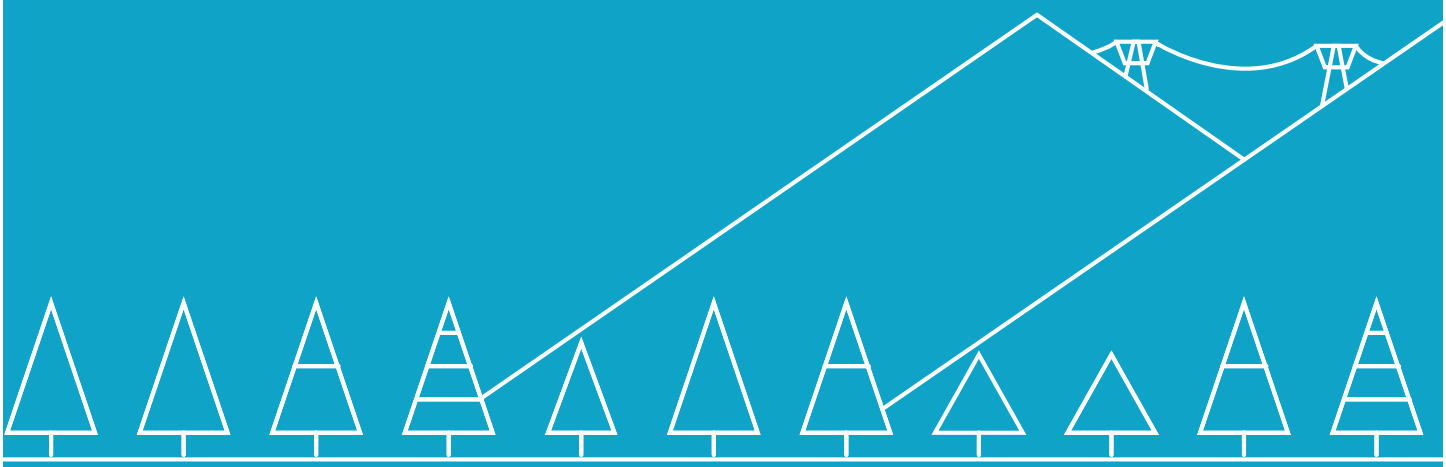
Generational challenge:

How B.C.'s generation system is adapting to extreme weather and unforeseen events



Report

April 2019

BC Hydro
Power smart

BCH19-372

Generational challenge: How B.C.'s generation system is adapting to extreme weather and unforeseen events

Extreme weather left BC Hydro's reservoirs at record low levels over the winter and the Enbridge gas pipeline explosion made the situation more challenging. The events of the past 12 months demonstrate how BC Hydro is adapting through integrated planning to meet the province's electricity demand and keep rates low in the face of changing weather and other challenges.

Highlights

- BC Hydro's hydroelectric system is directly impacted by variations in the weather—and the last 12 months have demonstrated how extreme that weather can be in certain years.
- Following a dry summer, BC Hydro's reservoirs were below normal, and by October, BC Hydro's two biggest reservoirs—Williston on the Peace River and Kinbasket on the Columbia River—reached a record seasonal low.
- Dry conditions in the Williston basin resulted in four consecutive months of low inflows, with September, October and November being the third, second and fourth lowest in 60 years.
- BC Hydro is used to variable water levels and can adapt during low water years; however, the catastrophic Enbridge pipeline explosion in October was not foreseen.
- The pipeline explosion caused a high-level of gas supply uncertainty in B.C. and the Pacific Northwest with only 80% of normal capacity expected throughout the winter. This led to FortisBC warning customers in the Lower Mainland and on Vancouver Island to conserve natural gas.
- Ultimately, the pipeline explosion affected western wholesale electricity markets by creating an increased demand for electricity to replace gas-generating units that would have otherwise been able to run.
- To ensure a consistent supply of affordable electricity for its customers, BC Hydro planners took steps beginning late in the fall to secure a sufficient supply of imports to meet evolving system needs over the winter season – particularly in the event of a cold, dry winter and continued gas supply challenges.
    - The decision to import electricity will not impact rates—securing a cost-effective supply of power has helped keep rates low.
- BC Hydro's planning efforts proved to be important, as B.C. experienced a record-breaking cold February, which resulted in three electricity demand records being broken that month, followed by the driest March on record in parts of the province.
    - This resulted in even more water being used than expected, and less water remaining in BC Hydro's reservoirs as demand for power remained high.
    - Independent power producers were down below projections too due to the weather and unable to meet the increased demand.
- Cold and dry weather delayed the onset of the spring freshet; however, inflows into the reservoirs have started to increase in April with the warmer weather. The onset of the spring freshet will soon start filling the reservoirs.
- Unpredictable weather patterns related to climate change are expected to continue in the years ahead and BC Hydro is constantly adapting to these evolving conditions.
    - While patterns are changing, current 2050 and 2080 models suggest a modest increase to overall inflows across the province as a result of increased precipitation.

