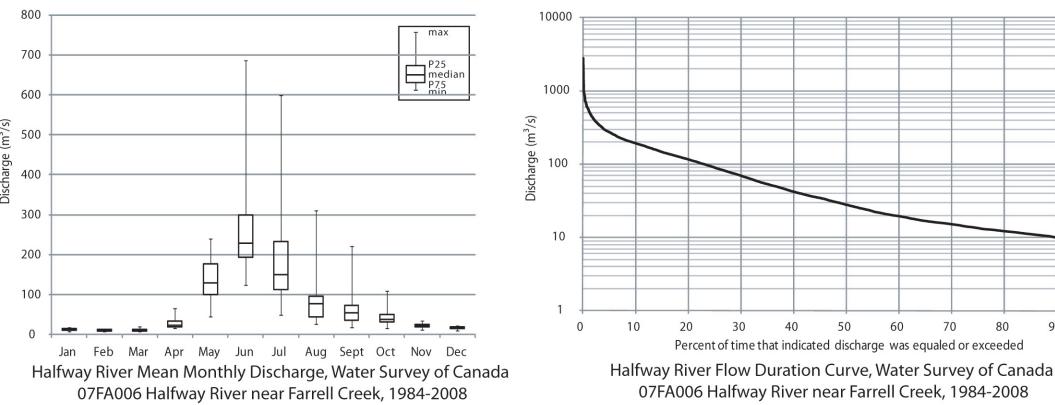
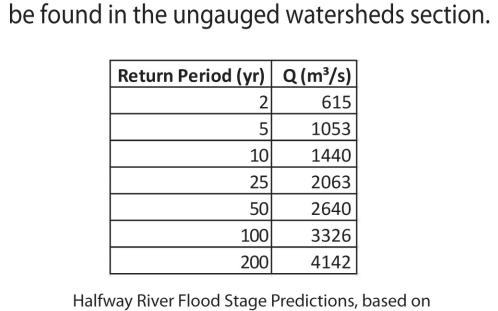
Streamflow



There are two active and three inactive hydrometric of Canada were analyzed to identify several key stations in the Halfway River watershed. Four of parameters of flow characteristics in the study area, these have periods of record suitable for annua comparisons, and this poster presents information on the most downstream currently active station,

discharge of 40m³/s near its confluence with the Peace. The largest volume of water regularly passes mean monthly flows during the spring freshet and a These analyses provide information useful to under- steeply sloped flow duration curve for large disstanding flow conditions in the associated water- charges emphasize the magnitude of flood events sheds such as intra-annual timing of peak flows, peritihis system experiences. Discharge in the Halfway ods of low flow and magnitude of flood and drought and it's tributaries is not significantly impacted flow events. Regression analyses were performed on during drought conditions. This is especially true for total annual flows, drought flows and peak flows to the Graham River, the southern-most major tributary



total annual flow volumes

inter-annual variability

seasonal flow volumes

Water Survey of Canada peak daily flow 07FA006 Halfway River near Farrell Creek, 1984-2008

Flood predictions assuming log-Pearson Type III Distribution

Water Balance

Creating a water balance for the hydrologic cycle weighs input to the system against outputs. Precipitation (rain and snowfall) are the only input to the system. Variations occur depending on when, where and at what rate precipitation occurs but for this purpose all of the water that enters the watershed leaves on an average annual basis. The three dominant processes that transport water out of the watershed are evaporation, transpiration and channel flow. Water that passes through ground water stores may take several years to exit the system. This complicates coupling water balances on a year to year basis. The relationship between ground water and surface water processes requires more in depth investigation, and in this application only considers ground water in communication with streams. Glacial meltwater may contribute to historical stream flow but is not accounted for here.

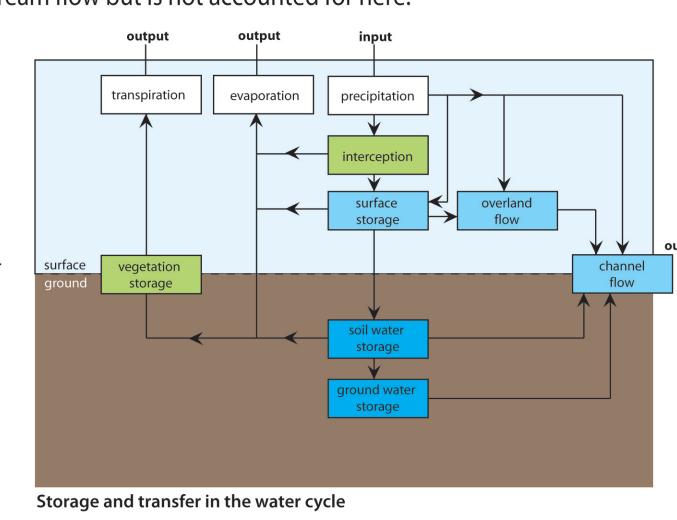
relate flow characteristics to watershed size, and can with headwaters deep in the Rockies.

