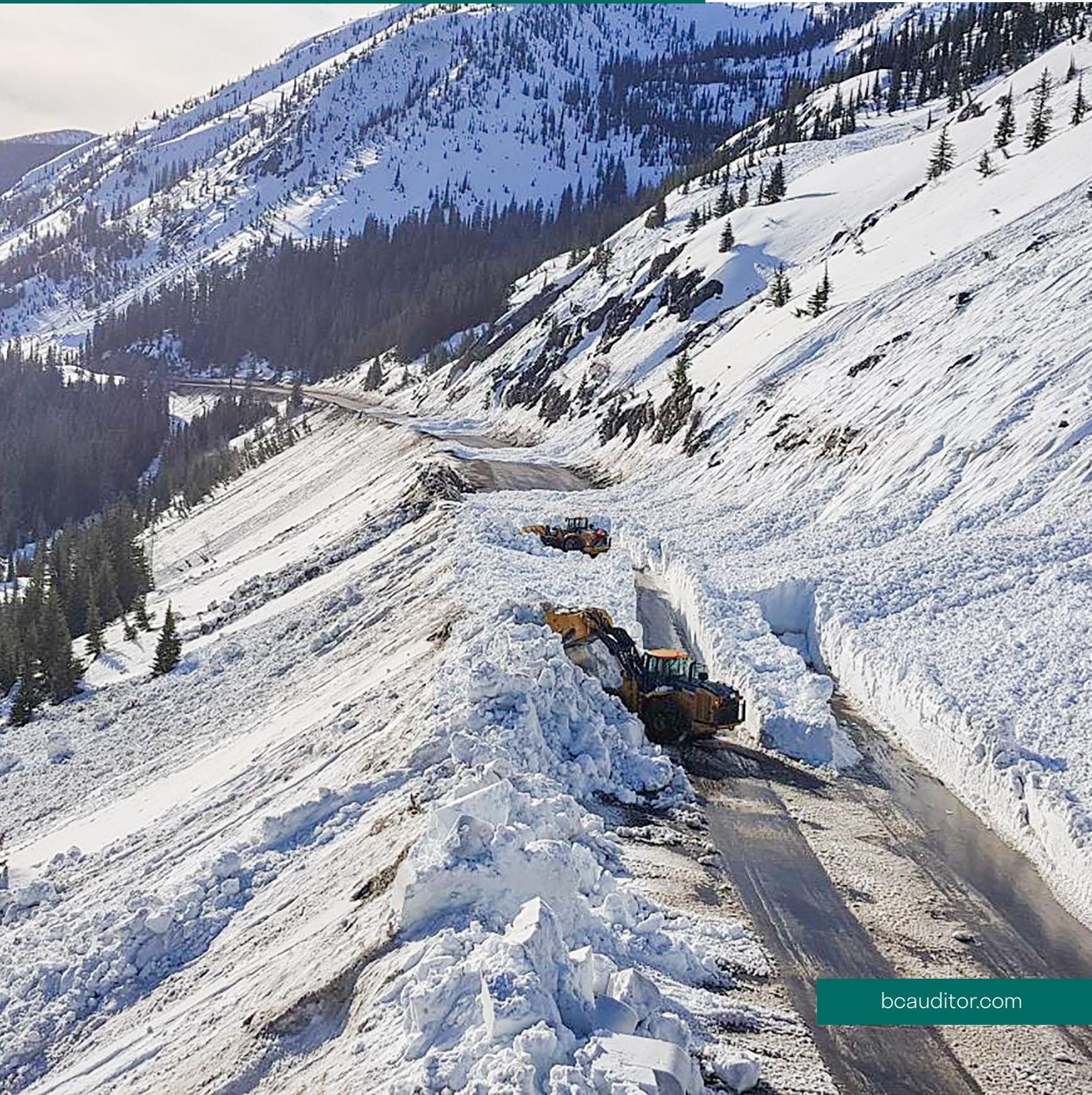




AVALANCHE SAFETY ON PROVINCIAL HIGHWAYS

An independent audit report

April 2021



The Honourable Raj Chouhan
Speaker of the Legislative Assembly
Province of British Columbia
Parliament Buildings
Victoria, British Columbia
V8V 1X4

Dear Mr. Speaker:

I have the honour to transmit to the Speaker of the Legislative Assembly of British Columbia the report *Avalanche Safety on Provincial Highways*.

We conducted this audit under the authority of section 11(8) of the *Auditor General Act*. All work in this audit was performed to a reasonable level of assurance in accordance with the Canadian Standard on Assurance Engagements (CSAE) 3001—Direct Engagements, set out by the Chartered Professional Accountants of Canada (CPA Canada) in the *CPA Canada Handbook—Assurance*.



Michael A. Pickup, FCPA, FCA
Auditor General of British Columbia
Victoria, B.C.

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The Office of the Auditor General of British Columbia would like to acknowledge with respect that we conduct our work on Coast Salish territories. Primarily, this is on the Lkwungen-speaking people's (Esquimalt and Songhees) traditional lands, now known as Victoria, and the WSÁNEĆ people's (Pauquachin, Tsartlip, Tsawout, Tseycum) traditional lands, now known as Saanich.

AUDIT AT A GLANCE

Why we did this audit

- Roughly 1,600 avalanche paths pose risks to the provincial highway system.
- Avalanches can cause serious injury or death.
- The reliability of highways is critical to the province's economy.

Objective

To determine whether the Ministry of Transportation and Infrastructure is effectively managing its **avalanche safety program** to:

- ensure the safety of highway users
- minimize the frequency and duration of avalanche-related road closures

Audit period:

- We examined the avalanche safety program from 2018 to 2020.
- We used historical data to assess trends in indicators of highway safety and reliability (2000 to 2020).

Conclusion

The ministry is effectively managing its avalanche safety program, ensuring the safety of highway users and minimizing the frequency and duration of avalanche-related road closures, with some exceptions.

The ministry has accepted all 8 recommendations we made to improve highway user safety and reliability.

