Farrell and Cache Creek Watersheds

December 2010

Montney Water Project Geoscience BC

Streamflow

Hydrometric stations operated by the Water Survey of Canada were analyzed to identify several key parameters of flow characteristics in the study area, including:

- total annual flow volumes
- inter-annual variability
- seasonal flow volumes
- drought flows
- peak flows
- flow duration

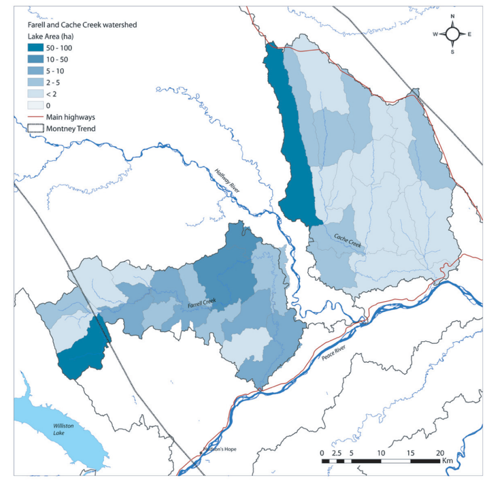
These analyses provide information useful to understanding flow conditions in the associated watersheds such as intra-annual timing of peak flows, periods of low flow and magnitude of flood and drought flow events. Regression analyses were performed on total annual flows, drought flows and peak flows to relate flow characteristics to watershed size, and can be found in the ungauged watersheds section.

No hydrometric data exists for the Farrell and Cache Creek watersheds. Stations 07FC003 and 07FB008 on the Blueberry and Moberly Rivers may provide useful analogue information. The watersheds for these stations are 1770 km^2 and 1520 km^2 in size, respectively.

Watersheds in the Montney Water Project Area
(highlighted watersheds are in the Peace River Valley)
* Modified Strahler order, the number of upstream branches in the watershed.
** Modified Shreves magnitude, the number of stream segments contributing to the outlet of the watershed.

Watershed	Area (km^2)	Stream Order*	Stream Magnitude**
Pine River	13497	8	23052
Halfway River	9358	8	18334
Kiskatinaw River	4053	6	3163
Moberly River	1897	6	2142
Pouce Coupe River	1633	6	1794
Cache Creek	935	6	850
Farrell Creek	643	5	597
Lynx Creek	320	5	220
Maurice Creek	262	5	226
Johnson Creek	210	5	324
Wilder Creek	100	4	119
Eight Mile Creek	96	4	50
Six Mile Creek	74	4	54
Dry Creek	58	3	29
Pingel Creek	41	4	48
Rudyk Coulee	40	3	18
Tea Creek	33	3	26
Four Mile Creek	12	3	10

Lakes



Surface area of lakes within assessment watersheds

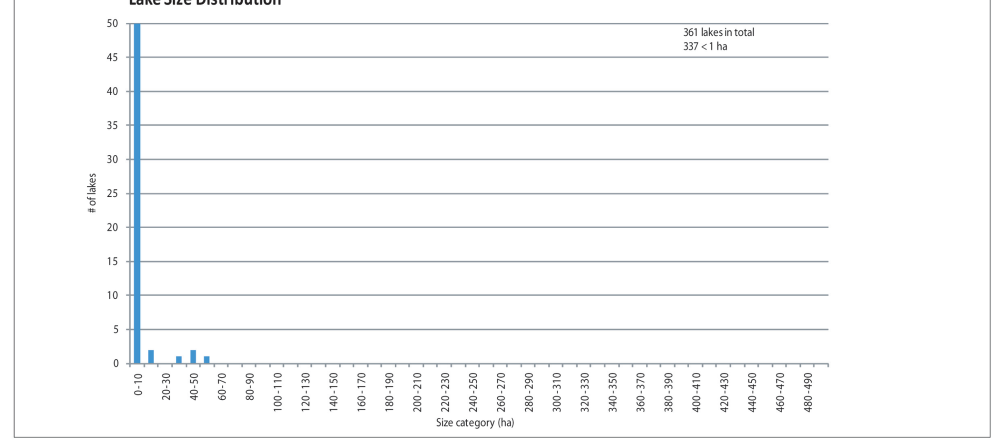
In the Cache Creek watershed, there are two lakes of significant size. Inga Lake (55 ha) forms the headwaters of Cache Creek, which passes through a slightly smaller (42 ha), unnamed lake approximately 15km downstream. Of the 201 other lakes in the watershed, all are under 3 ha. Chunamun (sic) Lake (46 ha) is the largest in the Farrell Creek watershed. There are 3 other lakes greater than 10 ha, all located in the central to northern extent of the watershed. All of the remaining 152 lakes are < 2 ha in size, and are generally located along or adjacent to streams.