limateBC and ClimateWNA (see Future Climate section) are models which were used to produce mean annual precipitation maps for the watersheds. These maps were summed to calculate total volume of water input. Gauged streamflow records provide one output calcula tions, leaving evaporation, transpiration and loss to groundwater (ET/GW) unknown. The Consultative Group for

International Agricultural Research esti-

mate actual evapotranspiration to be in

the range of 40 - 50 cm per year.



near Farrell Creek on the Halfway River (07FA006).

The Halfway is a large river system with an average

through the system in June. Large maximums for

Halfway River Total Annual Discharge, Water Survey of Canada

07FA006 Halfway River near Farrell Creek, 1984-2008

Water balances were calculated for three watersheds within the Halfway River system. Stations 07FA003 and 07FA005 are located on the two main rivers in the watershed, the Halfway River and the Graham River, and station 07FA006 is located on the Halfway downstream of the confluence with the Graham River. All three watersheds have significant precipitation and runoff. Values for ET/GW are similar for each, and lower than expected for the region. This may be due to the majority of precipitation occuring during the winter, at which time evapo-transpiration is low or zero. Precipitation is also likely underestimated as the majority of the watershed is forest and ranchland which require adequate levels of soil-water. Late summer and winter streamflow indicate that storage in the watershed (lakes, wetlands, groundwater) provides sustained contributions to baseflow. The future climate model from ClimateBC suggests that mean annual precipitation will increase within the watershed. The intraannual timing and location of this increase may affect the water balance as summer precipitation is more likely to be evaporated or transpired than winter.

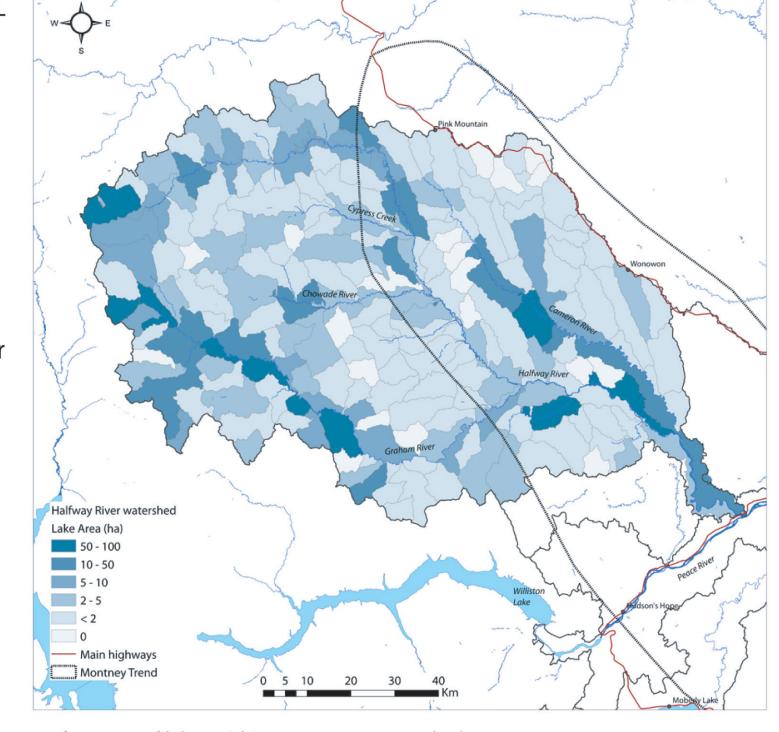
Watershed	Station	Area (km²)	Precip (cm/yr)	Runoff (cm/yr))	ET/GW (cm/yr)	% runoff	Precipitation 2025 (cm)
Halfway	07fa003	3745.5	57.6	28.5	29.1	49.5	60
	07fa005	2103.1	64.9	37.6	27.3	57.9	66.3
	07fa006	9260.9	56.9	25.2	31.7	44.3	58.1