What we found

Avalanche risk assessment and notification

Ministry has mapped avalanche paths, but some path information is outdated

- 1,600 avalanche paths mapped
- Unknown when 2/3 of avalanche paths were last updated
- Descriptive information missing from 14% of the 1,377 active avalanche paths

[Recommendation 1](#)

Ministry collects appropriate weather and snowpack data

- Weather network includes 68 remote avalanche stations and 99 road weather stations
- Snow profiles meet industry guidelines on snowpack

Ministry gives timely avalanche forecasts

- Highway users and stakeholders (including maintenance contractors, BC Emergency Health Services, District of Stewart) getting the information needed on avalanches

Resources, tools and training

Program almost fully staffed

- Field offices—8 fully staffed with 16 people
- Head office—1 of 3 positions vacant for 6 years

[Recommendation 2](#)

Staff trained as required

- Staff—industry certified

What we found (continued)

Resources, tools and training (continued)

Staff have tools to do job

- Day-to-day tools available
- Field equipment, signs, gates in place

Capital investments made but planning process lacking

- Ministry invests \$600,000 annually in maintaining its capital equipment
- Ministry invests in large infrastructure projects
- Capital planning process lacks formalized needs assessment

[Recommendation 3](#), [Recommendation 4](#)

Highway user safety

No avalanche-related deaths on highways in last 20 years

- No avalanche-related deaths on provincial highways in the last 20 years
- In 1999, 2 ministry staff died in avalanche

Fewer incidents but follow-up process lacking

- From 2010 to 2020, avalanche incidents averaged 3 per year, down from a high of 42 in 1982
- Ministry prepares incident reports but does not have a process to track and follow up
- Ministry closes roads when avalanche forecast is high, but large avalanches still hit open highways

[Recommendation 5](#), [Recommendation 6](#)

Frequency and duration of road closures

Fewer highway closures and lower total closure time

- Number of closures and total closure time show decreasing trends
- Ministry system outdated—roughly 10% of closure data missing due to data entry issues

[Recommendation 7](#), [Recommendation 8](#)

Staff have taken action to improve highway reliability

- Initiatives to improve highway reliability include:
 - new avalanche control systems
 - expanded ditches and catchment areas
 - updated maintenance requirements

Looking ahead

After reading the report, you may want to ask the following questions of government:

- 1. How will the ministry ensure that its future investments in avalanche control infrastructure are made where the need is greatest?*
- 2. How will the ministry measure its performance in meeting program objectives?*
- 3. As highway use continues to increase, how can the ministry best ensure highway safety and reliability?*

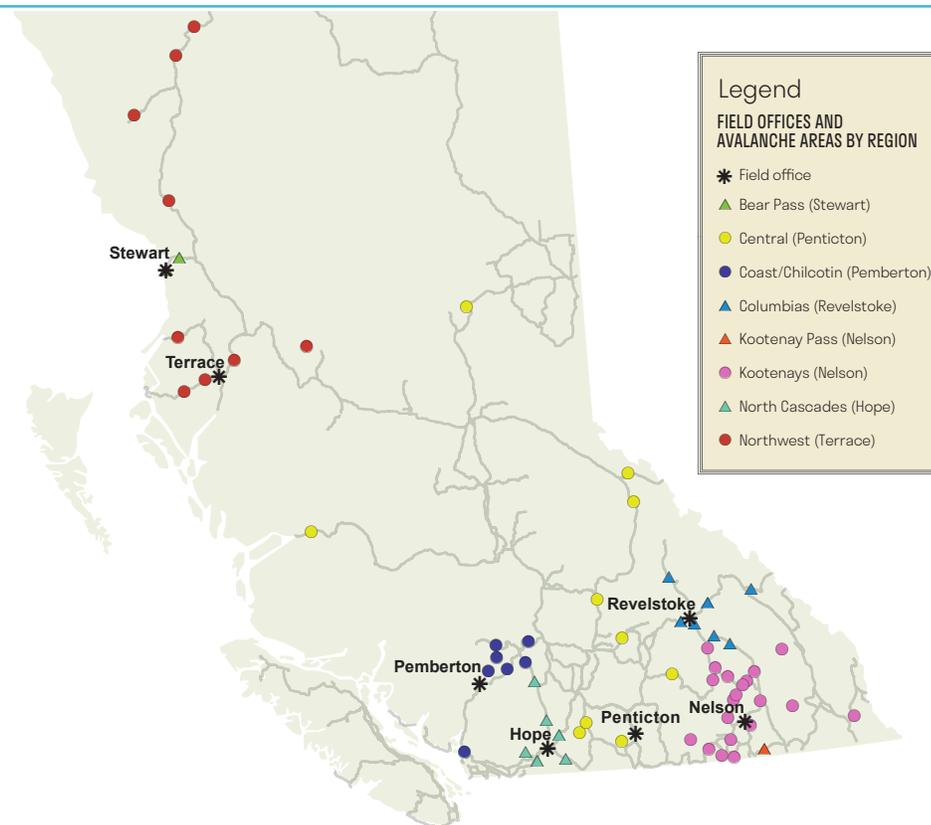
BACKGROUND

Each year, from early fall to late spring, there is a risk of avalanches on many stretches of British Columbia's highways. Avalanches can injure and kill highway users, damage vehicles and property, and close highways, restricting the movement of people and goods, and harming provincial and local economies.

The avalanche risk for highways was highlighted in 1974, when an avalanche destroyed the North Route Café near Terrace, killing seven people who were sheltering at the café because of avalanche activity on the highway. In response, the government set up a task force that led to the creation of the avalanche safety program at the Ministry of Transportation and Infrastructure.

The avalanche safety program is delivered through eight regional field offices and a head office in Victoria, B.C. (see Exhibit 1). The field offices report to the ministry's districts for budgeting and staffing, while the head office sets standards and policies.

EXHIBIT 1: *Avalanche safety program regional field offices and highway avalanche areas*



Source: Ministry of Transportation and Infrastructure, adapted by the Office of the Auditor General of British Columbia

The ministry has identified about 1,600 avalanche paths that pose risks for highway users. The main activities of the avalanche safety program are:

- **Avalanche hazard forecasting**—Staff set hazard levels, ranging from low to extreme, using data such as observed avalanche activity, weather forecasts and snowpack stability tests. Forecasts are used to determine whether road closures or avalanche control are needed.
- **Road closures and avalanche control**—Staff may close highways to allow avalanches to occur naturally, or they may trigger avalanches.

Most of the program's avalanche control work is conducted by heli-bombing—dropping explosives from helicopters at sites selected by staff. However, increasingly, the program uses remote avalanche control systems—explosive devices that use wireless technology to remotely trigger avalanches.



Avalanche safety program staff conducting a heli-bombing exercise in Northwest B.C. (Gamma avalanche area – Highway 37N)
Photo credit: Ministry of Transportation and Infrastructure

OBJECTIVE

The objective of our audit was to determine whether the Ministry of Transportation and Infrastructure is effectively managing its avalanche safety program to:

- ensure the safety of highway users
- minimize the frequency and duration of avalanche-related road closures

Scope

We examined the actions and initiatives of the Ministry of Transportation and Infrastructure's avalanche safety program to determine whether the ministry was managing its avalanche safety program effectively.

Highways in national parks, which are under federal jurisdiction, were excluded from the audit scope.