Solutions

- Despite the unpredictability of weather and outside events that can impact BC Hydro's electricity system, BC Hydro continues to be prepared.
  - Its system is designed and operated to perform safely across a wide range of conditions and extreme events, and BC Hydro staff are highly trained and experienced to adapt quickly to changing conditions.
  - BC Hydro is also:
    - Continuously working to improve its weather and inflow forecasting. For example, all coastal watersheds can now be forecasted down to the hour, which improves the forecast accuracy for extreme rainfall events.
    - Expanding its hydroclimate monitoring technology. This includes custom-made solutions that have been designed in-house, as well as upgrading snow survey stations to automated, real-time snow and climate stations.
    - Investing in capital projects—like spillway gate replacements – that will increase resiliency of the system to climate change

As a business that relies on water to generate clean electricity, BC Hydro is not immune from extreme weather swings, which are anticipated to continue as the climate changes. From a dry summer with low inflows to record-breaking cold temperatures in February, B.C. has experienced unusual weather conditions over the past 12 months. This has resulted in below average reservoir levels.

While BC Hydro is experienced in managing reservoir levels in low water years, October brought an unexpected twist—the Enbridge pipeline explosion—which impacted wholesale market prices for both natural gas and electricity.

This report will explore the unique weather experienced in 2018 and 2019, the impact the Enbridge pipeline explosion had on BC Hydro, and how these factors have impacted BC Hydro's generation system and what it is doing to adapt to the increasingly unpredictable weather.

A dry summer's effect

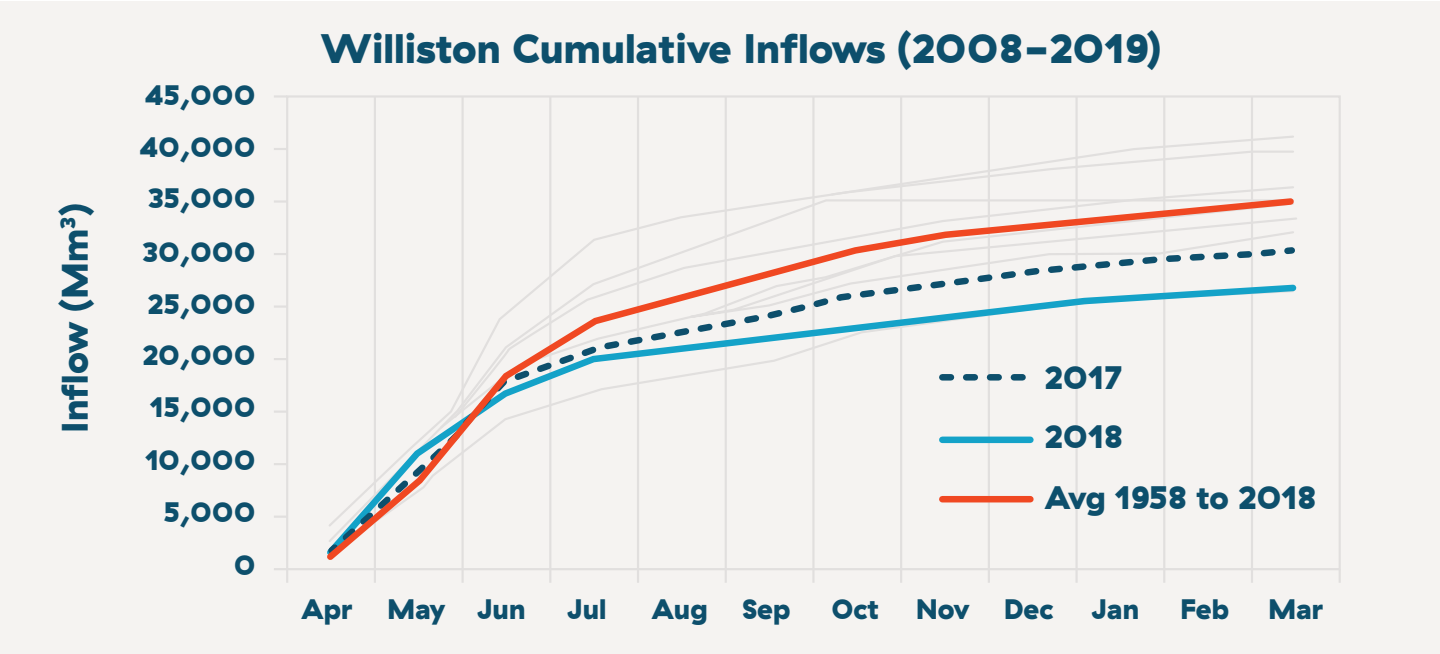
In years with average water inflows, BC Hydro's generating system has the capacity to produce a surplus of electricity to meet the province's electricity needs. Over the past five years, it has seen a range of inflows – both high and low—into its reservoirs.