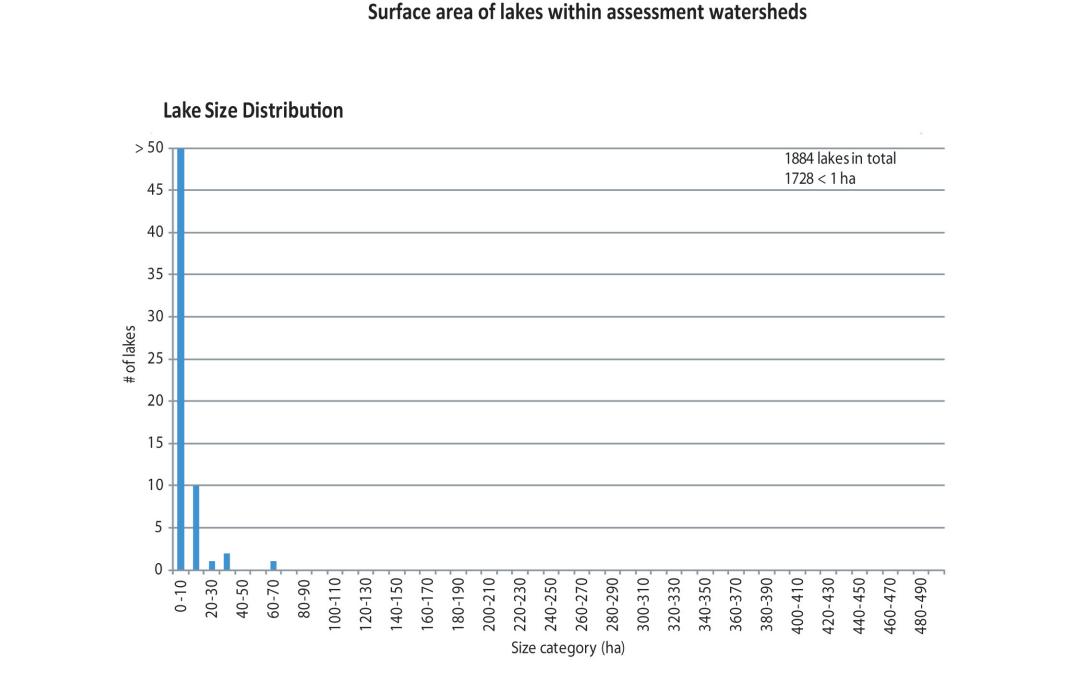
Average annual water balances for gauged watersheds in the Halfway River watershed Precipitation is based on PRISM data for period 1961-1990. Runoff is based on WSC data: 07fa003 - 1978-1995, 07fa005 - 1981-2008, 07fa006 - 1984-2008.

Lakes

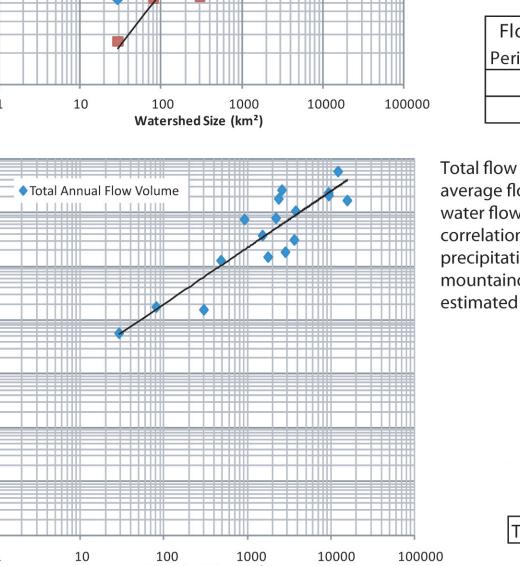
way River watershed, Robb and Lady Laurier Lakes, are deep in the Rocky Mountains and form the upper-most headwaters of the Halfway and Graham Rivers. Davis Lake (32 ha) is just south of the Halfway River near the confluence with the Graham River. 82 of the nearly 1900 lakes in the watershed are larger than 2 ha. The majority of the remainder are a fraction of a hectare in size. Many of these are abandoned oxbows or