Bathymetric maps exist for one lake in each of the Farrell and Cache Creek watersheds. Chunamun Lake is located in the far southwest of the Farrell Creek watershed, near Williston Lake. Inga Lake is in the far northwest of the Cache Creek watershed, close to the Alaska Highway. These bathymetric maps have been collected by the BC Ministry of Environment and provide information on maximum and average depths, perimeter, area and volume. All bathymetric maps for the Montney Water Project area are available in the database for this project.

Bathymetric Information for Lakes in Farrell and Cache Creek watersheds

Lake	Area (ha)	Volume (m^3)	Mean Depth (m)	Maximum Depth (m)
Chunamun Lake	42.8	1159000	2.7	6
Inga Lake	56.7	1610000	2.8	4.3

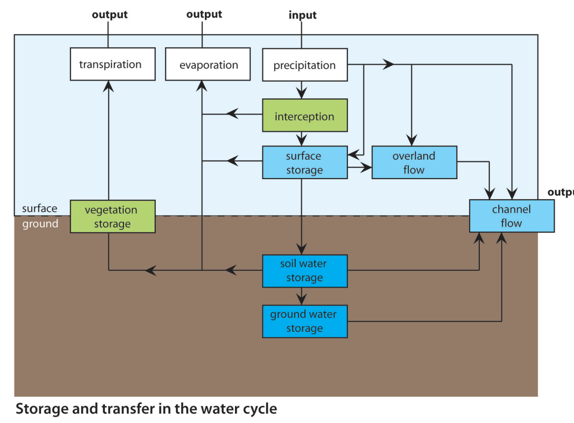
Lake Size Distribution



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.

ClimateBC 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 calculations, leaving evaporation, transpiration, and loss to groundwater (ET/GW) unknown. The Consultative Group for International Agricultural Research estimate actual evapotranspiration to be in the range of 40 - 50 cm per year.

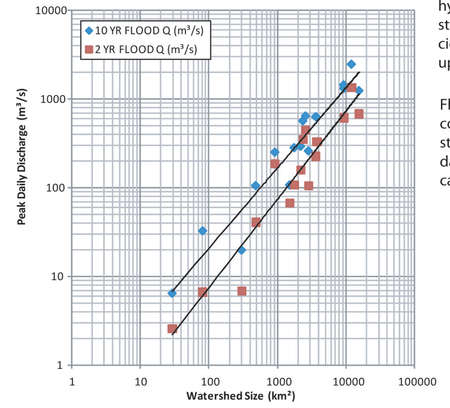


Storage and transfer in the water cycle

It was not possible to create a water balance for the Farrell and Cache Creek watersheds as there is no hydrometric data available. Consideration of water balances created for other watersheds in the Montney Water Project area, based on size and precipitation patterns may provide insight into the water balance in these watersheds. The water balances created for stations 07FC003 and 07FB008 are the closest analogues for the Cache and Farrell Creek watersheds, respectively. Water balances for these watersheds are available in the report accompanying the poster series.

Ungauged Watersheds

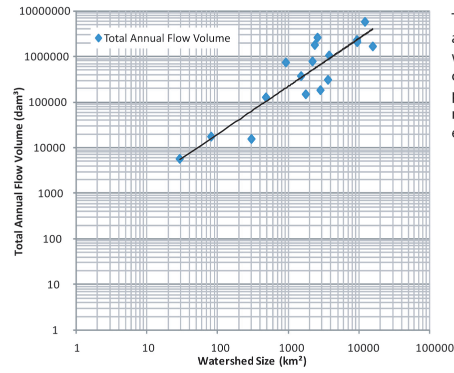
Hydrologic monitoring stations within the Peace region are in most cases located on major drainages. This leaves many watersheds without gauged hydrologic information. Using regression analysis, parameters identified at stations have been correlated with watershed size to develop sets of coefficients for estimating the same parameters in ungauged watersheds, using upstream drainage area.