The warm, dry summer of 2018, including the drought-like conditions in many parts of the province led to the combined storage of BC Hydro's two largest reservoirs—Williston on the Peace River and Kinbasket on the Columbia River—to reach record seasonal lows in the early fall 2018. In fact, Williston experienced four successive months of low inflows, with September, October and November inflows being the third, second and fourth lowest observed since 1958. By early October, storage levels at Williston were seven feet below the historic 10-year average elevation, which resulted in BC Hydro engaging regularly with local First Nations and stakeholders, as well as providing frequent updates.

Enbridge pipeline explosion

On October 9, an explosion occurred on Enbridge's 36-inch diameter T-South Pipe north of Prince George. The T-South Pipe represents about 75% of total gas delivery capacity to southern B.C. and the Pacific Northwest. The serious pipeline explosion led to further challenges for BC Hydro, as it reduced natural gas supply in the province and other jurisdictions in the Pacific Northwest to only 80% of normal capacity.

This impacted BC Hydro in two ways. First, it led BC Hydro to expect higher demand for electricity in the province as dual-fuel customers (those with both gas and electricity) were encouraged to limit their gas usage. More importantly, it ultimately affected the wholesale electricity market by creating increased demand in the region for electricity to replace gas-generating units that would have otherwise been able to run.



Winter forward wholesale electricity prices were affected as the gas supply issue affected the entire northwest—with utilities across the Pacific Northwest encouraging their customers to conserve gas and electricity. This resulted in the daily wholesale market price rising above $100 in October for the first time since 2007.

Independent power producers

BC Hydro has electricity purchase agreements with more than 130 independent power projects, including run-of-river, biomass, wind and solar. The majority are run-of-river projects that produce most of their energy during the spring freshet.

Over the winter, energy delivery from independent power producers was down below projections too. Run-of-river projects were producing less than projected because of the low water levels. As a result, they were unable to meet the increased demand. Run-of-river projects were not the only ones to fall below delivery expectations—wind resources delivered less than expected as well. For example, in February, run-of-river and wind projects only produced 29% and 50% respectively of what they were forecast to produce.

Protecting BC Hydro customers by ensuring reliable, affordable power

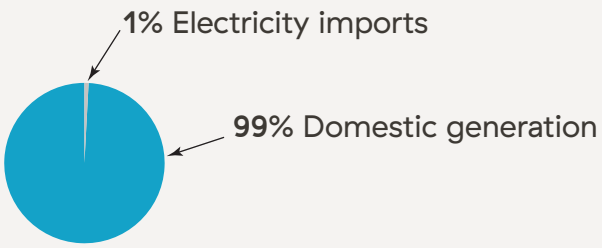
While BC Hydro has surplus energy on average on a planning basis, water inflows into its reservoirs fluctuate significantly year-to-year. When inflows are lower than average—as they were in the summer and early fall 2018—its multi-year reservoir storage and integrated system provides options, including withdrawing energy from storage and supporting imports and exports of energy. By the fall of 2018, due to low reservoir levels and the gas supply shortage, BC Hydro recognized the need to secure additional power in its system and notified the BC Utilities Commission of its supply situation.