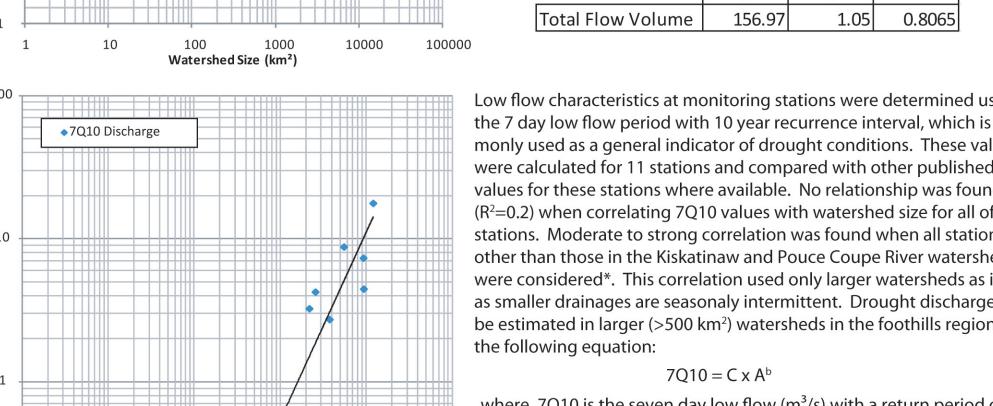
There are no lakes with publi-





cients for estimating the same parameters in ungauged watersheds, using upstream drainage area. frequency analysis using a log-Pearson Type III distribution was onducted to determine the peak daily discharge for 17 stations in the can thus be roughly estimated using the equation: Q is discharge in m³/s Tr is the return period C and b are coefficients





where 7Q10 is the seven day low flow (m³/s) with a return period of 10 years

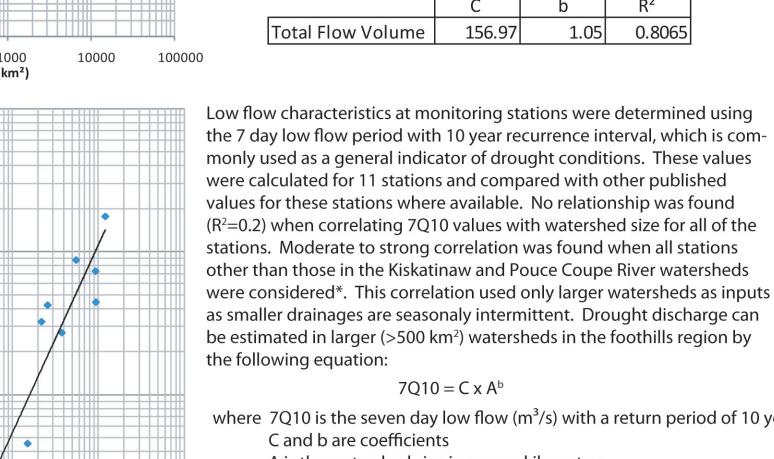
Methodology after British Columbia Streamflow Inventory, BC Ministry of Environment, 1998.

Hydrologic monitoring stations within the Peace region are in most cases ocated on major drainages. This leaves many watersheds without gauged ydrologic information. Using regression analysis, parameters identified at

study area. Regression analysis suggests that both the 2 and 10 year peak daily discharges are strongly correlated to watershed size. These values

A is the watershed size in square kilometres.

Total flow volume was calculated on a median annual basis using monthly average flow values, for stations with whole year records. Total volume of water flowing through drainages in the study area has a moderate to strong correlation with watershed size. Variation exists due to large differences in orecipitation values between some of the watersheds moving from more mountainous regions to lower plains settings. Total flow can be roughly estimated using the following equation: $V = C \times A^b$ where V is total flow volume in dam³ (1 dam³ = 1000 m³) C and b are coefficients A is the watershed size in square kilometre



Agriculture
Shrubs/Herbs/Bryoids

Surficial Materials of Canada, GSC Map 1880A Baseline Thematic Mapping, GeoBC Freshwater Atlas, GeoBC

Surficial Materials and Land Use

Approximately 60% of the Halfway River watershed is glacial till, with colluvium and alpine complexes being found moving into the Rocky Mountains and a glaciofluvial plain buffering the Halfway River downstream of the confluence with the Graham River. The map to the left is coarse scale, national mapping at 1:5,000,000 scale. As part of the Montney Water Project more detailed mapping is being compiled into digital format. N.T.S. Map Sheets 94A and 93P will be available at 1:250,000 and 94A/SE and 93P/NE will be available at 1:50,000. Surficial material type is an important component for ological modelling and can provide other operational benefits such as construction aggregate resource identification.

The B.C. Ministry of Forests Vegetation Resources Inventory provides detailed stand level mapping including tree species, age and height estimates. Coverage of the Montney Water Project area is not complete. GeoBC provides Baseline Thematic Mapping, which reflects current conditions as of the date of imagery of the product (1992) which is out of date for time sensitive or transitional areas (e.g. burned, logged, etc). A third data set useful in characterizing vegetation characteristics is the Biogeoclimatic Ecosystem Classification (BEC) Program which classifies the province into zones based on forest type, moisture and temperature.