Audit period

Our audit examined the avalanche safety program from 2018 to 2020. Where possible, we used historical data to assess trends in indicators of highway safety and reliability from 2000 to 2020

[Learn more about the audit criteria.](#)

[Learn more about how we did this audit.](#)

CONCLUSION

We concluded that the Ministry of Transportation and Infrastructure is effectively managing its avalanche safety program, ensuring the safety of highway users and minimizing the frequency and duration of avalanche-related road closures, with some exceptions.

In the last 20 years, no avalanche-related fatalities have been reported on provincial highways. Over a similar period, both the frequency and duration of highway closures decreased, although this data is highly variable because of annual fluctuations in snowpack and weather conditions. The ministry has assessed risks to highway users by mapping avalanche paths around the province. It uses relevant snow and weather data for avalanche forecasting and reviews avalanche incidents.

However, the ministry can still improve in some areas. For example, some data on avalanche paths, road closures, and incidents were not recorded or were outdated, impeding performance monitoring and analysis.

Avalanches can be unpredictable, and risks to highway users are ongoing. The ministry can mitigate, but not eliminate, risks to highway users as it continues to strive to keep highways open and safe.

FINDINGS AND RECOMMENDATIONS

Assessing avalanche risk

The Ministry of Transportation and Infrastructure, through eight avalanche safety program field offices, works to understand the likelihood of avalanche risk near provincial highways. It maps and monitors avalanche paths and collects data on weather and snow conditions. The ministry records avalanche paths in its Snow Avalanche Weather System.

Avalanche path features can change over time as a result of various factors, including vegetation changes due to fires and logging, terrain changes due to rock and mudslides, and changes to nearby highways due to widening and alignment work. Avalanche path information therefore needs to be updated periodically.

Ministry staff gather data on weather and snow conditions from various sources and decide whether they have enough information to make a reliable forecast.

Through these actions, the ministry aims to mitigate risks to an acceptable level.

Ministry has mapped avalanche paths, but some path information is outdated

What we looked for

We examined if the ministry had assessed the risks that avalanches pose to the provincial highway system, specifically whether the ministry had:

- identified locations where avalanches may occur, and their potential severity and likelihood
- reviewed this information to ensure that it was current

[Learn more about the audit criteria.](#)

What we found

The avalanche safety program has identified locations where avalanches may occur and their potential severity and likelihood; however, some avalanche path information is outdated. The program has inventoried and mapped about 1,600 avalanche paths across 62 highway avalanche areas. Regional field office staff work with these paths to forecast avalanche risk and carry out control operations.

The ministry documents avalanche paths in its Snow Avalanche Weather System. It also records path characteristics, such as the expected frequency of avalanches, the length of highway that would be affected, and the vertical fall length. However, the ministry has not consistently documented path characteristics. The ministry did not have descriptive information for 14% of the 1,377 avalanche paths that it classified as “active.” Further, for two-thirds of all paths, there was no indication of when the ministry had last updated the path information.

Ministry staff advised that they monitor changes to paths on an ongoing basis but acknowledged that path information in the system requires updating. They also said that some recorded paths may no longer be relevant because of highway realignment.

Why this matters

Complete and current avalanche path information helps avalanche safety program staff understand where avalanches pose risks to highway users.

Recommendation

We recommend that the ministry:

- 1 update its records for avalanche paths that pose a risk to highway users, and implement a schedule to periodically update this information**

[See the response from the auditee.](#)

Ministry collects appropriate weather and snowpack data

What we looked for

We examined if the ministry had collected the weather and snowpack data necessary to manage avalanche risk on provincial highways.

[Learn more about the audit criteria.](#)

What we found

The ministry collects appropriate weather and snowpack data to manage avalanche risk on highways. It obtains weather data primarily from its own weather network, which includes:

- **68 remote avalanche weather stations**—in areas where highways intersect with avalanche terrain, at roadside, mid-mountain elevation, or mountain top, depending on the local requirements for avalanche forecasting
- **99 road weather stations**—used primarily to support highway maintenance activity, but information collected is also used for avalanche forecasting

We reviewed the coverage provided by the ministry’s network of weather stations in relation to provincial highways with avalanche risk. We found that highway areas with avalanche risk are close to remote avalanche weather stations or road weather stations. When that’s not the case, the ministry uses weather data from other agencies, such as local airports. In addition, the ministry obtains and shares weather data with other stakeholders via the Canadian Avalanche Association’s Information Exchange (see text box). We also spoke with regional staff, who confirmed that the weather data they collect meets program needs.

CANADIAN AVALANCHE ASSOCIATION’S INFORMATION EXCHANGE

Information Exchange (InfoEx) is operated by the Canadian Avalanche Association to facilitate the daily exchange of snow, weather, avalanche and terrain information between subscribers. Subscribers to InfoEx include Canadian Avalanche Association professional members from various industries and operations, such as ski hills, backcountry lodges, heli-skiing companies, national parks and the ministry. The information collected and shared by subscribers helps provide information to assist others in forecasting avalanche risk.

The ministry also collects information on snowpack structure and stability through snow profile observations. Snow profiles are taken by staff at predetermined sites or at safe locations near avalanche starting zones. Depending on other available information, staff decide whether they require a comprehensive, multi-observation record (a full snow profile) or just a few key observations (a test snow profile).

We reviewed a sample of 26 snow profiles from across the province and compared them with Canadian Avalanche Association guidelines for snowpack observation. We found that the data collected by ministry staff for snowpack profiles was consistent with the snowpack guidelines: data was gathered across a range of characteristics, such as snow temperature, grain size, and strength and stability.

Why this matters

Program staff need the right weather and snowpack data to accurately forecast avalanche hazards and decide when to conduct avalanche control operations.

Informing highway users and stakeholders of risks

The ministry plays an important role in distributing avalanche-related information to various stakeholders and highway users.

The ministry must keep highway workers, who are primarily maintenance contractors, informed of current avalanche hazard levels so they can follow correct safety procedures. Highway maintenance contractors are responsible for year-round highway upkeep; they are also responsible for removing snow and avalanche deposits from highways.

In addition, the ministry provides avalanche hazard forecasts, under interagency agreements, to the District of Stewart and BC Emergency Health Services (BCEHS).

The highway into Stewart and part of the townsite itself are at risk from avalanches. Under the agreement, the ministry is required to provide a number of services to assist the town in dealing with avalanche risk, including providing avalanche forecasts.