BC Hydro's hydroelectric system and high-voltage transmission network exists within the Western Interconnection—a connected network of high-voltage transmission that spans from Alberta and B.C. through several western U.S. states to the Baja Peninsula in Mexico. This allows Powerex—BC Hydro's trading arm—to buy and sell wholesale electricity throughout the western North American Interconnection. Power trading involves the acquisition of rights to use transmission service, which is done under a regulated framework established by regulatory bodies such as the BC Utilities Commission and the U.S. Federal Energy Regulatory Commission.

In late 2018, BC Hydro made arrangements to import energy over the winter season, securing a sufficient, cost-effective supply of power to meet the evolving system needs. This was particularly important because of the potential for a cold, dry winter with elevated electricity demand, lower wholesale electricity supply as a result of a potential gas shortage due to a lack of the Enbridge gas pipeline supply, and independent power producers were down below projections too.

BC Hydro has been a net importer of electricity since November 2018, and electricity imports have represented around 1% of BC Hydro's electricity production. The decision to import electricity will not impact rates—securing a cost-effective supply of power has helped keep rates low.

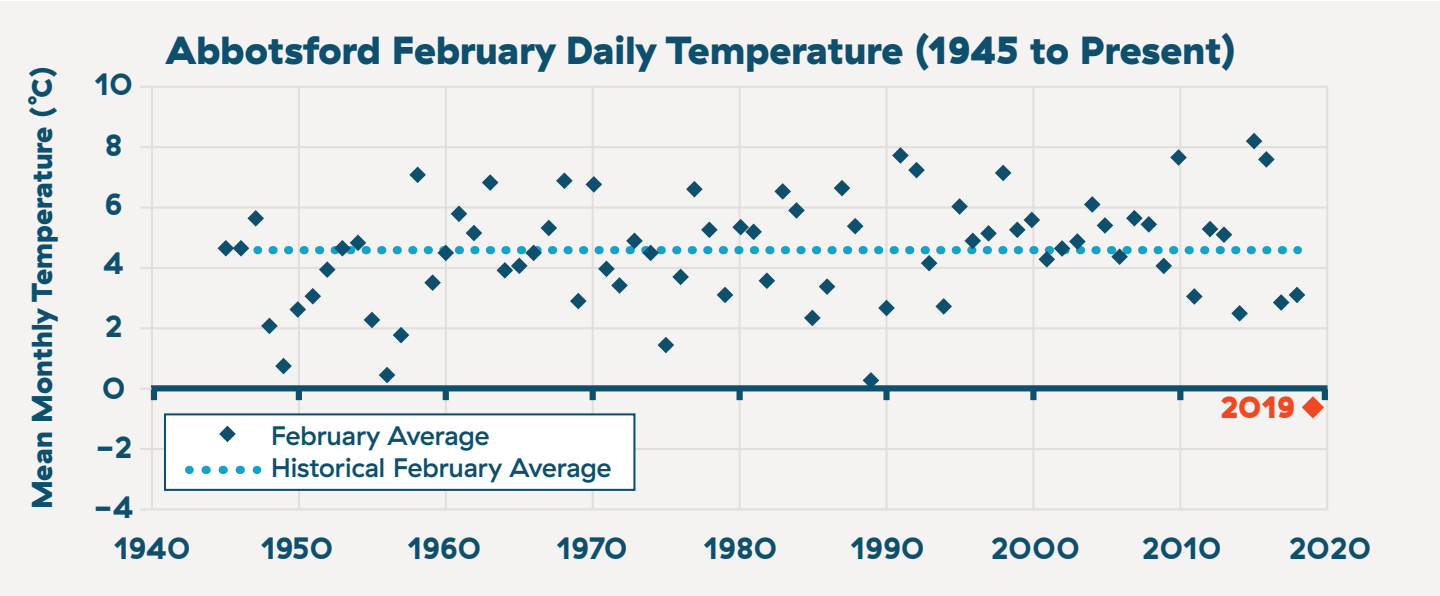
Total Electricity Production



Integrated planning efforts paid off

BC Hydro's February energy studies – which model future scenarios and determine the energy required by the electricity system – indicated there was more extreme weather in store for B.C. that increased the challenges facing BC Hydro. They predicted a significant increase in expected load over February and into March, and a significant decrease in available energy over the January energy studies, driven by the cold snap in February as well as reductions in small hydro and independent power producer output. Overall, BC Hydro forecasted a nearly 2,000 gigawatt hour increase in system shortfall as a result of these conditions.