Flood frequency analysis using a log-Pearson Type III distribution was conducted to determine the peak daily discharge for 17 stations in the study area. Regression analysis suggests that both the 2 and 10 year peak daily discharges are strongly correlated to watershed size. These values can thus be roughly estimated using the equation:

$Q_{Tr} = C \times A^b$ where Q is discharge in m^3/s
Tr is the return period
C and b are coefficients
A is the watershed size in square kilometres.

Flood Return Period Tr (years)	Coefficient C	Coefficient b	R^2
2	0.0752	0.9974	0.9029
10	0.318	0.9067	0.9139

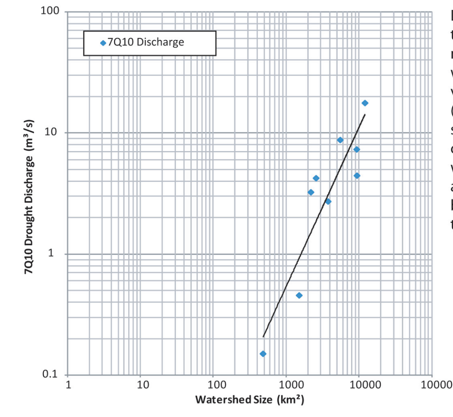


Total flow volume was calculated on a median annual basis using monthly average flow values, for stations with whole year records. Total volume of water flowing through drainages in the study area has a moderate to strong correlation with watershed size. Variation exists due to large differences in precipitation 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 dam^3 (1 dam^3 = 1000 m^3)
C and b are coefficients
A is the watershed size in square kilometres.

	Coefficient C	Coefficient b	R^2
Total Flow Volume	156.97	1.05	0.8065



Low flow characteristics at monitoring stations were determined using the 7 day low flow period with 10 year recurrence interval, which is commonly used as a general indicator of drought conditions. These values were calculated for 11 stations and compared with other published values for these stations where available. No relationship was found (R^2=0.2) when correlating 7Q10 values with watershed size for all of the stations. Moderate to strong correlation was found when all stations other than those in the Kiskatinaw and Pouce Coupe River watersheds were considered*. This correlation used only larger watersheds as inputs as smaller drainages are seasonaly intermittent. Drought discharge can be estimated in larger (>500 km^2) watersheds in the foothills region by the following equation:

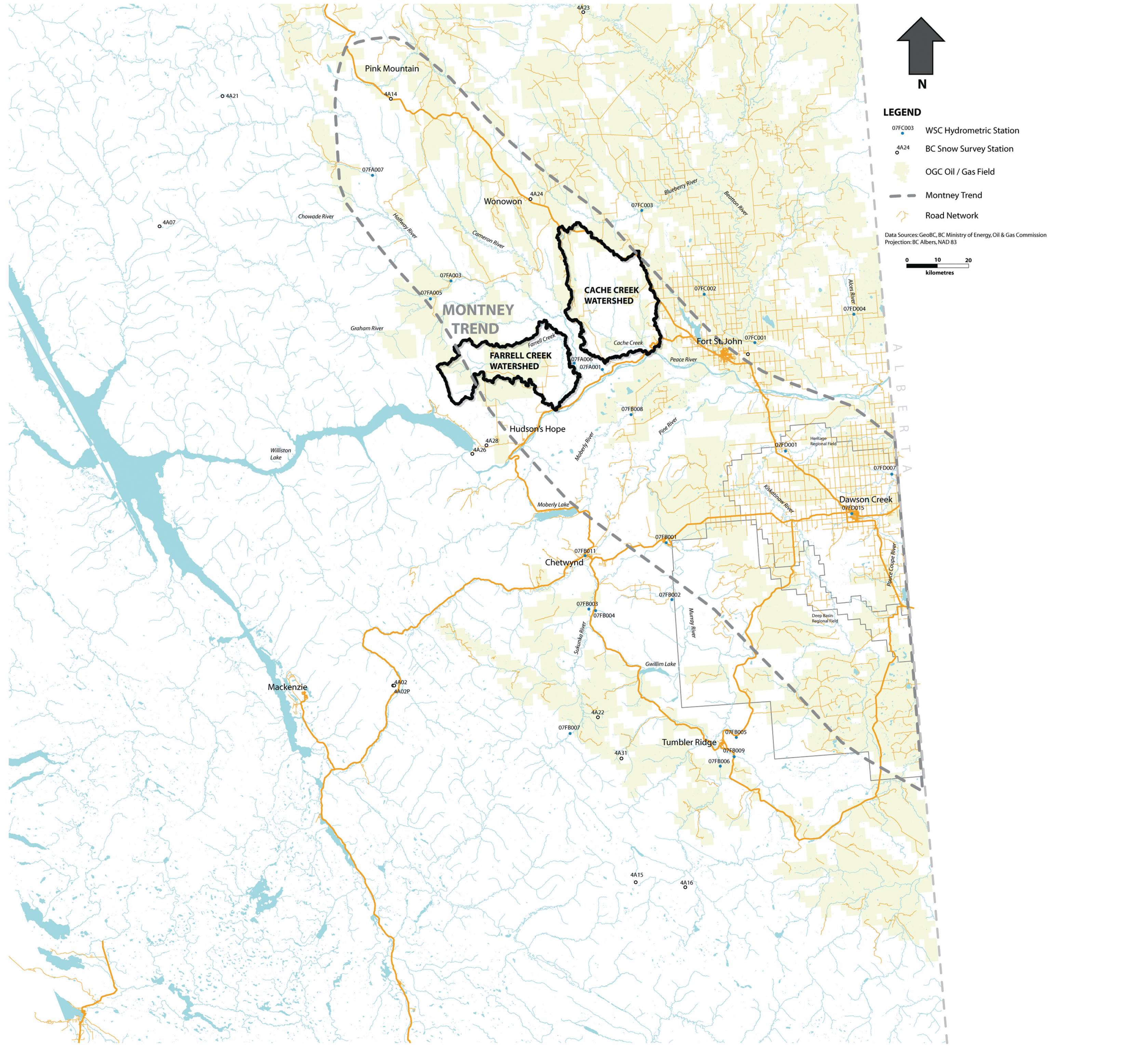
$7Q10 = C \times A^b$

where 7Q10 is the seven day low flow (m^3/s) with a return period of 10 years
C and b are coefficients
A is the watershed size in square kilometres.

	Coefficient C	Coefficient b	R^2
Drought Flow (7Q10)	0.00006	1.3146	0.8317

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

*refer to BC streamflow inventory section on Northeast Plains Low Flow zone for the Kiskatinaw and Pouce Coupe watersheds.



Farrell and Cache Creek Watersheds Overview

The Farrell and Cache Creek watersheds are located on the north side of the Peace River on either side of the Halfway River watershed. These two watersheds contain scattered settlements and farmsteads.

Cache Creek watershed is directly east of the Halfway River watershed and is 901 km^2 in size. The watershed is roughly 75% forested, with the majority of the remaining land cover being comprised of farm and ranch lands. The main economic activities in the watershed include logging, natural gas exploration and development, and agriculture. Coal tenures are located in the western border of the watershed.

Farrell Creek watershed is directly west of the Halfway River watershed and is 609 km^2 in size. Almost 80% of the watershed is forested. This watershed is comprised of more wetlands than Cache Creek watershed and fewer areas suitable for agriculture. Natural gas and forest activities occur throughout the watershed.