Higher elevations are predominantly forested with coniferous trees moving into broadleaf stands and agricultural and range lands in lower elevations. Substantial wetlands are scattered throughout the watershed and comprise a fair portion of the landscape in the downstream reaches.

Vegetation Resources Inventory, BC Ministry of Forests and Range

Halfway River Watershed Overview

The Halfway River originates in the Muskwa Ranges of the Rocky Mountains and flows from Robb Lake east to Pink Mountain continuing south and south-west until emptying into the Peace River downstream of Hudson's Hope. The Halfway River watershed is substantially covered by forested lands with the remaining area consisting of alpine areas and wetlands. Several major watercourses flow into the mainstem of the Halfway, including the Graham, Chowade and Cameron Rivers and Cypress Creek.

Oil and gas activity is scattered throughout the eastern half of the watershed. Forestry operations also occur in the watershed as well as guide-outfitting, ranching and tourism.

The Halfway River watershed is home to the Upper Halfway First Nations Reserve with a population of approximately 225 band members. There are also about a dozen ranches scattered along the Halfway River just north of the Upper Halfway Reserve.



Peace Region

The Peace River originates in the mountains of British Columbia and forms the southwestern branch of the Mackenzie River System. From its headstreams in the Rocky Mountains the Peace River flows northeast into Alberta and eventually empties into the Slave River, which enters the Arctic Ocean through the Mackenzie basin. The Peace River's total course from the head of the Finlay is 1,923 km, and it covers a total area of 302,500 km². The B.C. portion of the Peace River basin covers an area of 41,600 km².

The largest tributaries of the Peace River basin in B.C. are the Pine, Halfway, Beatton, Moberly, and Kiskatinaw Rivers. The Peace River is influenced by BC Hydro's WAC Bennett and Peace Canyon Dams in the upper reaches of its drainage. These hydro-electric dams produce 31% of British Columbia's hydro-electric power.

The basin includes the major communities of Fort St. John, Dawson Creek, Chetwynd Mackenzie, Tumbler Ridge, and Hudson's Hope. Much of the basin is forested with significant natural gas exploration and production in the Montney shale gas play, a northwest to southeast trending geologic zone underlying the river basin from Pink Mountain to the BC border at Dawson Creek. Agricultural production occurs near the communities of Fort St. John and Dawson Creek. Natural gas, mining, agriculture, forestry, and tourism are the basis of the local and regional economies with mining and natural gas development being the biggest employers in the region.

