

Attachment #1

Snow Survey & Water Supply Bulletin March 1, 2022

Snow Survey and Water Supply Bulletin – March 1st, 2022

The March 1st snow survey is now complete. Data from 123 manual snow courses and 87 automated snow weather stations around the province (collected by the Ministry of Environment and Climate Change Strategy's Snow Survey Program, BC Hydro and partners), and climate data from Environment and Climate Change Canada and the provincial Climate Related Monitoring Program have been used to form the basis of the following report¹.

Executive Summary

The March 1st, 2022 snow pack throughout British Columbia is slightly above normal. The average of all measurements across B.C. decreased to 105% in the past month due to drier conditions (February 1st: 109%). The snow basin index for the Fraser River at Hope is above normal at 119%. By early March, nearly 80% of the annual B.C. snow pack has typically accumulated. Snow pack throughout the province ranges from 83 to 129% of normal. There is a higher risk for snowmelt related flooding during the spring months (freshet). The combination of normal to above normal March 1st snow pack, La Niña conditions forecast to persist through spring, and seasonal weather forecasts that predict cooler conditions for the province means an elevated risk for freshet-related flooding. Snow pack is also only one factor related to freshet flood risk. Weather conditions from April through June determine the timing, magnitude and rate of snow melt, and heavy rainfall events can exacerbate the situation.

Weather

Weather patterns over the past month contrasted significantly between the northern and southern halves of the province. The north experienced generally warmer conditions and greater precipitation than normal, with the warmest and wettest conditions occurring in the most northwesterly sections of B.C. In contrast, southern regions of the province recorded seasonable temperatures and dry conditions. The driest weather relative to normal occurred on Vancouver Island and the South Coast.

The strong storm system at the end of February continued into the first couple days of March, adding additional precipitation. This strong storm system at the very end of the February accounted for most of the monthly precipitation in the south. Relatively dry conditions have persisted since and are expected to continue for the near future. An unsettled weather pattern is forecast to return this weekend (March 11-13) and will likely continue next week.

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Snowpack

Snow basin indices for March 1st, 2022 range from a low of 83% of normal on Vancouver Island to a high of 129% in the Upper Fraser East (Table 1 and Figure 2, 3). Generally, the province has slightly above normal snow pack for March 1st, with the average of all snow measurements across the province at 105%. This has decreased from 109% observed on February 1st. The Okanagan and Vancouver Island are the only basins that are slightly below normal (80-89%) for March 1st. Normal snow packs (90-110%) were measured for the Upper Fraser West Nechako, Lower Fraser, South Thompson, West Kootenay, Boundary, Similkameen, South Coast, Central Coast, Skagit, Peace, and Skeena-Nass. Slightly above normal snow packs (110-120%) exists in the Middle Fraser, East Kootenay and Stikine. Snow basin indices that are above normal (120-130%) include the Upper Fraser East, North Thompson, Upper Columbia, Liard and Northwest.

The average of all snow measurements for the entire Fraser River basin (e.g., upstream of the Lower Mainland and inclusive of Upper Fraser West, Upper Fraser East, Nechako, Middle Fraser, Lower Fraser, North Thompson and South Thompson) is 107%, decreasing slightly from 108% on February 1st. The River Forecast Centre calculates an additional Snow Basin Index for the Fraser River at Hope based on each basin's contribution to the total annual flow of the river. For example, the Upper Fraser East contributes approximately 30% of the total flow for the Fraser River at Hope, the North Thompson about 16%, the South Thompson about 11% and the Quesnel approximately 9%. The Fraser River at Hope Snow Basin Index is 119%, which is 11th highest since 1970, due primarily to the high snow pack in the Upper Fraser East, North Thompson and Quesnel. The current year's March 1st value is the 5th highest in the last 30 years (1999: 140%, 2007: 128%, 2012: 121%, 1997:120%).

As the Middle Fraser encompasses a large and geographically diverse area, we divide it into sub-basins to analyze snow conditions and potential flood risks in localised areas. The Bridge region measures 105% of normal, the Quesnel area 125%, the Lower Thompson 99% and the Chilcotin sub-basin is at 163%. Beginning March 1st, a Nicola Snow Basin Index, comprised of stations in the Lower Thompson that are within the Nicola and Okanagan sites that border the Nicola, is calculated at 89% of normal. Please review the full summary data tables at the end of this report for further interpretation.

