waterSMART
Water Management Solutions

Western Economic Diversification Canada/ Diversification de l'economie de l'Ouest Canada

Appendix B: Hydrology Baseline Summary Report

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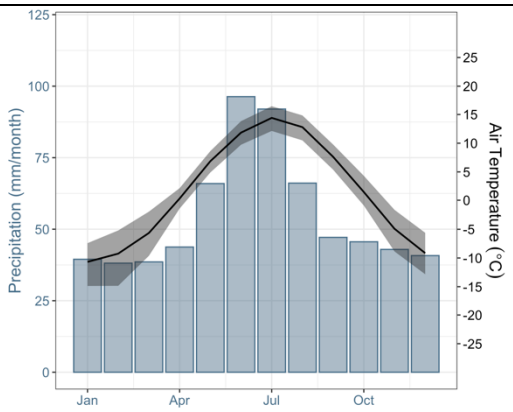
Upper North Saskatchewan River

Natural Ecoregions
Rocky Mountains, Foothills, some Boreal

Headwater Source
Rocky Mountains (headwater stream)

3.1.1.13 Climate

Period	Average Air Temperature	Annual Precipitation
1986-2005	1.3 °C	657 mm
2021-2040	2.7 °C	694 mm
2041-2060	3.5 °C	702 mm

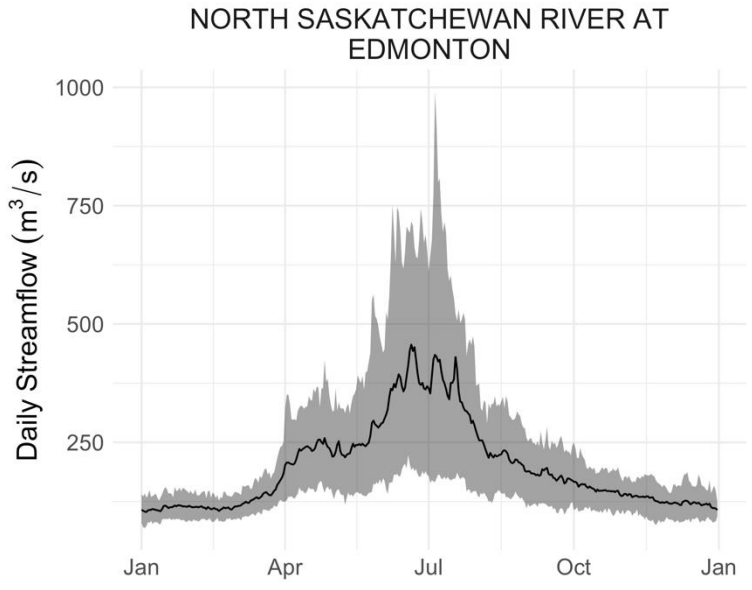


Climate in the upper North Saskatchewan sub-region is classified as Continental. The majority of the sub-region is classified as subarctic (*Dfc*) while the most westerly and highest elevations are considered Polar Tundra (*ET*). The region has relatively cool air temperatures, with monthly averages below freezing from October through March, but with mild summers. The sub-region has relatively high precipitation. Winter months are the driest in the region, with average monthly precipitation of less than 50 mm/month from September through April. Precipitation is highest during the summer, with July precipitation peaking at approximately 98 mm/month on average.

The western half of the sub-region is primarily mountainous and forested, much of which falls within Banff and Jasper National Parks. The eastern half of the region is composed of forested foothills, further east giving way to agriculture and more densely populated areas, including Edmonton, AB (NSWA 2005). The sub-region has very high relief, ranging from over 3300 m in the west to 650 m at Edmonton, AB. Higher elevations in the west have substantially colder air temperatures and a longer below-freezing period, as well as much higher precipitation than the warmer, more arid eastern reaches. The region is projected to become substantially warmer (up to 1.8°C by 2040). Modest increases in precipitation are projected (6% increase by 2040), while some studies project higher increases of 10% on average, though with substantial variability (MacDonald et al. 2012; Golder 2008).

3.1.1.14 Hydrology

Flow in the upper North Saskatchewan sub-region originates high in the Rocky Mountains along the Continental Divide. Streamflow follows a heavily snowmelt driven pattern, characterized by lower flows during the winter months and higher flows during the summer. Overall, streamflow in the North Saskatchewan peaks during July, which is later than in southern sub-regions owing mainly due to the cold, high elevations of the western reaches of the watershed. In addition to high winter snowpack, the sub-region also has substantial glacier coverage (over 1% of the land cover upstream of Edmonton, AB). Glaciers are estimated to contribute approximately 3.7% of the annual streamflow on average, but are critical to late-summer flows, where they average 7.4% of the July-September discharge (Marshall et al. 2011). Annual runoff in the sub-region is 223 mm, making it the most productive sub-region in the study area, while inter-annual flow variability was 21%, which is the lowest in the study area. There is high spatial variability in runoff within the sub-region, with water generation several times higher in the Rocky Mountains. For instance, runoff is approximately 900 mm upstream of Abraham Lake, while east of the Foothills, runoff is less than 50 mm in most sub-basins (Kienzle 2012).