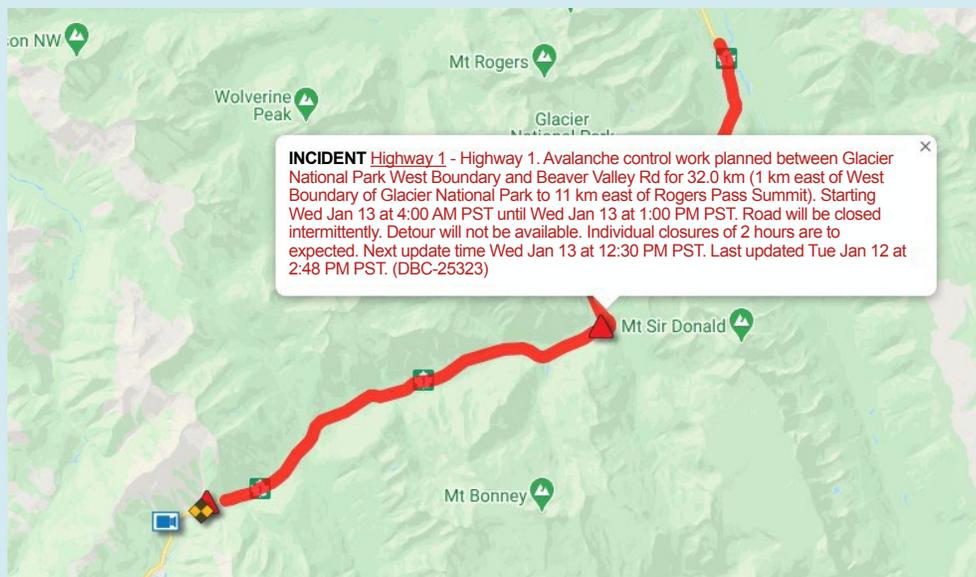
Under a separate agreement, the ministry is required to assist BCEHS in minimizing avalanche risk to its employees by providing current avalanche information.

Finally, the ministry provides the travelling public with avalanche-related information through DriveBC. DriveBC provides the public with road and weather condition information, so highway users can decide when to travel and which route to take (see [text box](#)). This includes notifying the public of any highway closures due to high or extreme avalanche hazard, avalanche control work, or snow or deposit removal. However, the ministry primarily uses highway closures, not public notifications, to reduce the risk of avalanches to highway users.

DRIVEBC PUBLIC NOTIFICATIONS

DriveBC is the public internet and telephone portal for information on highway conditions across B.C. The ministry uses standardized statements relating to avalanche closures made available to the public through DriveBC. Updates to DriveBC are initiated by ministry staff or maintenance contractors on the scene, including details such as location, what's happening, when the next update will be, available detours and estimated opening time.

EXHIBIT 2: DriveBC message on an avalanche-related road closure on Highway 1 on January 13, 2021



Source: DriveBC, adapted by the Office of the Auditor General of British Columbia

Ministry provides timely and relevant information

What we looked for

We examined whether the ministry provides timely avalanche information to key stakeholders: maintenance contractors, the District of Stewart and BCEHS. We also examined whether the ministry, through DriveBC, provides the public with relevant information on avalanche-related highway closures. However, our primary focus was on whether highways were closed when there was a high or extreme forecast avalanche (we assess this under [Ensuring highway user safety](#)).

[Learn more about the audit criteria.](#)

What we found

The ministry provides timely avalanche forecast information to key stakeholders. It also provides, through DriveBC, relevant avalanche-related highway closure information to the travelling public.

To determine whether the ministry had fulfilled its obligations to the District of Stewart and BCEHS, we interviewed individuals from both the District of Stewart and BCEHS. We found that the ministry had provided the District of Stewart and BCEHS timely avalanche forecast information, consistent with their agreements.

We also interviewed representatives from four maintenance contractors across B.C., who told us that they were satisfied with the ministry's communication, and that the avalanche information and weather data received from the ministry met their needs.

Annually, there are approximately 130 highway closures. We examined 30 closure events over a three-year period and found that DriveBC had published public messages that matched the avalanche-related events.

Why this matters

Relevant and timely avalanche-related information helps highway users and stakeholders plan their travel and activities, and make informed safety decisions.

Staffing the program and training staff

In the 2020/21 season, the avalanche safety program had 18 permanent and 14 seasonal staff across eight regional field offices and a head office.

The ministry requires staff who perform avalanche control operations to be members in good standing of the Canadian Avalanche Association, the governing body for all avalanche-related training in the country. Individuals are required to complete ongoing professional development to remain in good standing with the association. The ministry also requires staff directly involved in avalanche control to hold industry-standard certifications, such as occupational first aid, transport of dangerous goods, and blasting for avalanche control.

It is the responsibility of ministry districts to ensure that field office staff have met certification requirements, although the avalanche safety program head office provides additional quality assurance by monitoring staff certification levels.

Avalanche safety program almost fully staffed

What we looked for

We examined whether the avalanche safety program was fully staffed.

[Learn more about the audit criteria.](#)

What we found

We found that the avalanche safety program was fully staffed, except for one position. All 16 permanent positions across the eight regional field offices were staffed.

Two permanent positions in the avalanche safety program's head office were staffed, but one position, the senior avalanche officer, had been vacant for about six years. This position ensures that field offices follow provincial safety standards through on-site visits, inspections and program reviews.

Why this matters

The program needs to be fully staffed to operate effectively. The senior avalanche officer vacancy may mean that head office staff cannot complete program reviews and quality assurance processes as often as intended.

Recommendation

We recommend that the ministry:

- 2** **decide whether the avalanche safety program has the head office staff it needs to effectively oversee avalanche control activities**

[See the response from the auditee.](#)

Staff appropriately trained

What we looked for

We examined whether regional field office staff were appropriately trained to manage the avalanche safety program.

[Learn more about the audit criteria.](#)

What we found

We reviewed the Canadian Avalanche Association membership and training as well as industry-standard training certifications of one staff member from each of the eight field offices. We found that in all eight cases, avalanche safety program staff met ministry training requirements.

Why this matters

Having the appropriate training ensures that ministry staff have the skills and experience to effectively forecast avalanche risk, close highways and perform avalanche control activities.

Having the necessary tools and infrastructure

The avalanche safety program's tools and infrastructure allow staff to perform avalanche control operations. Ministry districts are responsible for providing the avalanche safety program's field offices with the necessary tools for daily operations, while the program's head office coordinates with ministry districts in assessing resources and installing large avalanche control infrastructure.

In addition to large infrastructure investments (described below), the ministry spent \$4.97 million on operating costs for avalanche safety in 2019/20. The ministry also spent \$0.61 million rehabilitating and preserving infrastructure in 2019/20.

Program staff have the right tools for daily operations

What we looked for

We examined whether program staff have the necessary tools for daily operations (field equipment, explosives, signs, gates).