Table 1 - BC Snow Basin Indices – March 1, 2022

Basin	% of Normal (Feb 1 st value)	Basin	% of Normal (Feb 1 st value)
Upper Fraser West	103 (117)	Okanagan	86 (89)
Upper Fraser East	129 (119)	Boundary	91 (88)
Nechako	95 (97)	Similkameen	100 (95)

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Middle Fraser	111 (115)	South Coast	94 (102)
Lower Thompson*	99 (86)	Vancouver Island	83 (102)
Bridge*	105 (117)	Central Coast	101 (128)
Chilcotin*	163 (170)	Skagit	98 (126)
Quesnel*	125 (109)	Peace	99 (101)
Lower Fraser	95 (103)	Skeena-Nass	109 (108)
North Thompson	124 (118)	Stikine	110 (96)
South Thompson	102 (102)	Liard	123 (143)
Upper Columbia	123 (130)	Northwest	123 (N/A)
West Kootenay	108 (116)	Fraser	107 (108)
East Kootenay	111 (117)	Fraser River at Hope	119 (N/A)
Nicola**	89 (N/A)	British Columbia	105 (109)

* sub-basin of Middle Fraser

** sub-basin of Lower Thompson – includes representative stations within Okanagan

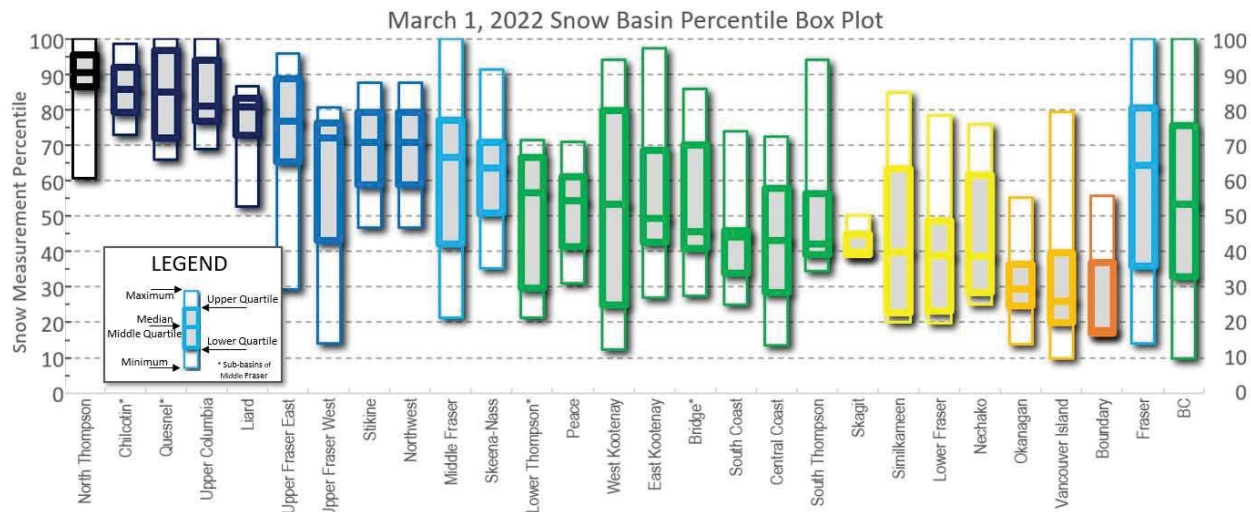
There are three snow stations with period of record highs for March 1st; however, the stations have relatively short periods of record:

- 1C33A Granite Mountain: 246 mm SWE (141% of normal) – period of record 16 years (QUESNEL – MIDDLE FRASER)
- 1E14P Cook Creek: 790 mm SWE (161% of normal) – period of record 12 years (NORTH THOMPSON)
- 2A30P Colpitti Creek: 906 mm SWE – period of record 12 years (UPPER COLUMBIA)

The River Forecast Centre began including percentiles in addition to using percent of normal to analyze snow pack in the 2020 bulletin. Percentiles offer a more accurate interpretation of variance, especially in regions when the percent of normal can be extremely high or low. The region with the highest average percentile is the North Thompson (87th percentile); the region with lowest is the Boundary (30th). A box plot displaying the percentile variance ordered from highest to lowest median, including sub-basins, is provided below in Figure 1.

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Figure 1. Snow Basin Percentile Box Plot – March 1st, 2022



Outlook

The Climate Prediction Center (CPC) shows that El Niño Southern Oscillation (ENSO) demonstrated La Niña conditions during the fall of 2021. This is the second La Niña in a row, with La Niña present during the fall-winter of 2020-21. La Niña occurs when oceanic temperature anomalies along the equatorial Pacific Ocean region are below normal for an extended period. Historically, La Niña conditions create cooler temperatures for British Columbia and wetter weather in the South Coast and Vancouver Island during the winter months.

