evacuate livestock from areas prone to snow melt flooding (e.g., flood plains).
- Ensure there is a warning system in place to notify community residents of a potential snow melt floods and to evacuate areas prone to snow melt flooding (e.g., flood plains).
- Ensure there is a warning system in place to notify emergency response personnel of a potential snow melt flood and to prohibit entry into areas subject to flooding
- Ensure community members and organizations within the community (or nearby) have participated in and maintain Search and Rescue (SAR) training and certification.
- Ensure there is a warning system in place to notify Search and Rescue (SAR) personnel of a potential snow melt flood.
- Ensure evacuation routes for flood-prone areas have been identified and posted.
- Ensure that plans are in place to offer property buyouts and/or permanent relocation in areas subject to repetitive flooding.
- Review community eligibility to see if the community can apply for funding from the [National Disaster Mitigation Program](#).
- Ensure that the community has taken steps to upgrade physical infrastructure such as roads and storm sewers in anticipation of the impacts of climate change on flooding.
- Ensure that the community has undertaken improvements in building and housing to mitigate the impacts of climate change through promotion of natural infrastructure such as green roofs, stormwater wetlands and tree planning to offset runoff.

- Ensure that flood risk is assessed not only based on flood plain mapping but includes the exposure of people, property and infrastructure as well as their vulnerabilities to the flooding hazard.

Glaciers and Glacier Avalanches

- Ensure community officials check frequently with weather forecasting agencies such as Environment Canada and monitor glacier conditions that may lead to avalanches associated with glaciers.
- Ensure community-based discussions, including Traditional Knowledge holders, have taken place in the community-at-large regarding glaciers of concern and safety around glaciers.
- Ensure the community and mountain resorts have posted visible signs in multiple languages warning residents and visitors of avalanches associated with glaciers and marking areas of the glacier safe for visitors (if any).
- Ensure the community has plans in place or has reduced the risk of glacial lakes flooding by constructing a draining tunnel to remove water from the lake and away from any settlements or development (e.g., roads).
- Ensure the community has plans in place to reduce the risk of a glacier avalanche by controlled ice blasting or having snow sheds in place to protect roads and other areas.
- Ensure the community has plans in place to reduce the risk of portions of glaciers breaking off such as controlled ice blasting.
- Ensure the community monitors glaciers with annual aerial photos and/or surveillance cameras to see changes and potential risks and shares information with residents to keep them informed.
- Ensure there is a warning system in place to notify community residents and visitors of a potential avalanche associated with glaciers and to evacuate the threatened area.
- Ensure there is a warning system in place to notify Emergency Response Personnel of avalanche risks associated with glaciers.
- Ensure community-based glacier avalanche evacuation exercises have taken place in the community-at-large (e.g., table-top or full-scale exercises)

Icebergs, Sea Ice and Icefloes

- Community-based marine accidents involving icebergs, ice islands or sea ice exercises have taken place in the community-at-large (e.g., table-top or full-scale exercises).
- Community officials check frequently with weather forecasting agencies such as Environment Canada and monitor icebergs, ice islands or sea ice conditions that may lead to marine accidents.
- Ensure community-based discussions, including Traditional Knowledge holders and subject matter experts, have taken place in the community-at-large regarding ice bergs, ice islands and sea ice.
- Ensure most community members who hunt and fish at the floe edge or operate boats around sea ice have been given safety training (related to polar bears, ice conditions and safe boating in ice infested waters) and carry appropriate safety gear (survival suits, rescue equipment for pulling people from the water etc.) and communication mechanisms (radio or other); generate common practice for hunters and fisherfolk to travel in teams of two or more and leave trip plans with a family member in case rescue is needed.

- Ensure community members and organizations within the community (or nearby) have participated in and maintain Search and Rescue (SAR) training and certification; access to appropriate rescue vehicles is also available.
- Ensure there is a warning system in place to notify Search and Rescue vessels (marine or helicopter) in case a community member is caught on an ice floe.