BC Hydro's planning efforts paid off as the energy study predictions proved to be accurate. A frigid February resulted in temperature records being broken across the province. By mid-February, BC Hydro was forecasting the only February on record with an average temperature below freezing. In fact, according to Environment Canada, it turned out to be the coldest February on record in Metro Vancouver since 1937.



The cold days led to BC Hydro breaking three demand records during the month. These included the highest ever February power load, the highest daily average energy consumption and the highest peak hourly demand—the hour its customers use the most electricity—when demand reached more than 10,000 megawatts on February 11.

A cold February was followed by continued cold and dry conditions in March, especially in the Lower Mainland and Vancouver Island. For example, inflows into the Stave Lake Reservoir near Mission were the lowest in the 60 years of records for February through March.

This cold resulted in high demand for electricity, which meant more water was used at BC Hydro's reservoirs to generate electricity, while at the same time there were less water inflows due to lower than average precipitation levels. The result was low reservoir levels at most of BC Hydro's facilities. BC Hydro responded to these conditions by importing power from Powerex on a sustained basis in March and April.

Late spring and summer will bring more water, higher temperatures

Outlooks issued by national weather agencies and modelling centres indicate that warmer-than-average temperatures will be dominant through the next three months in the province. The general consensus is that El Nino was slow to develop over the winter period and will now have a small potential influence on temperatures during the spring period.

Cold and dry weather delayed the onset of the spring freshet—the spring thaw resulting from snow and ice melt in rivers. However, inflows into the reservoirs have finally started to increase in April with the warmer weather. The onset of the spring freshet will soon start filling the reservoirs.

Future outlook – reservoir inflows

BC Hydro's system is designed and operated to perform safely across a wide range of conditions and extreme events, and its staff are highly trained and experienced to adapt quickly to changing conditions. Its reservoirs are influenced by a combination of conditions, including precipitation, snow melt and spring runoff. To monitor these factors it manages a network of over 150 automated, real-time weather stations that monitor climate, snow and surface water. It then uses this data for reservoir management.

BC Hydro has been keeping inflow records for its reservoirs for the past 35 to 47 years – depending on the reservoir. Evidence suggests a modest increase in annual inflows over time, but the trends are too small to be considered statistically significant. However, there is evidence that suggests the seasonality of reservoir inflows has changed. Fall and winter average inflows have increased in almost all regions, and there is some evidence of a modest decline in late summer flows in basins that are primarily filled with glacial ice or seasonal snowpack melt.

BC Hydro has collaborated with the Pacific Climate Impacts Consortium at the University of Victoria to understand the potential impacts of climate change. Despite seeing lower

inflow contribution from glaciers, climate change projections for BC Hydro's reservoirs suggest a modest increase in overall water supply on average annually to interior basins, and little change to average annual water supply on Vancouver Island. BC Hydro does anticipate larger changes to the timing of runoff, with more runoff in winter and early spring, and less water available in summer, particularly across the southern half of the province. It has already seen changes in the timing of spring runoff and lower summer flows in recent years, including 2015 and 2018.

The seasonal timing of the inflows are also expected to change due to an increased frequency of drier summers and wetter winters, as well as an increase in more extreme weather events. As a result, climate change projections suggest there will be a decrease in summer streamflow, which will mean a decline in the amount of water available in BC Hydro reservoirs in the summer. Snowmelt is anticipated to start earlier and flows will also peak earlier.