Forecasts from the CPC indicate a likelihood (77% chance) of continued La Niña conditions (March-May 2022), with a potential transition to neutral conditions (56% likelihood) into summer (May-July 2022). Historically, the April 1st snow pack is often above normal when winter La Niña conditions exist in British Columbia, particularly for the South Coast and Southern Interior. La Niña conditions that persist into the spring can lead to late-season snow accumulation and delayed snowmelt, which increases the risk for freshet flooding.

Seasonal weather forecasts from late February by Environment and Climate Change Canada indicate an increased likelihood of colder than normal temperatures from March through May for the entire province. There is an increased likelihood of greater than normal precipitation in the Upper Fraser East and East Kootenay for March to May, whereas there is no climatological trend forecast for precipitation over the rest of the province. Seasonal precipitation forecast tend to have lower forecast skill in comparison to seasonal temperature forecasts.

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Seasonal volume runoff forecasts (see below) are near-normal (90-110%) for the Quesnel, Thompson, Bulkley and Skeena. Slightly above normal (110-120%) flows are forecast for the Upper Fraser and Cowichan River. Runoff in the Similkameen is forecast to be well above normal (>130%), likely a reflection of extremely high antecedent conditions caused by extreme rainfall last November. In 2021, an updated model was developed for Nicola Lake, Nicola River, Okanagan Lake and Kalamalka-Wood Lake (further details can be found in the February 1st 2021 Snow Bulletin). There is significant variability between the new and old seasonal volume forecasts for Nicola Lake, Nicola River, Okanagan Lake and Kalamalka-Wood Lake. Several predictor variables were outside the historic range for which the newer modeling was developed, resulting in increased uncertainty for the upcoming forecast. In addition, the newer model calculated inconclusive results for the Nicola River at Spences Bridge. Any interpretation of seasonal volume runoff forecasts must include this critical fact. Slightly below normal snow pack on Vancouver Island and the South Coast indicates an average year of spring runoff for other watersheds within the regions.

Spring Flood Risk (Freshet)

Flooding is a provincial risk every spring due to a combination of snowmelt and/or rainfall (also known as freshet). Every region is at risk for flooding, even if the snow pack is slightly below normal. The weather conditions during spring play a critical role in the rate at which the snow melts. For example, a gradual warming under dry conditions is ideal to lessen the flood risk. A lengthy cold period with high amounts of precipitation followed by a sudden extreme heat wave could lead to catastrophic conditions, especially if additional rain follows. Spring weather is impossible to predict with accuracy in advance, and so communities and residents vulnerable to flooding should prepare accordingly; information for [*Be Prepared for Floods*](#) is available from Emergency Management BC.

Typically, regions with above normal snow pack have a higher risk for flooding. As of March 1st, 2022, these areas include:

- The Upper Columbia measures 123% of normal, the highest index since 1996. Communities (e.g., Golden) in the Upper Columbia will be at risk for flooding through the freshet and may remain at risk into late June or even July due to significant high elevation snow pack.
- The North Thompson measures 124% of normal, which is the highest index since 1999, the 2nd highest since 1977.
- The Quesnel region (within the Middle Fraser) is 125% of normal and is the highest since 1999.
- The South Thompson is near normal at 102%. However, there are only four sites reporting across the entire basin that calculate the snow basin index. Since the South Thompson borders the North Thompson and Upper Columbia (which have significantly higher snow basin indices), it is possible that the snow pack is higher than the snow basin index suggests.
- The Upper Fraser East is high at 129% of normal. Although well above normal, this year's index is still slightly below recent years (like 2007, 2012 and 2014).

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- The Chilcotin Region is well above normal at 163% of normal (the highest index since 1996). There are only two measurements within this region; these measurements are made at lower elevation and represent typical shallower snow packs leading to potentially high or low percentages of normal from small snow water equivalent differences. The average percentile across sites is the 86th percentile, indicating significantly above normal but not necessarily record high conditions.
- The Liard River and Northwest are at 123% of normal.

In addition to the above, other regions contain a significant number of anomalously high snow pack observations, either as a % of normal measure or as described by percentiles. These include the Upper Fraser West, Skeena-Nass, Stikine, Northwest, West Kootenay and East Kootenay.