Flow Statistics	
Regulation Level	*Regulated*
Gross Drainage Area	28,100 km^2
Contributing Area	96%
Runoff	223 mm
Incremental Runoff	223 mm
Inter-Annual Flow Variability	21%
Allocated Water	591,949 dam^3

3.1.1.15 Licensing and Regulation

The upper North Saskatchewan sub-region has relatively high runoff and little water demand; only 591,949 dam^3 of annual runoff is allocated, qualifying as “Low” water stress (OECD 2019). Water demands are highest for commercial (420,600 dam^3), municipal (146,000 dam^3), and industrial (20,400 dam^3) uses, which include hydroelectric power generation, oil and gas extraction, mining, and agriculture/irrigation as well as demand for the City of Edmonton and smaller municipalities (NSWA 2005).

Streamflow in the sub-region is regulated by two major dams. The Bighorn Dam is located upstream of Nordegg, AB and regulates flow in the mainstem of the North Saskatchewan River, creating Lake Abraham which has a live storage of 1,405,000 dam^3 at full capacity. Bighorn Dam is the largest hydroelectric power producer in Alberta and is managed by TransAlta (TransAlta 2019). The Brazeau Dam is located on the Brazeau River a major tributary of the North Saskatchewan River originating in the mountains of Jasper National Park. The Brazeau Dam is located near Drayton Valley, AB, has a live storage of 487,000 dam^3, and is primarily used for power generation (NSWA 2005; TransAlta 2019).

3.1.1.16 Summary and Future Outlook

The upper North Saskatchewan sub-region is characterized by high runoff which is strongly controlled by snowpack and snowmelt originating along the Rocky Mountains. Much of the headwaters lie within Banff and Jasper National Parks, however much of the Front Ranges and Foothills of the sub-region do not have formal protection. Additional runoff is supplemented by glacier melt, which is important in maintaining late summer streamflow and regulating water temperatures. The sub-region contains two major hydroelectric projects which, in addition to power generation, also serve to regulate streamflow by increasing low-flow periods and dampening peak flows. Future climate conditions will likely lead to less reliable snowpack and overall substantially less reliable precipitation as well as continued glacier retreat (Marshall et al. 2011). These factors may yield lower runoff from this sub-region in the future, which will increase water scarcity and likely negatively affect power generation potential. The sub-region currently has relatively low flow variability; however, decreased snowpack and glacier melt will likely increase inter-annual variability in the coming decades, which will also likely have a negative impact on power generation potential.

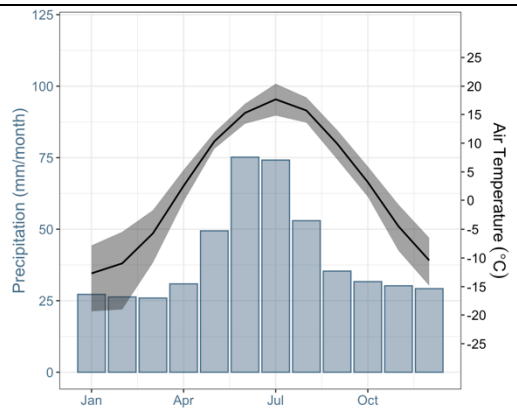
Middle North Saskatchewan River

Natural Ecoregions
Boreal and Parkland

Headwater Source
Upper North Saskatchewan River

3.1.1.17 Climate

Period	Average Air Temperature	Annual Precipitation
1986-2005	2.5 °C	488 mm
2021-2040	3.9 °C	518 mm
2041-2060	4.7 °C	522 mm