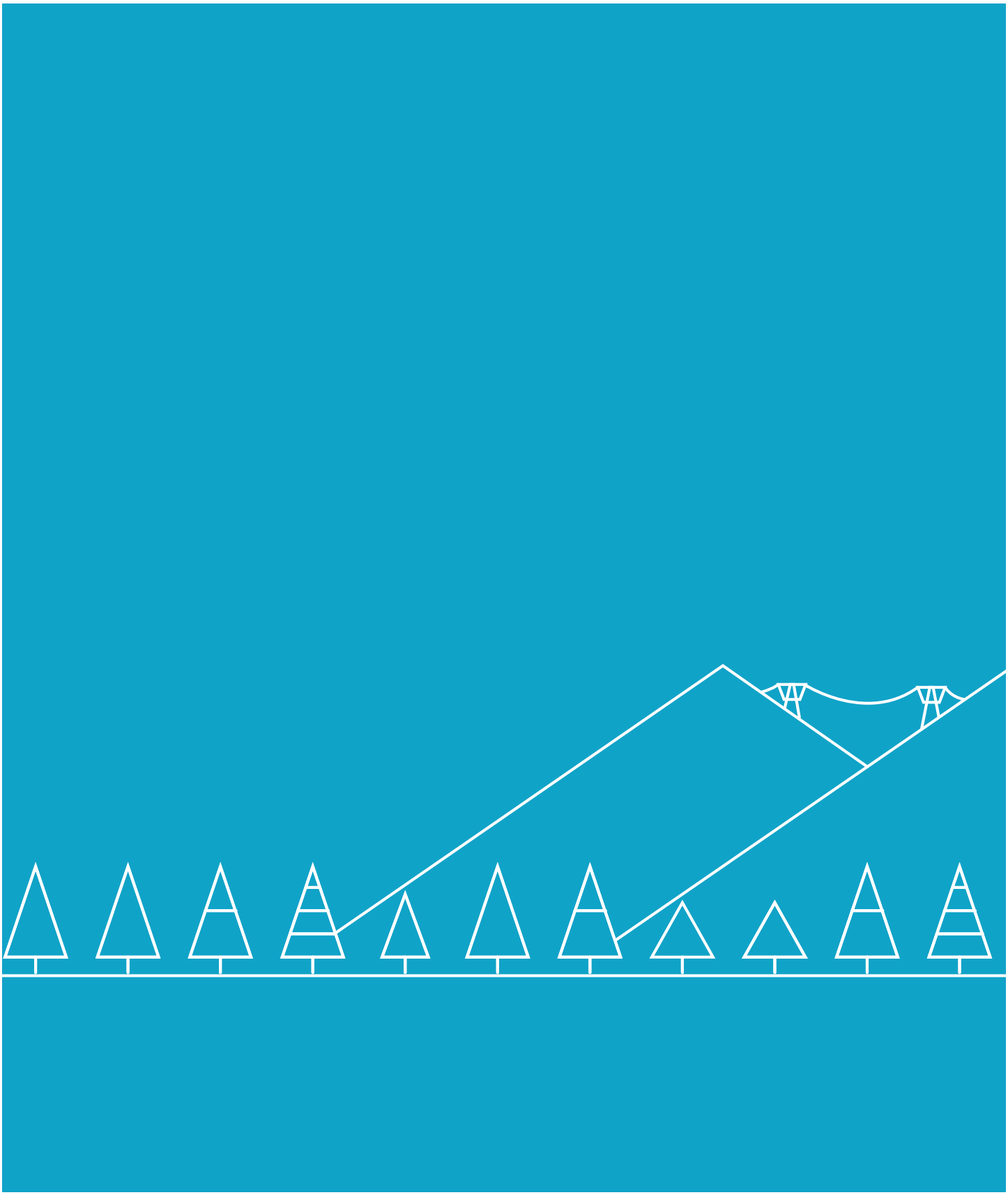
Solutions

BC Hydro also has the tools and expertise to continue to manage the unpredictable weather and climate change. This includes in-house weather forecasting and ensemble runoff forecasting, operations planning optimization methods, and its own climate, water and snow monitoring network. It is also a contributing partner in complementary networks in B.C. for water, climate, snow and glacier monitoring.

It is continuously working to improve the weather and inflow forecasting. For example, all coastal watersheds can now be forecasted at an hourly time step, which improves the forecast accuracy for extreme rainfall events. Probabilistic forecasts are available for a two week forecast horizon. Seasonal ensemble forecasts are being extended to better predict extreme scenarios.

BC Hydro continues to invest in expanding its hydroclimate monitoring technology to provide even more accurate and timely information about the current state and to monitor for changing trends in temperature, precipitation, snow and surface water availability. For example, off the shelf technology has proven insufficient to meet precipitation and snow water monitoring requirements. As a result, all season precipitation and snow water monitors are custom-made and designed in-house, and research and development is ongoing to improve accuracy and robustness. BC Hydro is also upgrading snow survey stations to automated, real-time snow and climate stations.

Through its current capital infrastructure plan, BC Hydro will invest $2.4 billion over the next five years at our generation facilities. This provides it with the opportunity to achieve both the original purpose of our generating facilities and also increase the resiliency of the generation system to climate change. This includes projects such as upgrading the controls for discharge facilities and spillway gates at the Mica and John Hart dams, replacing or refurbishing generators at the Bridge River and Revelstoke facilities, and increasing discharge capacity from some reservoirs like Strathcona.



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