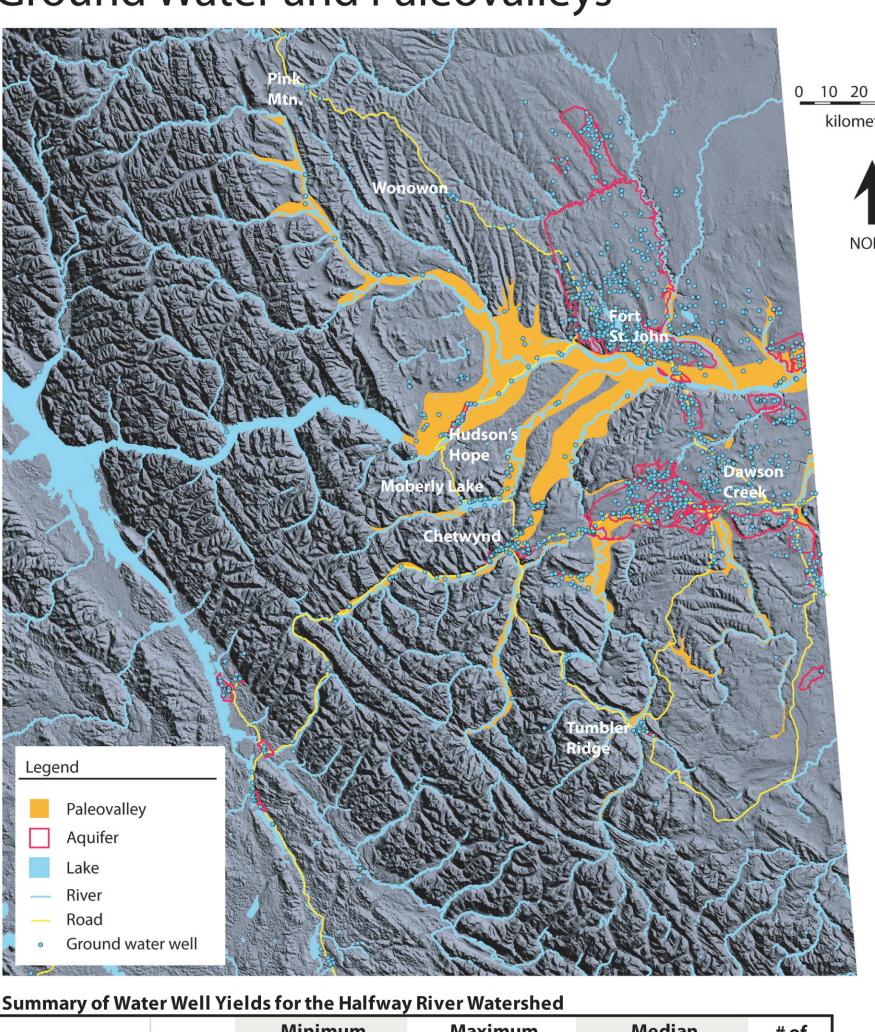
Ground Water and Paleovalleys

^{07FC003} WSC Hydrometric Station

^{4A24} BC Snow Survey Station

OGC Oil / Gas Field

Montney Trend



n US GPM L/s US GPM L/s Artesian

11 2.0 0.13 22.0 1.39 5.0 0.32

4 2.0 0.13 12.5 0.79 11.0 0.69 0

Undifferentiated 5 1.5 0.09 18.0 1.14 11.0 0.69 0

The majority of the Peace Region is covered by glacial and interglacial sediments deposited during repeated glaciations in the Quaternary Period. These sediments o 10 20 30 40 vary significantly in thickness. In some locations, bedkilometres rock is covered by a thin veneer of sediment or is exposed at surface. In others places, such as in pre-glacial buried paleovalleys, these sediments can be over 100 m thick. In many cases modern rivers occupy pre-glacial iver valleys and the thick unconsolidated valley-fill sediments may host aquifers with significant volumes of water. Areas with thick Quaternary sediments are targets for further aquifer evaluation.

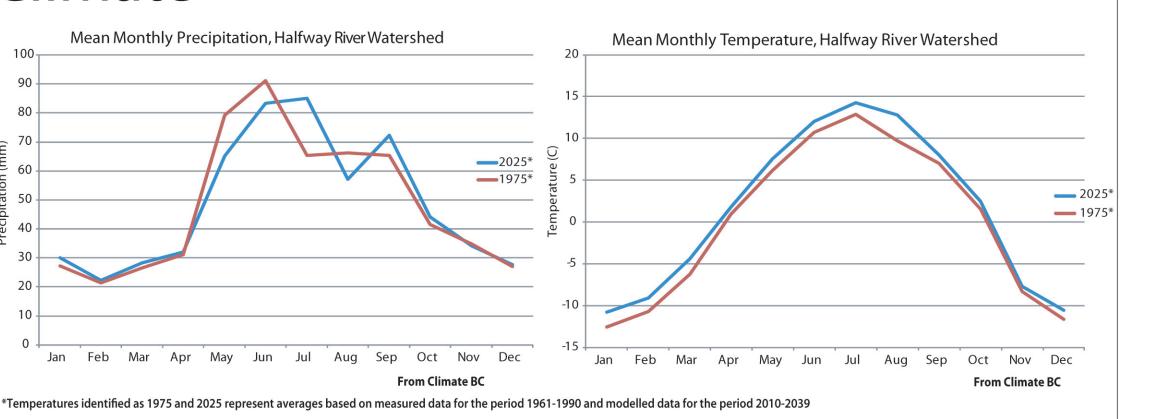
> The BC Ministry of Environment maintains a database of water wells drilled in the province and delineates ground water aquifers based on this database and other geologic and hydrogeological information.

As part of the Montney Water Project, geologic analysis is being performed by the B.C. Ministry of Energy to more accurately map the thicknesses of Quaternary sediments that may have potential for hosting water. The B.C. Ministry of Environment is collecting additional water well information, which is being used to update the online water well database and refine mapping of aguifers in unconsolidated sediments and bedrock.

This map illustrates the geographic distribution of water wells, currently mapped and classified aquifers and areas that likely have thick Quaternary sediment which will be evaluated for their aquifer potential.