Photos:
above: Cache Creek confluence with the Peace River
left: mixed forest and shrubs along a tributary in the Peace region

Photo credits: Adrian Hickin, B.C. Ministry of Energy, flickr.com user 'Tuchodi'

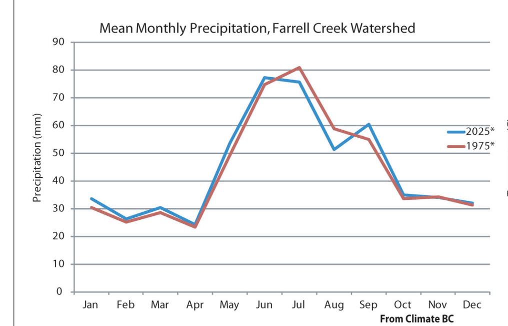
Peace Region

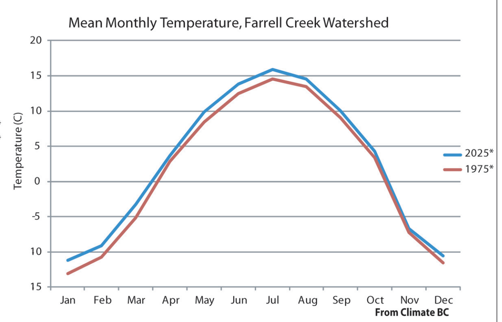
The Peace River originates in the mountains of British Columbia and forms the southwestern branch of the Mackenzie River System. From its headstreams in the Rocky Mountains the Peace River flows northeast into Alberta and eventually empties into the Slave River, which enters the Arctic Ocean through 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 km^2. The B.C. portion of the Peace River basin covers an area of 41,600 km^2.

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.

Climate





*Temperatures identified as 1975 and 2025 represent averages based on measured data for the period 1961-1990 and modelled data for the period 2010-2039

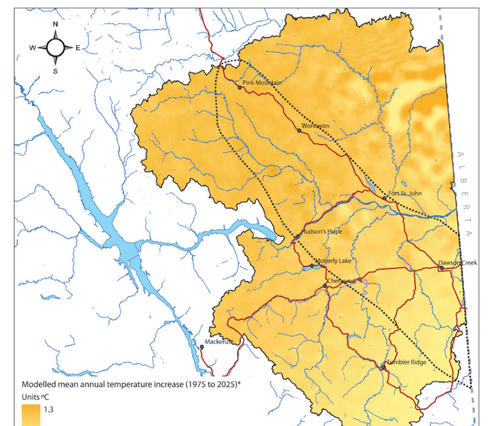
In the Farrell and Cache Creek watersheds, intra-annual timing and rate of precipitation is similar with largest values occurring during the summer. In the Farrell Creek watershed, the greatest precipitation occurs in the west during the summer and winter. In the Cache Creek watershed, winter precipitation is greatest in the eastern portion and summer precipitation in the northern parts of the watershed.

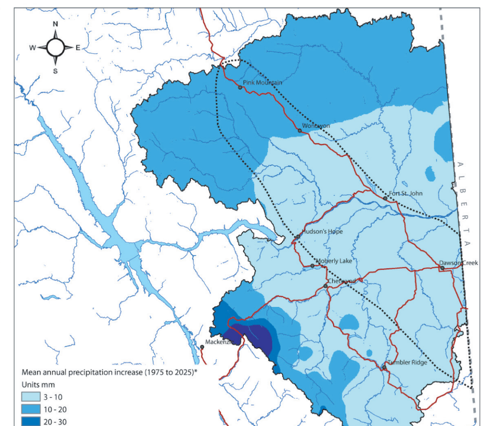
At Pine Pass, an automated snow pillow collects information on snow accumulations. Peak accumulation regularly occurs in April. Snow water equivalent (swe) is a standardized method of communicating the water volume in snow pack considering depth and density.

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 major watersheds. Station 4A24 at Wonowon is approximately 15 km northwest of the headwaters of the Cache Creek watershed. Time of maximum accumulation is variable at this location.

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.