The combination of high snow pack in the Upper Fraser East, Quesnel and North Thompson indicates a heightened concern for flooding for Prince George, Kamloops, and the overall Fraser River. Based solely on the contributions to the Fraser River from the Upper Fraser East, Quesnel and North Thompson, this year ranks as the 8th highest snow pack since 1970 and 3rd highest in the last 30 years.

November 2021 Atmospheric River Floods

The unprecedented and catastrophic flooding that occurred in November 2021 has made many rivers more vulnerable to freshet high flows. Fortunately, the March 1st snow pack in the Nicola, Similkameen and Lower Fraser is not above normal. However, due to the significant erosion and possible changes in river channel morphology that occurred within many areas (including but not limited to the Coldwater River, Nicola River, Tulameen River, Coquihalla River and lower Fraser River), rivers may be at increased vulnerability to flooding at lower levels than previous freshet seasons. The freshet season differentiates from the fall flooding season as flows tend to be sustained for longer periods of time during snowmelt compared to shorter duration rainfall events.

The risk for flooding in the Sumas Prairie will be based on potential for flooding of the Nooksack River and stability of the dikes along the Nooksack River. Flooding of the Sumas Prairie from Canadian contributions could occur from flooding of the Fraser River if extreme water levels exceeded flood protection infrastructure, such as occurred in 1894 and 1948.

2021 Wildfire Season

The 2021 Wildfire season was very active in the province with many watersheds sustaining significant burns. Based on a study conducted by the RFC in Spring 2018 and briefly summarized in the April 1st, 2018 Snow Bulletin, disturbances such as fire affect the hydrologic response of streams, rivers and lakes relevant to potential flooding. Specifically,

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flows from snowmelt dominated watersheds impacted by fires tend to be greater and peak earlier as compared to undisturbed areas, even under normal weather conditions. Areas that experienced burns are at greater risk for higher peak flows.

Extreme Weather Events

In general, flooding usually occurs due to extreme weather. In 2021, there were two extreme weather events that resulted in catastrophe: the heat dome in late-June and atmospheric rivers in November. Alpine temperatures during the heat dome reached up to 38°C, triggered extraordinary snow melt rates (80-100 mm SWE / day) at high elevation automated snow weather stations with snow remaining. If such an extreme heat event occurred earlier in the freshet season when there is more snow to melt (May or early-June), it could lead to significant flooding at a provincial scale.

Atmospheric rivers tend to affect the province primarily between September through January. However, strong storms can occur as early as August for the North Coast and there are numerous examples of atmospheric rivers occurring on the South Coast into February and March. It is less likely that these events will occur in May or June, but not impossible.

Although not as extreme as the previous examples, the most likely cause for major flooding would be a period of persistent cool temperatures and wet weather into the late spring, followed by a sudden heat wave of at least five or more days. There is evidence that 1948 and 1894 floods on the Fraser River were caused by this scenario. Based on current snow stations that had measurements in 1948, the snow conditions for March 1st were considered average, showing the importance of spring weather to flooding. A secondary risky scenario is a widespread heavy rainfall event that occurs during the high flows from snowmelt.

Wrap-around low pressure, or cold low, systems pose an additional risk of primarily rain-driven flooding. The risk of these events occurring increases in June and typically extends into July. These systems can deliver extreme rainfall which wraps around the province and typically leads to upslope precipitation enhancement to eastern slope mountainous regions. These can be augmented or enhanced by snowmelt and high antecedent streamflow conditions. Flood events from this phenomena have occurred in the Peace Region in 2012 and 2016, Fernie (and Calgary/Alberta) in 2013, and in the Chilcotin in 2019.

Gaps in Snow Monitoring

Regions in the province that lack physical snow monitoring (manual or automated) include:

- Cache Creek and Bonaparte River. There were no March 1st measurements at 1C32 Deadman River or 1C42 Caverhill Lake New. The Bonaparte River watershed borders the Quesnel and North Thompson, so there are risks that the snow level is relatively high.

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- The Nazko and West Road River regions no longer has snow monitoring. This region experienced intense flooding in 2018 and sustained high flows in 2020.
- The Chilako River (just north of the West Road River).
- Salmon River near Prince George.

Remote sensing is supporting areal-based assessment of snow coverage in these regions; however, it is difficult to accurately determine seasonal flood risks in these areas due to the lack of on-the-ground measurements. These regions typically are the first rivers in the season to experience significant increases in flow from snowmelt due to their lower elevation.

La Niña Conditions

Under La Niña conditions, the snow pack can accumulate into late spring. Areas in the South Interior (including the Okanagan, Boundary and Kootenay) can receive significant additional precipitation in March and April which could push Snow Basin Indices above normal for April 1st or May 1st.