Ground water Aquifers, B.C. Ministry of Environment aleovalleys, B.C. Ministry of Energy unpublished Ground water wells, B.C. Ministry of Environment

Climate



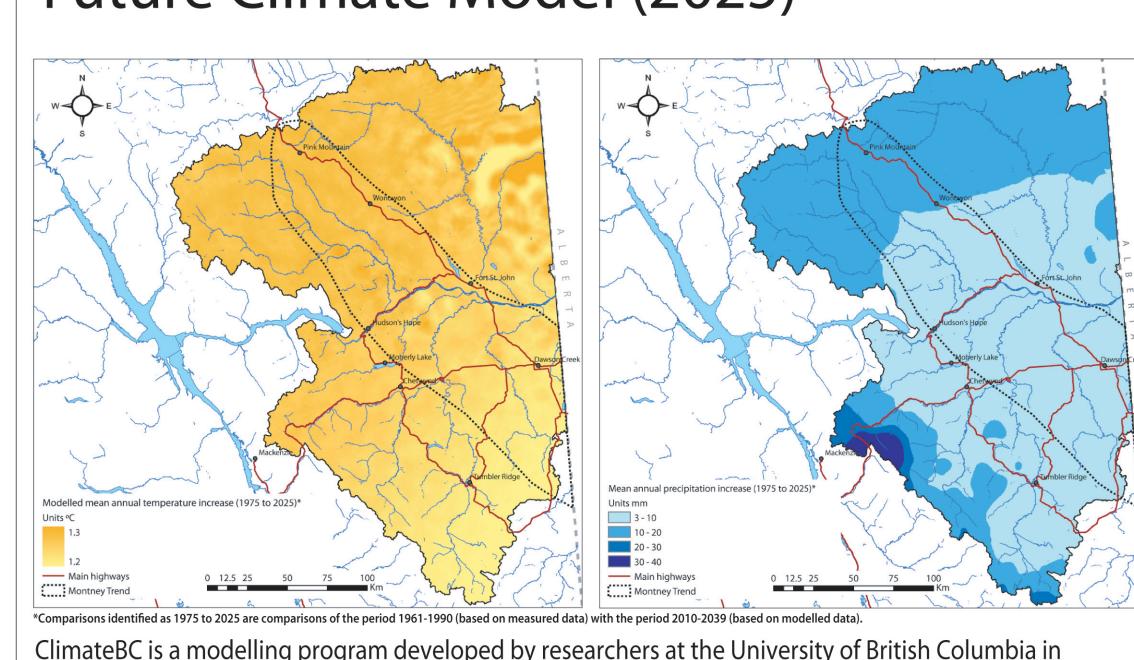
In the Halfway River watershed, highest precipitation occurs from May to September. Throughout the year, precipitation is greater at higher elevations in the western portion of the watershed. This contrast is more subtle during the winter.

At Pine Pass, an automated snow pillow collects information on snow accumulations. Peak accumulation regularly occurs in April. Snow water equivalent (swe) is a standardized method of communicating the water volume in snow pack considering depth and density.

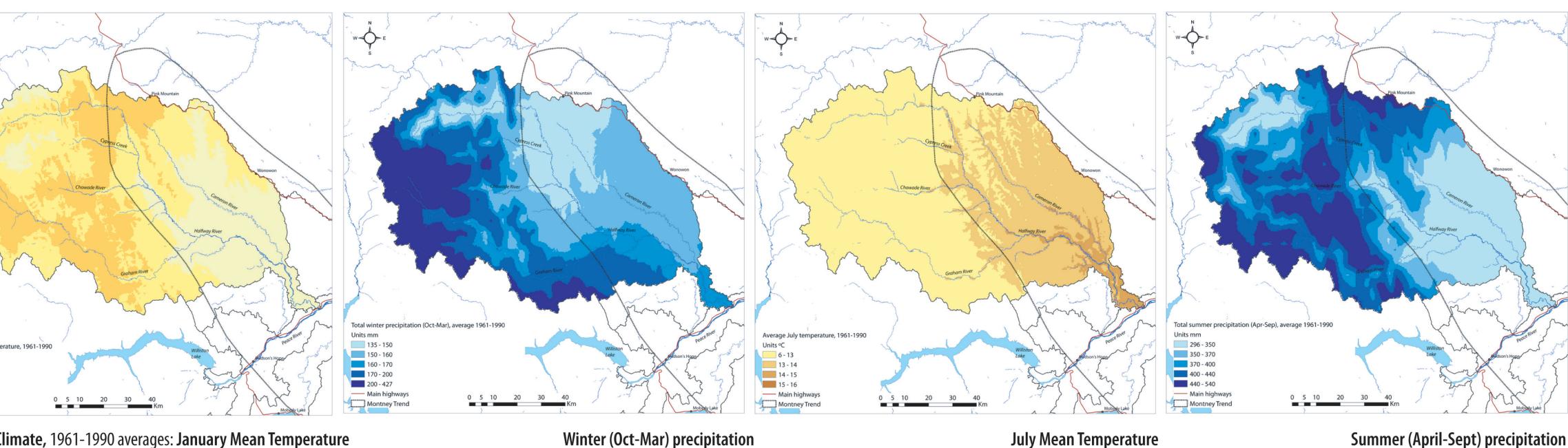
There are 14 other snow monitoring locations within or very near the Montney Water Project area, the majority of which are high in the mountains in the headwaters of the watersheds. Stations 4A07, 4A21, 4A14, and 4A24 provide snow records at mid to high elevations in the headwaters of the watershed at Lady Laurier Lake, Mount Stearns, Pink Mountain and Wonowon