[Learn more about the audit criteria.](#)

What we found

We interviewed regional staff and reviewed regional field office annual reports, in which staff assess their day-to-day resource needs and highlight equipment bought or replaced during a season. We determined that regional field offices have the day-to-day tools needed to manage the program.

Why this matters

Having the proper tools is necessary for staff to effectively perform avalanche control operations.

Infrastructure investments made but capital planning process lacking

What we looked for

We examined whether the ministry had invested in avalanche control infrastructure to improve avalanche control operations.

[Learn more about the audit criteria.](#)

What we found

The program has invested in infrastructure to improve avalanche control operations, but it lacks a process to assess and rank large-scale investments. Regional field offices assessed and identified their need for large infrastructure investments, such as remote avalanche control, in their annual reports, in incident reports, and in discussions between regional staff, ministry district managers, and head office staff. In addition, head office staff also monitored and forecasted future capital maintenance needs over a 10-year period. Since 2016, the ministry has invested in new infrastructure in three locations:

- remote avalanche control systems at **Three Valley Gap near Revelstoke** and **[35 Mile near Terrace](#)**
- automated avalanche detection system at **Bear Pass near Stewart**

The ministry has also invested in remote avalanche control replacements in recent years at Kootenay Pass and near Pemberton, as well as making smaller-scale investments, such as expanded ditches and catchment areas for avalanche runout zones.

NEW REMOTE AVALANCHE CONTROL SYSTEM—NORTHWEST REGION



In 2019, the ministry installed a series of remote avalanche control systems at a site previously identified as a challenge for avalanche control, called 35 Mile, 55 kilometres west of Terrace. These new remote avalanche control systems, called O'Bellx, are triggered by program staff, who operate the system remotely from a nearby safe location. The ministry said that these systems can be fired independently or in unison, 24/7. The project cost \$1.6 million, and the ministry anticipates that it will reduce highway closure time.

But while the program gathers and incorporates information on infrastructure needs from regional staff, it lacks a province-wide needs assessment process for ranking large-scale investments based on safety and the economic impacts of highway closures.

One tool that could be used to help prioritize infrastructure needs is the avalanche hazard index, which determines the relative seriousness of avalanche risk across regions and could provide a ranking. The ministry used this index previously, when it established the avalanche safety program; however, the index has become out of date because of changes in infrastructure, highway design, terrain, and traffic patterns.

Why this matters

Determining and prioritizing where to install avalanche control infrastructure allows the ministry to identify challenging areas and take action to mitigate the most significant risks to highway safety and reliability.

Recommendations

We recommend that the ministry:

- 3 identify avalanche control infrastructure investment needs in a long-term provincial plan based on avalanche safety program objectives**

[See the response from the auditee.](#)

- 4 update the province-wide avalanche hazard index, or a similar tool, to ensure that future capital projects mitigate the most significant risks to highway safety and reliability**

[See the response from the auditee.](#)

Ensuring highway user safety

Ensuring highway user safety is a primary objective of the avalanche safety program, and the impetus for its creation. In this report, and consistent with ministry definitions, the term *highway user* refers to the public travelling on highways as well as the workers who maintain and operate the highway system, including program staff.

The ministry's *Avalanche Safety Plan* states that avalanches can be unpredictable and unexpected, that forecasting avalanche risk will always have some uncertainty, and that occasionally avalanches exceed the ministry's acceptable risk threshold. The ministry's *Threshold Guidelines for Avalanche Safety Measures* states that the ministry will close a highway if there is a high or extreme avalanche hazard forecast.

Avalanche-related incidents may range from an avalanche that affects an open highway but causes no vehicle damage to an avalanche that harms highway users and damages property. The ministry's *Avalanche Safety Plan* says that reviews of these events will offer insight into their causes and possible improvements to practices.

No deaths in last 20 years

What we looked for

We examined whether there had been any avalanche-related deaths on provincial highways in the last 20 years.

[Learn more about the audit criteria.](#)

What we found

We reviewed data from the ministry and reports by the Coroners Service, and interviewed ministry staff. We found that there were no reported avalanche-related deaths on B.C. highways in the past 20 years.

However, avalanche-related deaths near highways had occurred before that period. In January 1999, two avalanche safety program staff died while undertaking field work (see [text box](#)). The most recent death involving the public occurred in 1976, the first year of the ministry's avalanche safety program operations.

While there have been no avalanche-related fatalities on B.C. highways in the past 20 years, there have been occasional incidents—for example, where a vehicle has been struck by a small avalanche, incurring some physical damage to the vehicle but no injuries to the occupants, and where a vehicle attempted to cross an avalanche snow deposit and got stuck. We discuss the ministry's process for reviewing avalanche-related incidents in the following section.

TWO PROGRAM STAFF WERE KILLED IN 1999

Avalanches near highways pose risks to both highway users and ministry staff who go into avalanche terrain to collect snowpack data and perform avalanche control. On January 7, 1999, two program staff were killed by an avalanche as they descended a slope after conducting helicopter bombing in the Ningunsaw Pass area near Highway 37, about 350 kilometres north of Terrace.

Why this matters

A key goal of the program is highway user safety. Although the ministry cannot eliminate all risks, it can and has mitigated them as it strives to keep highways open and safe.

Fewer incidents but follow-up process is lacking

What we looked for

We examined if the ministry had:

- closed highways each time the avalanche hazard was high or extreme, to prevent incidents
- reviewed avalanche incidents and took action to prevent them in the future

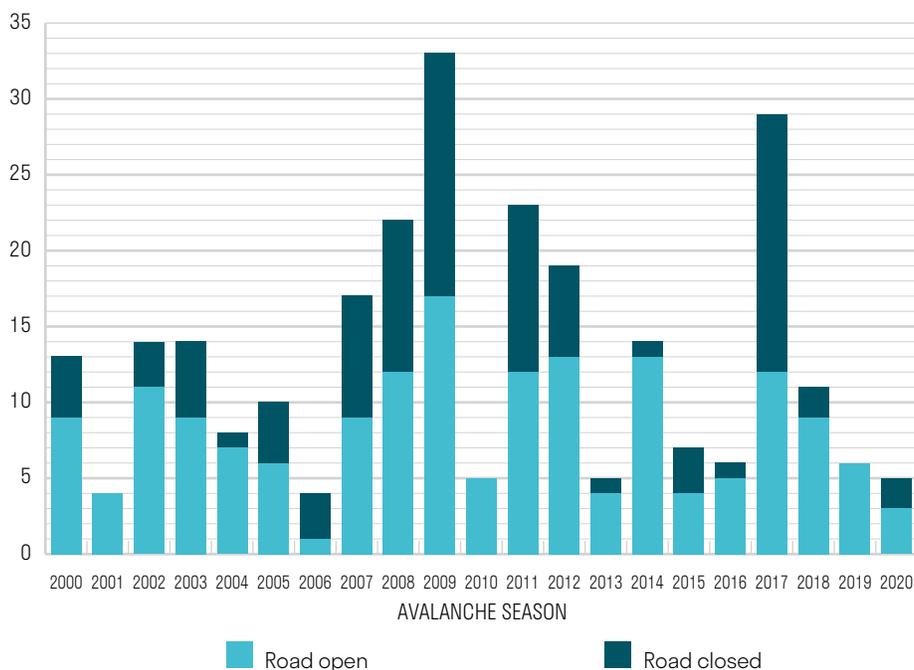
[Learn more about the audit criteria.](#)

What we found

We reviewed ministry data on avalanche hazard forecasts and highway closure data from 2006 to 2020. We found that the ministry did close highways each time there was a high or extreme forecast. Limitations in the ministry’s forecast data prevented us from assessing high or extreme forecasts in the years prior to 2006.