Typically, freshet (snowmelt) flood risk is limited on Vancouver Island and the South Coast as precipitation from Atmospheric Rivers in the Fall/Winter period overshadows the effect of snowmelt during spring.

Summary

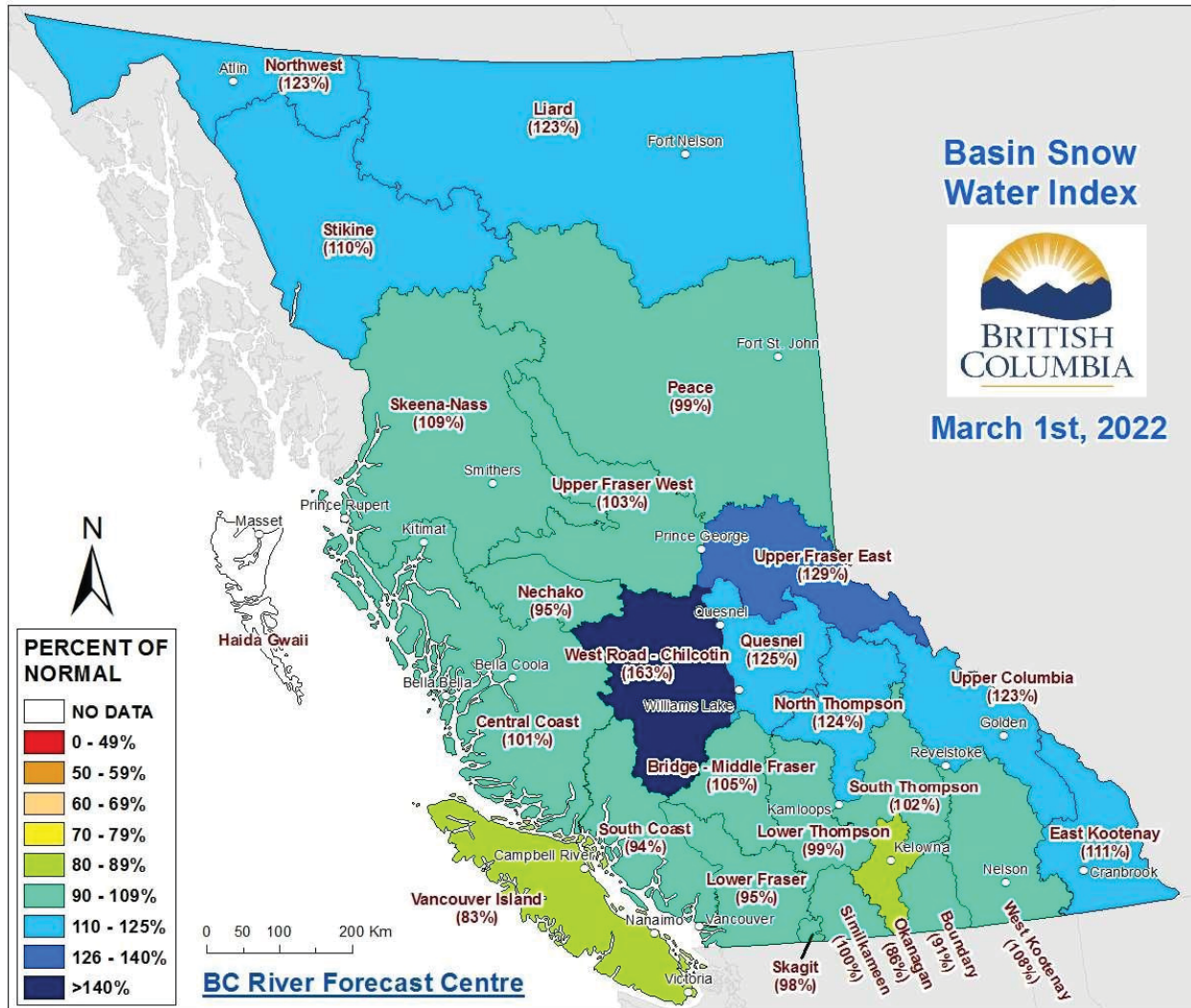
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The River Forecast Centre will continue to monitor snow pack conditions and will provide an updated seasonal flood risk forecast in the April 1st, 2022 bulletin, which is scheduled for release on April 8th.

BC River Forecast Centre
March 9, 2022

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Figure 2: Basin Snow Water Index – March 1st, 2022



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