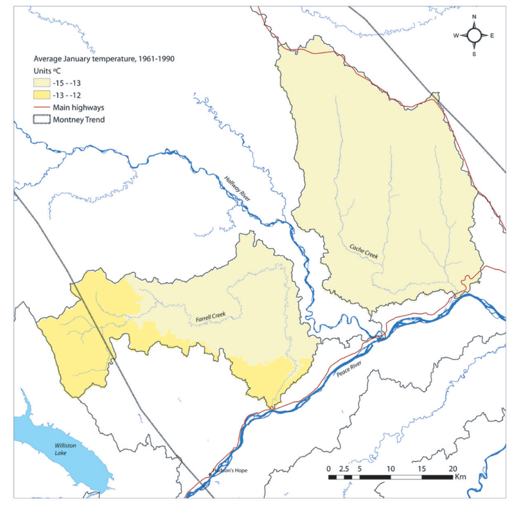
Future Climate Model (2025)

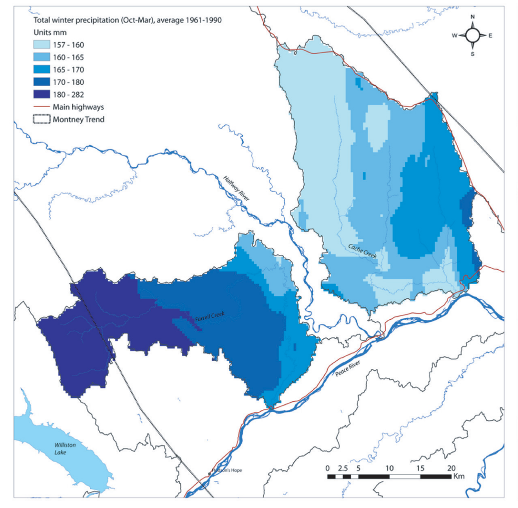


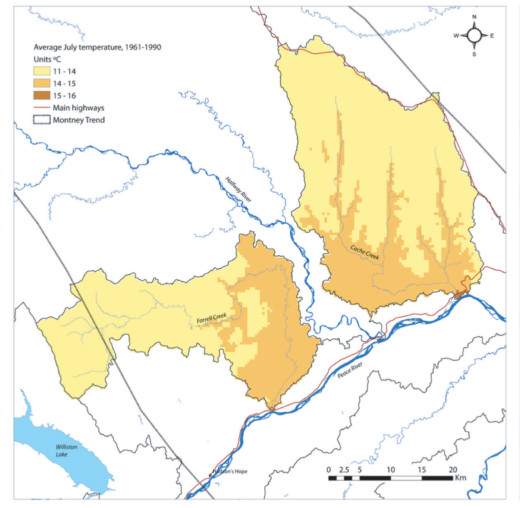


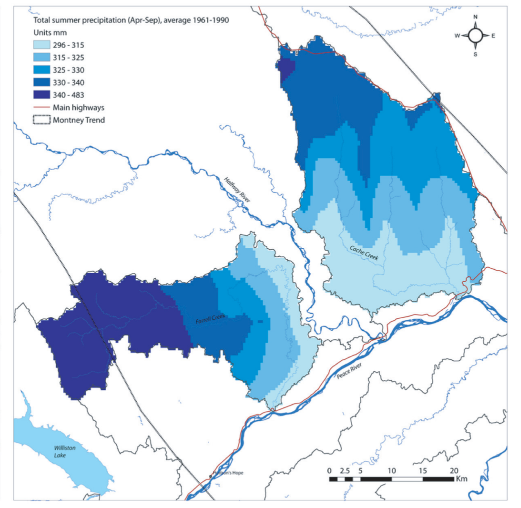
*Comparisons identified as 1975 to 2025 are comparisons of the period 1961-1990 (based on measured data) with the period 2010-2039 (based on modelled data).

ClimateBC is a modelling program developed by researchers at the University of British Columbia in 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. The 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.