While highways were closed each time the avalanche hazard forecast was high or extreme between 2006 and 2020, some large avalanches have hit open highways over the last 20 years (see Exhibit 3). Depending on how much the avalanche affects the highway, the path terrain features (steep or gradual slope) and traffic volumes, these large avalanches could harm highway users. The graph also shows that the ministry has pre-emptively closed highways to allow large avalanches to occur naturally and protect highway users. The ministry aims to balance safety with keeping highways open.

EXHIBIT 3: Number of natural avalanches Size 3 or greater hitting highways, 2000 to 2020



Source: Office of the Auditor General of British Columbia, based on Ministry of Transportation and Infrastructure data

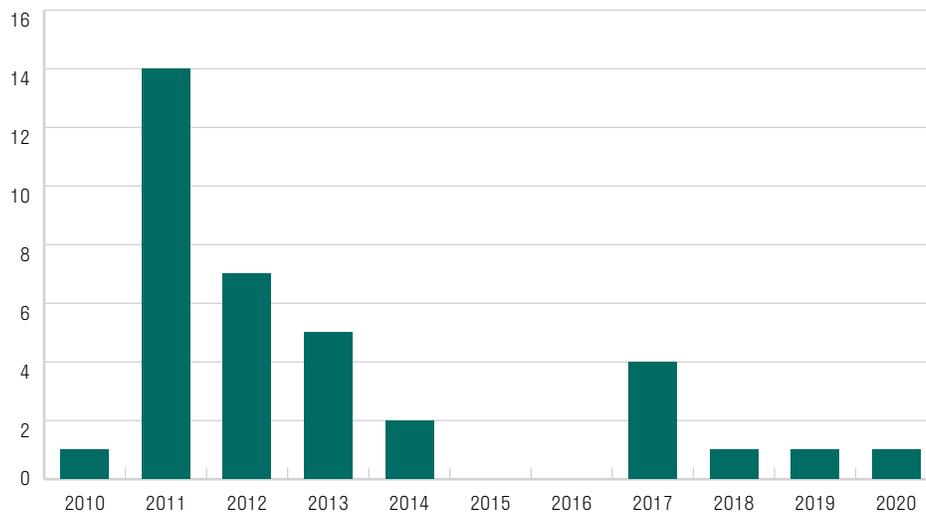
Notes: Large avalanches are defined as those Size 3 or greater. Size 3 avalanches could bury and destroy a car, damage a truck, destroy a small building, or break a few trees. The data used for this exhibit was not subject to the same limitations as [our analysis on high/extreme forecasts](#), which enabled the team to review trends from 2000 to 2020.

Years are reflective of avalanche seasons (e.g., 2020 = fall 2019 to spring 2020).

We found that the program reviewed avalanche incidents. Incident reports prepared by field office staff provided a thorough description of the event, including snowpack and weather conditions; staff actions before, during and after the event; and photographs. The incident reports also identified lessons learned and recommendations, which staff advised are considered and discussed among their teams. However, while there are examples where the ministry responded to incident report recommendations, it does not have a process for tracking and following up on actions to determine whether they were eventually implemented in policy or practice.

We reviewed data on avalanche incidents and found that the number of incidents declined considerably over time. Recorded incidents peaked in 1982, at 42, and have declined since then. The average annual number of incidents between 2010 and 2020 was 3.3 (see Exhibit 4). Some incidents during this period were not recorded in the ministry’s Snow Avalanche Weather System, but the program identified them and provided us with the data.

EXHIBIT 4: *Number of avalanche-related incidents, 2010 to 2020*



Source: Office of the Auditor General of British Columbia, based on Ministry of Transportation and Infrastructure data

Why this matters

By reviewing incidents, the ministry can identify risks and mitigate them in the future. A process for monitoring whether actions have been taken is essential in determining their effectiveness. And complete, accurate records of incidents are needed to study trends and performance throughout the province.

Recommendations

We recommend that the ministry:

5 record all incident data

[See the response from the auditee.](#)

6 track and follow up on incident report recommendations to ensure that actions have been considered or taken

[See the response from the auditee.](#)

Minimizing frequency and duration of road closures

Reliable provincial highways are vital to the provincial economy because the movement of people and goods depends on open, accessible highways. To that end, the avalanche safety program is mandated to minimize the frequency and duration of avalanche-related road closures.

The ministry closes provincial highways to allow avalanches to occur naturally or to allow staff to perform avalanche control. Most avalanche control work is conducted through heli-bombing, but the program is increasingly using remote avalanche control systems. Over time, older technologies, such as compressed gas guns called “avalaunchers” and recoilless rifles, have been replaced by these remote systems. The systems, which can be fired remotely and used regardless of weather conditions or time of day, are intended to minimize the impact of avalanche control on highways, with more frequent but shorter closures, as smaller avalanches require less deposit removal time.

Staff need to coordinate with highway maintenance contractors before and after road closures, as contractors must clear the snow and debris before the ministry can reopen the highway.

Fewer highway closures and lower total closure time

What we looked for

We examined whether the ministry had minimized the frequency and duration of highway closures from avalanches.