Environment Canada, and the BC Ministries of Transportation and Forests operate weather stations throughout the Peace region. Climate data from these stations is available in the database for the project

Future Climate Model (2025)



collaboration with the BC Ministry of Forests, in order to provide high resolution climate data for resource management in Western Canada. Recent updates have expanded the scope of the project to Western North America in ClimateWNA. These products are based on PRISM Climate Data developed by Oregon State University, with improved elevation related variations, additional modelled parameters, and the introduction of forward looking climate predictions based on a variety of global circulation models. T period of normals (1961-1990) has been compared with predicted values for the period 2010-2039 using the CGCM2-A2x global circulation model. Mean annual temperatures as well as mean annual precipitation is expected to increase across the Peace region. Temperature is expected to increase in a relative way, consistent across the region, while the magnitude of precipitation will vary.



Seasonal Climate, 1961-1990 averages: January Mean Temperature All data from ClimateBC

Diagram of Hydrol

discussion, and references.

For the surface water component of the Montney Water Project, several parts of

the water cycle have been assessed and described. Themes include flow charac-

water balances and discussion of estimating conditions in ungauged watersheds.

Posters have been created highlighting key aspects of these themes, in each of the

accompanying the poster series, and includes additional analyses, more thorough

major watersheds in the region. Supporting information is available in a report

teristics in gauged watersheds, lake size distributions, climate and projected

future climate, groundwater, vegetation and surficial geology characteristics

The Montney Shale Gas Play in northeast British Columbia is a world-class unconventional natural gas resource development. Operations in the Montney are moving into developmen drilling, which will increase the demand for water and deep sites for the disposal of fluids. Provincial, First Nations and local governments, industry, communities, and environmental groups all want to ensure that water sources are carefully managed during natural gas development. These stakeholders require detailed, scientifically-based and unbiased information about existing water resources to make appropriate policies, regulations and permit decisions as well as to support public discussion on issues related to water use.

In response to this need, Geoscience BC met with industry and government in early 2010 and began a collaboration to undertake water studies in the Montney area. The Project is designed to create a comprehensive database of surface water, ground water and deep saline aguifers in the Montney area.

Phase I of the study focuses on collecting, analyzing and interpreting available water information in the Montney region. If required, a second phase of the study will focus research on addressing remaining data gaps. Three components of the project are as follows:

- Surface Water: Collection and presentation of data on surface water system (lakes, streams and wetlands) and processes that control availability of water (timing and amount). Analysis of these components provides insight into important aspects of the regional water cycle, including seasonal flow conditions, climate, vegetation and land use

· Unconsolidated and shallow bedrock: Unconsolidated and shallow bedrock aguifers host a significant source of water in the Peace Region. These aguifers are best developed in areas with thick Quaternary age sediments often associated with buried paleovalleys. This component of the MWP has focused on compiling a database of available surface and subsurface data that elucidates the thickness of the unconsolidated drift and the bedrock topography. These data will be used to model and map major drift thickness trends and bedrock topography which represent high potential target areas for water in unconsolidated aquifers.

Deep bedrock: Define and characterize candidate aquifers (water sources) and potential deep disposal zones, providing a general description and indicating the homogeneity of each aquifer. The work focuses in zones deeper than domestic water wells and in zones typically explored by the oil and gas sector, greater than 250 m below surface. Compilation of existing hydro-stratigraphic data and development of groundwater flow models for select areas will assist in the identification of regional aquifers with suitable reservoir characteristics, fluid content, and capacity to be viable source/disposal candidates.

Montney Water Project Partners:

Geoscience BC is an industry-led, industry-focused not-for-profit society. Its man-

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www.geosciencebc.com



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date includes the collection, interpretation and marketing of geoscience data and expertise to promote investment in resource exploration and development in British Columbia. Geoscience BC is funded through grants from the Provincial Government and works in partnership with industry, academia, government, First Nations and communities to attract mineral and oil & gas investment to B Derek Brown, Janet Fontaine - Strategic West Energy Ltd