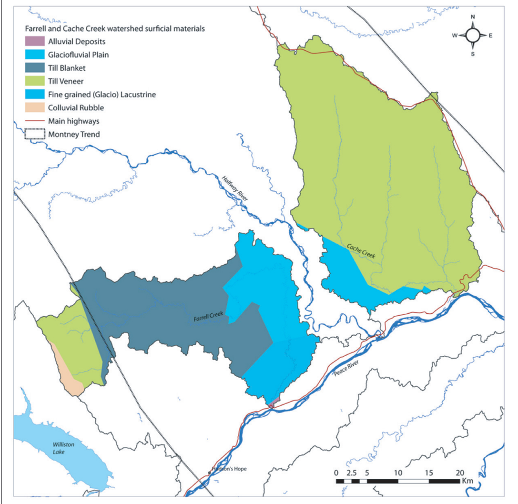


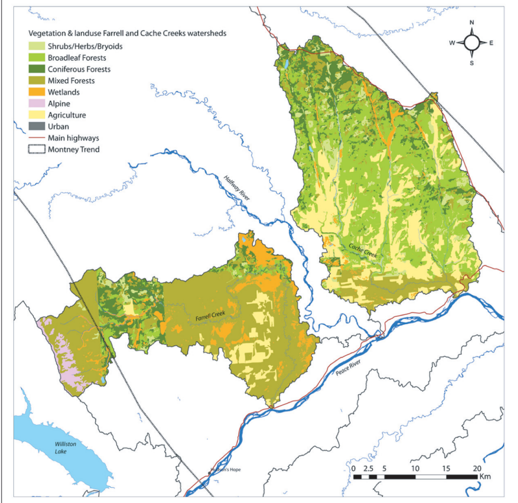




Seasonal Climate, 1961-1990 averages: **January Mean Temperature** | **Winter (Oct-Mar) precipitation** | **July Mean Temperature** | **Summer (April-Sept) precipitation**
All data from ClimateBC

Surficial Materials and Land Use





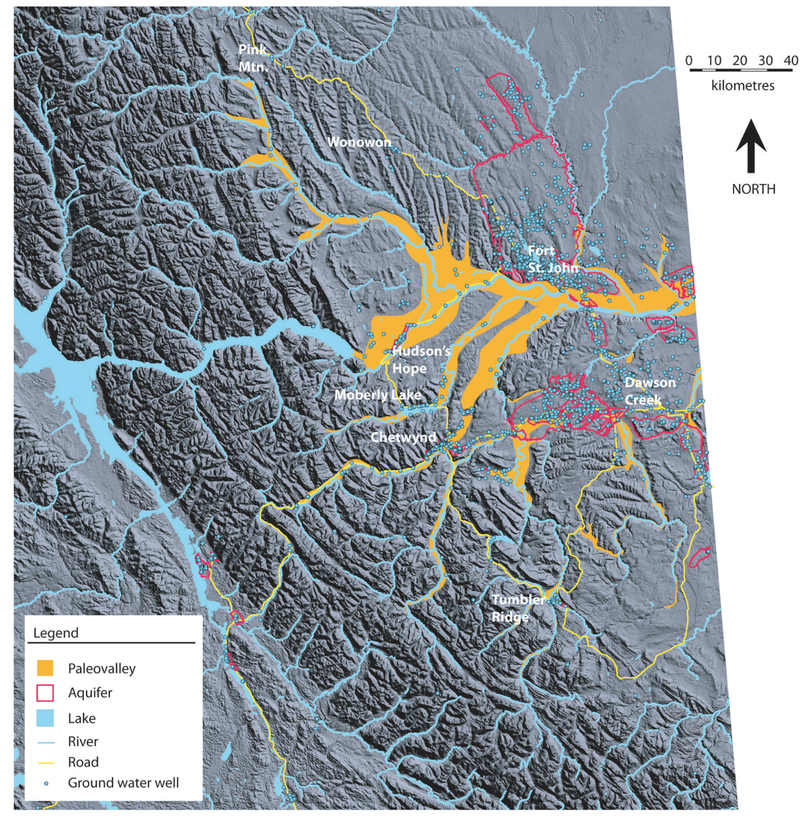
Glacial till is the dominant surficial material type in the Cache and Farrell Creek watersheds, with substantial glaciofluvial and glaciolacustrine deposits near the confluence of the Halfway and Peace Rivers. The map to the left is coarse scale, national mapping at 1:5,000,000 scale. As part of the 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 hydrological 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.

Both watersheds are mostly forested, in the Cache by broadleaf trees such as aspen and poplar, and in the Farrell by mixed stands of deciduous and evergreen. Significant agricultural lands are found in both watersheds, and extensive wetlands exist in the Farrell Creek watershed.