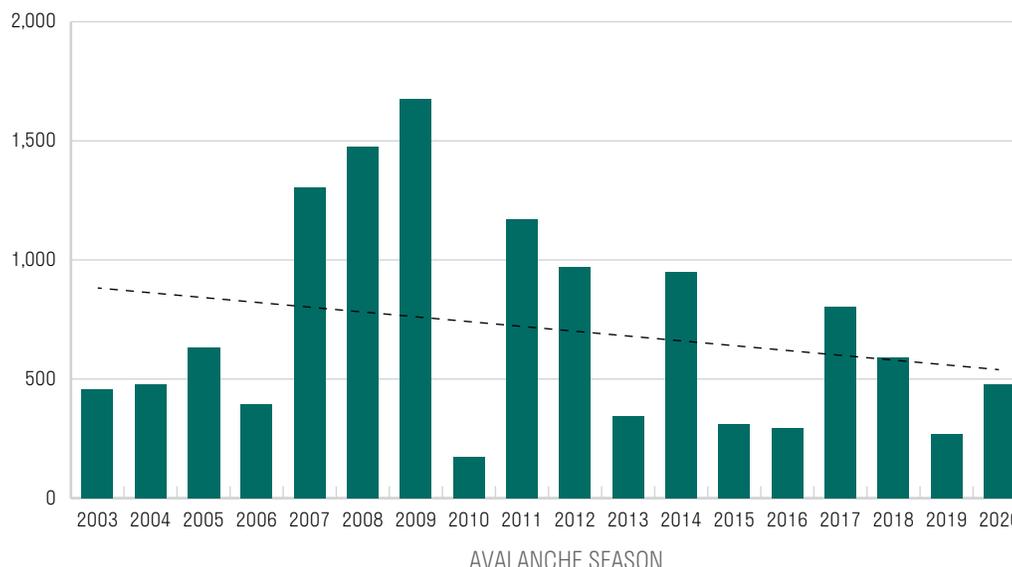
[Learn more about the audit criteria.](#)

What we found

We reviewed ministry road closure data from 2003 to 2020 and found that there was a decreasing trend in the total duration of avalanche-related road closures (see Exhibit 5). There was a slightly decreasing trend in the frequency of avalanche-related road closures during this time (see [Exhibit 6](#)).

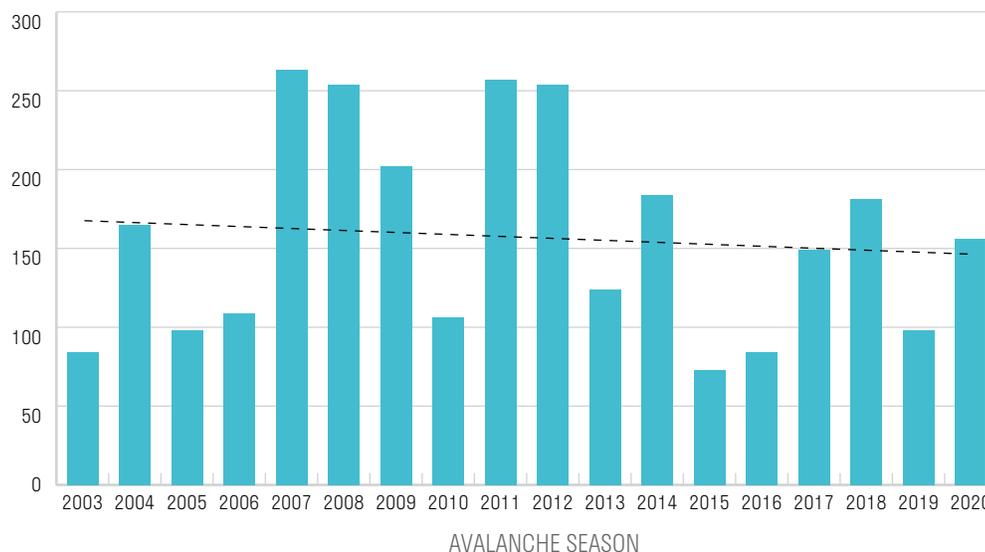
However, there is considerable fluctuation in the duration and number of road closures from year to year due to annual changes in snowpack and weather conditions. As shown in Exhibit 5, the total duration of avalanche-related closures ranged from 175 hours (2010) to 1,678 hours (2009). [Exhibit 6](#) shows that the number of avalanche-related closures ranged from 73 (2015) to 263 (2007).

EXHIBIT 5: Duration of avalanche-related road closures in hours (2003 to 2020)



Source: Office of the Auditor General of British Columbia, based on Ministry of Transportation and Infrastructure data (2003–2020)

Note: Years are reflective of avalanche seasons (e.g., 2020 = fall 2019 to spring 2020). The period 2003–2020 was selected for examining trends, as road closure data was not widely available prior to 2003.

EXHIBIT 6: Number of avalanche-related road closures (2003 to 2020)

Source: Office of the Auditor General of British Columbia, based on Ministry of Transportation and Infrastructure data (2003–2020)

Note: Years are reflective of avalanche seasons (e.g., 2020 = fall 2019 to spring 2020). The period 2003–2020 was selected for examining trends, as road closure data was not widely available prior to 2003.

In our review of avalanche-related road closures, we found that the ministry’s data was incomplete. We estimate that about 10% of road closures were not recorded, which the ministry advised was due to data entry problems.

The ministry recognizes that the existing avalanche and weather information systems are outdated and present challenges related to capability and support. It is developing and implementing a new system under the Weather Services Transformation Project to replace the existing Snow Avalanche Weather System and streamline and improve avalanche and weather data collection and dissemination. The project is scheduled for completion in fall 2022.

Finally, while regional field offices review closure durations and seasonal conditions annually, the ministry has not defined performance measures and targets to monitor its performance against program objectives.

Why this matters

Reduced frequency and duration of avalanche-related highway closures increases highway reliability. Performance measures and targets, using complete and accurate data, will let the ministry better assess long-term trends and decide whether it is meeting intended outcomes and where it can make improvements.

Recommendations

We recommend that the ministry:

- 7 complete the Weather Services Transformation Project, or implement a similar project, to streamline and improve avalanche data collection**

[See the response from the auditee.](#)

- 8 define performance measures, set targets and monitor its performance against avalanche safety program objectives and intended outcomes**

[See the response from the auditee.](#)

Staff have identified ways to improve highway reliability

What we looked for

We examined whether the ministry had taken action to minimize the frequency and duration of highway closures.

[Learn more about the audit criteria.](#)

What we found

The ministry has taken action to improve highway reliability.

The ministry has installed avalanche control infrastructure throughout the province, and has added to that network in recent years. It has also undertaken smaller-scale initiatives, such as expanding ditches and catchment areas for avalanche runout zones, to minimize the impacts of avalanches on highways.

Further, under its road and bridge contract renewal project, the ministry changed maintenance contract specifications to ensure that maintenance contractors promptly remove snow when assisting in avalanche control operations and cleanup. The first round of revised maintenance contracts came into effect in 2018, with other maintenance contracts being revised in the years following.

Why this matters

Reduced frequency and duration of avalanche-related highway closures increases road safety and reliability.