Lake Outburst Natural and Human-Caused

- Ensure community officials check frequently with geological agencies such as Natural Resources Canada and monitor landslide conditions that may lead to lake outbursts.
- Ensure community officials check frequently with weather forecasting agencies such as Environment Canada and monitor glacier dam conditions and slope stability around glacier lakes to identify places where lake outbursts could occur.
- Ensure community-based lake outburst exercises have taken place in the community-at-large (e.g., table-top or full-scale exercises).
- Ensure the community and mountain resorts have posted visible signs in multiple languages warning residents and visitors of the potential for lake outbursts associated with glaciers.
- Ensure the community has plans in place or has reduced the risk of lake outbursts by removing water from glacial lakes or implementing controlled breaches, overflows, engineered outlet channels, siphoning or other approaches gathered from Traditional Knowledge holders and subject matter experts.
- Ensure the community has plans in place to reduce the risk of a glacier avalanche by controlled ice blasting or having snow sheds in place to protect roads and other areas.
- Ensure the community monitors glaciers and glacial lakes with annual aerial photos and/or surveillance cameras to see changes and potential risks and to create hazard maps to inform land use planning and development.
- Ensure there is a warning system in place to notify community residents and visitors of a potential lake outburst associated with glaciers and to evacuate the threatened area.
- Ensure there is a warning system in place to notify emergency response personnel of potential lake outbursts associated with glaciers.

References

- Armenakis, C., Du, E. X., Natesan, S. Persad, R.A., & Zhang, Y. (2017). [Flood risk assessment in urban areas based on spatial analytics and social factors](#). *Geosciences*, 7(4). 10.3390/geosciences7040123
- Associated Programme on Flood Management. (2007). [Guidance on flash flood management](#). World Meteorological Organization and the Global Water.
- Belore, H. S., Burrell, B. C., & Beltaos, S. (1990). [Ice jam mitigation](#). *Canadian Journal of Civil Engineering*, 17, 675-685.
- Campbell, C., Bakermans, L., Jamieson, B., & Stethem, C. (2007). [Current and future snow avalanche threats and mitigation measures in Canada](#). Canadian Avalanche Centre.
- Canadian Institute for Climate Choices. (2020). [Tip of the iceberg. Navigating the known and unknown costs of climate change for Canada](#).
- Das, A. & Lindenschmidt, K. (2021). [Evaluation of the implications of ice-jam flood mitigation measures](#). *Journal of Flood Risk Management/Early View*, e12697. <https://doi.org/10.1111/jfr3.12697>
- Decaulne, A. (2007). Snow-avalanche and debris-flow hazards in the fjords of north-western Iceland, mitigation and prevention. *Natural Hazards*, 41, 81-98. <https://doi.org/10.1007/s11069-006-9025-x>
- Derksen, C., Burgess, D., Duguay, C., Howell, S., Mudryk, L., Smith, S., Thackeray, C. & Kirchmeier-Young, M. (2019). [Changes in snow, ice, and permafrost across Canada](#). In E. Bush & D.S. Lemmen (Eds.), *Canada's changing climate report* (pp. 194-260). Government of Canada.
- Environment Canada. (2013). [Reducing flood damage](#).
- Mears and Wilbur. (n.d.). [Avalanche mitigation](#).
- Montz B.E. (2001). Assessing the effects and effectiveness of flash flood mitigation strategies. In E. Grunfest, & J. Handmer (Eds.) *Coping with flash floods*. NATO Science Series (Vol. 77). Springer. https://doi.org/10.1007/978-94-010-0918-8_14
- Mustaff, Z., Hamid, E., Al-Qadami, H., Shah, S. M. H. & Wan Yusof, K. (2020). [Impact and mitigation strategies for flash floods occurrence towards vehicle instabilities](#). Intechopen. doi:105772/intechopen.92731
- National Conference of State Legislatures. (2019). [Flood mitigation](#). NCSL.
- National Research Council. (2013). [Implementing flood risk management strategies](#). In *Levees and the National Flood Insurance Program: Improving policies and practices* (pp. 98-126). National Academies Press. <https://doi.org/10.17226/18309>
- Public Safety Canada. (2021). [National disaster mitigation program](#).
- Romang, H. (Ed.). (2009). [Best practice of integral risk management of snow avalanches, rock avalanches and debris flows](#). Irasmus.

Slater, A. (2000). *Non-structural flood mitigation in Canada: Linking the resources of today with a strategy for tomorrow* [Master's Thesis]. University of British Columbia.

Whiteman, C.A. (2011). *Cold region hazards and risks*. Wiley.