Data Sources:
Surficial Materials of Canada, GSC Map 1880A
Vegetation Resources Inventory, BC Ministry of Forests and Range
Baseline Thematic Mapping, GeoBC
Freshwater Atlas, GeoBC

Ground Water and Paleovalleys



Summary of Water Well Yields for the Farrell and Cache Creek Watersheds

Aquifer	n	Minimum US GPM	Minimum L/s	Maximum US GPM	Maximum L/s	Median US GPM	Median L/s	# of Artesian
Undifferentiated	9	1.0	0.06	50.0	3.15	3.0	0.19	0
Bedrock	10	1.7	0.11	10.0	0.63	3.4	0.22	0
Unconsolidated	4	7.5	0.47	60.0	3.79	14.5	0.91	0

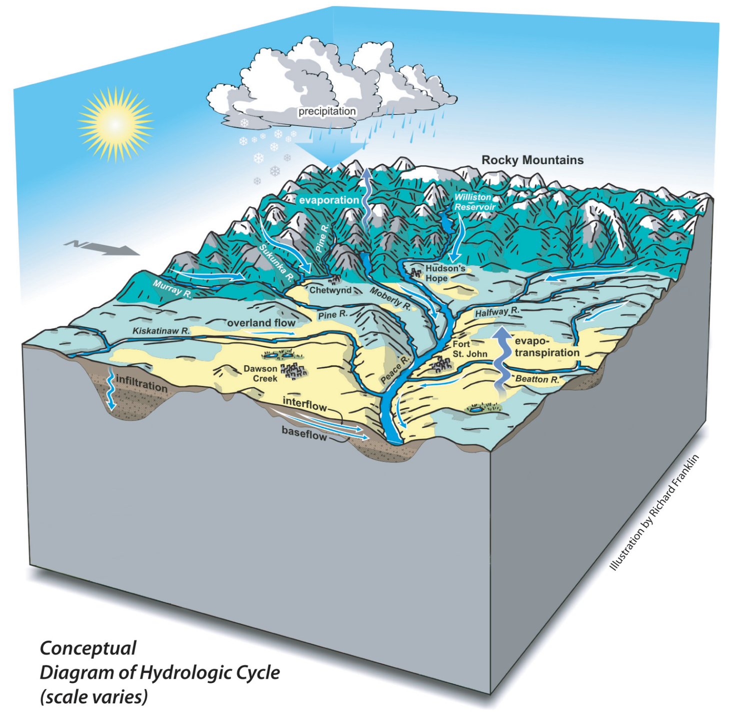
The majority of the Peace Region is covered by glacial and interglacial sediments deposited during repeated glaciations in the Quaternary Period. These sediments vary significantly in thickness. In some locations, bedrock is covered by a thin veneer of sediment or is exposed at surface. In others places, such as in pre-glacial buried paleovalleys, these sediments can be over 100 m thick. In many cases modern rivers occupy pre-glacial river 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 aquifers 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 sediments which will be evaluated for their aquifer potential.

Data Sources:
Ground water Aquifers, B.C. Ministry of Environment
Paleovalleys, B.C. Ministry of Energy unpublished
Ground water wells, B.C. Ministry of Environment
Freshwater Atlas, GeoBC



Conceptual Diagram of Hydrologic Cycle (scale varies)

For the surface water component of the Montney Water Project, several parts of the water cycle have been assessed and described. Themes include flow characteristics in gauged watersheds, lake size distributions, climate and projected future climate, groundwater, vegetation and surficial geology characteristics, water balances and discussion of estimating conditions in ungauged watersheds. Posters have been created highlighting key aspects of these themes, in each of the major watersheds in the region. Supporting information is available in a report accompanying the poster series, and includes additional analyses, more thorough discussion, and references.

Montney Water Project Overview:

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 development 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 aquifers 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 characteristics.
- Unconsolidated and shallow bedrock: Unconsolidated and shallow bedrock aquifers host a significant source of water in the Peace Region. These aquifers 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:

ARC Resources Ltd. | ConocoPhillips Canada | Progress | British Columbia – The Best Place on Earth | devon | encana natural gas | Talisman Energy | scek | Geoscience BC

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

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