ABOUT THE AUDIT

We conducted this audit under the authority of section 11(8) of the *Auditor General Act* and in accordance with the Canadian Standard on Assurance Engagements (CSAE) 3001—Direct Engagements, set out by the Chartered Professional Accountants of Canada (CPA Canada) in the *CPA Canada Handbook—Assurance*. These standards require that we comply with ethical requirements and conduct the audit to independently express a conclusion against the objective of the audit.

A direct audit involves understanding the subject matter to identify areas of significance and risk, and to identify relevant controls. This understanding is used as the basis for designing and performing audit procedures to obtain evidence on which to base the audit conclusion.

The audit procedures we conducted include:

- reviewing good practices and industry standards for avalanche hazard forecasting and control operations
- reviewing ministry reports, regional field office annual reports, incident reports, snow profiles, weather station data, project proposals and reports
- analyzing ministry Snow Avalanche Weather System data
- interviewing staff from the Ministry of Transportation and Infrastructure and various stakeholders
- visiting field offices to observe avalanche data collection and control operations
- consulting a subject matter expert who reviewed our findings and draft report

We believe the audit evidence we have obtained is sufficient and appropriate to provide a basis for our conclusion.

Our office applies the Canadian Standard on Quality Control (CSQC 1) and we have complied with the independence and other requirements of the code of ethics issued by the Chartered Professional Accountants of British Columbia that are relevant to this audit.

Audit report date: April 19, 2021



Michael A. Pickup, FCPA, FCA
Auditor General of British Columbia
Victoria, B.C.

APPENDIX A: RECOMMENDATIONS AND AUDITEE RESPONSE

RECOMMENDATION 1: We recommend that the ministry update its records for avalanche paths that pose a risk to highway users, and implement a schedule to periodically update this information.

RECOMMENDATION 1 RESPONSE: **The ministry agrees with this recommendation.**

The ministry will review avalanche path inventory to identify gaps in the data. The ministry will reassess all the avalanche paths to ensure up to date avalanche path information is reflected in the avalanche atlases.

There are approximately 1600 avalanche paths that pose a risk to the provincial highway system, and there are 126 individual avalanche atlases and associated strip maps that will require updating. The avalanche path information will be updated into the new Weather Services Transformation Project (fall/winter 2022).

The ministry will consider modern technologies and methodologies in updating avalanche path information, avalanche atlases and strip maps of our avalanche areas.

Project initiation, summer 2021, to be completed by fall 2023.

RECOMMENDATION 2: We recommend that the ministry decide whether the avalanche safety program has the head office staff it needs to effectively oversee avalanche control activities.

RECOMMENDATION 2 RESPONSE: **The ministry agrees with this recommendation.**

The ministry is considering filling vacant positions and is undertaking a further review to ensure staffing levels are adequate to meet program goals and objectives.

Project initiation, summer 2021, to be completed by fall 2021.

RECOMMENDATION 3: We recommend that the ministry identify avalanche control infrastructure investment needs in a long-term provincial plan based on avalanche safety program objectives.

RECOMMENDATION 3 RESPONSE: The ministry agrees with this recommendation.

The ministry will produce a long-term provincial strategic plan for avalanche risk management investments in accordance with program objectives. Avalanche HQ will work with District, Regional and Headquarters staff in the development of a strategic avalanche risk management investment plan. The Avalanche Hazard Index project will inform this plan. Strategic plan will be updated annually after completion in 2023.

Project initiation summer 2021, to be completed by summer 2023.

RECOMMENDATION 4: We recommend that the ministry update the province-wide avalanche hazard index, or a similar tool, to ensure that future capital projects mitigate the most significant risks to highway safety and reliability.

RECOMMENDATION 4 RESPONSE: The ministry agrees with this recommendation.

The ministry will conduct a review of the Avalanche Hazard Index (AHI).

The ministry will look for updated AHI methodology to assess not only avalanche risk but economic risks.

Project initiation, summer 2021, to be completed by fall 2022.

RECOMMENDATION 5: We recommend that the ministry record all incident data.

RECOMMENDATION 5 RESPONSE: **The ministry agrees with this recommendation.**

The Avalanche and Weather Programs have implemented processes to ensure incident data is adequately recorded.

Training will be provided to all avalanche staff to ensure incident data is adequately recorded.

An update to our operational requirements will be made to clearly define the process and expectations for incident data recording.

Project is underway, to be completed by fall 2021.

RECOMMENDATION 6: We recommend that the ministry track and follow up on incident report recommendations to ensure that actions have been considered or taken.

RECOMMENDATION 6 RESPONSE: **The ministry agrees with this recommendation.**

The Avalanche and Weather Programs have implemented processes to ensure documented follow up to ensure actions or recommendations have been considered or taken.

An update will be made to our operational documents that clearly define the process, and documentation requirements to clearly demonstrate diligent follow up on potential recommendations that may result from an incident.

Project is underway, to be completed by fall 2021.

RECOMMENDATION 7: We recommend that the ministry complete the Weather Services Transformation Project, or implement a similar project, to streamline and improve avalanche data collection.

RECOMMENDATION 7 RESPONSE: **The ministry agrees with this recommendation.**

This project is underway. The Transportation and Infrastructure Information Management Branch (IMB) is leading this project. The Avalanche and Weather Programs is the project sponsor.

Project is underway, scheduled for completion in the fall of 2022.

RECOMMENDATION 8: We recommend that the ministry define performance measures, set targets and monitor its performance against avalanche safety program objectives and intended outcomes.

RECOMMENDATION 8 RESPONSE: **The ministry agrees with this recommendation.**

The ministry will collect and analyze data, as well as examine best practices for performance measures and targets from other similar avalanche programs. This will aid us in developing performance measures and targets to evaluate and monitor the effectiveness of the ministry's avalanche safety program.

Project initiation summer 2021, to be completed fall 2023.

APPENDIX B: CRITERIA

| Line of enquiry 1: Avalanche risk assessment and notification | |
|---|---|
| Criteria 1.1 | The ministry has assessed the risks posed to the provincial highways system by avalanches. |
| Criteria 1.2 | The ministry collects the data necessary for determining avalanche risk on provincial highways. |
| Criteria 1.3 | The ministry provides timely avalanche forecasts for provincial highways to highway users. |
| Line of enquiry 2: Resources, tools and training | |
| Criteria 2.1 | Ministry staff are appropriately trained to manage the avalanche safety program. |
| Criteria 2.2 | Ministry staff have the necessary tools and resources to manage the avalanche safety program. |
| Line of enquiry 3: Highway user safety | |
| Criteria 3.1 | The ministry has ensured the safety of all highway users from avalanches. |
| Line of enquiry 4: Frequency and duration of road closures | |
| Criteria 4.1 | The ministry has minimized the frequency and duration of highway closures from avalanches. |



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