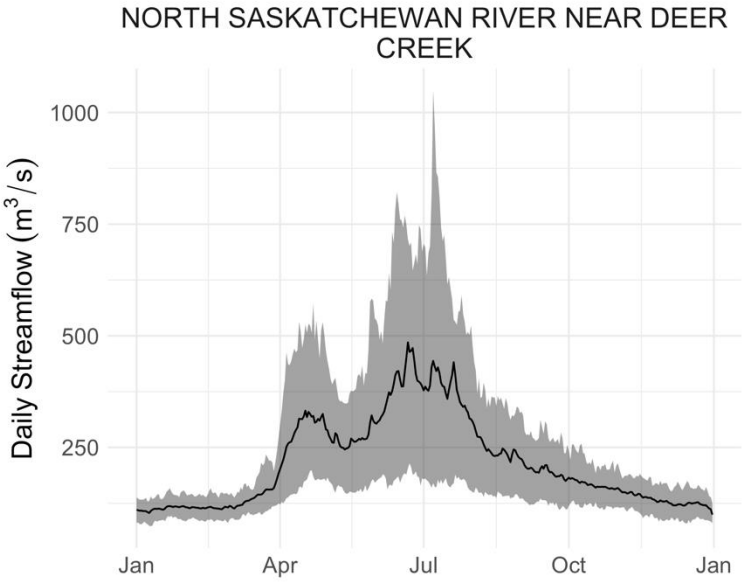


Climate in the middle North Saskatchewan sub-region is classified as Continental. The majority of the sub-region is classified as warm-summer humid continental climate (*Dfb*) while some north and east margins are considered subarctic (*Dfc*). The region has relatively cool air temperatures, with monthly averages below freezing from November through March, and warm summers. The sub-region has low precipitation. Winter months are the arid in the region, with average monthly precipitation of less than 30 mm/month from October through April. Precipitation is highest during the summer, with June precipitation peaking at approximately 75 mm/month on average. Much of the land cover in this sub-region is agricultural, with sparse forested areas, primarily in the north, and low population-density. The region is projected to become substantially warmer (up to 1.8°C by 2040) and slightly wetter (7% more annual precipitation by 2040).

3.1.1.18 Hydrology

Flow in the middle North Saskatchewan sub-region predominantly originates from its headwaters in the upper North Saskatchewan River in the Rocky Mountains. This is demonstrated by relatively high total runoff (118 mm) but low incremental runoff (18 mm), indicating most streamflow originates outside of the sub-region (i.e. west of Edmonton, AB). Streamflow in the sub-region follows a largely snowmelt-dominated pattern, very closely following the upper North Saskatchewan sub-region. In addition, a second, smaller peak is discernible in late April/early May, coinciding with snowmelt within boreal and parkland portions of this sub-region. These areas are much warmer and drier than in the westernmost

mountain headwaters and therefore snow melts much earlier in the spring. Inter-annual flow variability is 21% in the sub-region (the same as the upper North Saskatchewan River sub-region), which is the lowest variability in the study area. Large portions of the sub-region are non-contributing, particularly in the east, while almost all of the North Saskatchewan River headwaters contribute to streamflow. Over the entire sub-region the contributing area is 73%, meaning roughly half of this sub-region is hydrologically disconnected from the mainstem.



Flow Statistics	
Regulation Level	*Regulated*
Gross Drainage Area	57,200 km^2
Contributing Area	73%
Runoff	118 mm
Incremental Runoff	18 mm
Inter-Annual Flow Variability	21%
Allocated Water	1,261,701 dam^3

3.1.1.19 Licensing and Regulation

Approximately 1,261,701 dam^3 of the water in the middle North Saskatchewan sub-region is allocated, qualifying as “Moderate” water stress (OECD 2019). Unlike its headwaters, this sub-region generates little water and has substantial allocations, meaning users rely on streamflow from upstream headwaters to satisfy water demands. Allocations in this sub-region are largely classified as ‘Commercial’ (575,000 dam^3), though the sub-region also has substantial industrial users (56,800 dam^3), contains several urban centres (including the City of Edmonton), and has substantial agricultural land use (NSWA 2005).

Although streamflow is regulated by two dams located upstream in the upper North Saskatchewan River sub-region, there are no major dams on the mainstem in this sub-region. Two control structures are located on the Vermilion River which regulate flow, mitigate flooding, and maintain reservoirs for municipal and irrigation consumption during late-season low flow periods (Golder Associates 2009).

3.1.1.20 Summary and Future Outlook

Streamflow in this sub-region is determined almost entirely by upstream inputs and little flow is generated within this arid and primarily non-contributing area. As such, although the North

Saskatchewan River maintains relatively high streamflow throughout the year, major tributaries, such as the Vermilion River, dry up in the late summer (NSWA 2005; Golder Associates 2009). Given this dynamic, water demands that are not associated with the mainstem could experience much higher scarcity than is captured in the sub-region wide statistic. Notably, storage facilities are required in the Vermilion River region to mitigate this seasonality. Although precipitation is projected to increase slightly under future climate change, substantial increases in air temperatures are likely to substantially increase evaporation rates and create less reliable streamflow, particularly on tributaries in the region, which will bring about more local water shortages. In addition, given that much of the area in this sub-region is not hydrologically connected to the North Saskatchewan River, engineered drainage networks could have important impacts on wetland environments and local water supply (NSWA 2005; Golder Associates 2009).

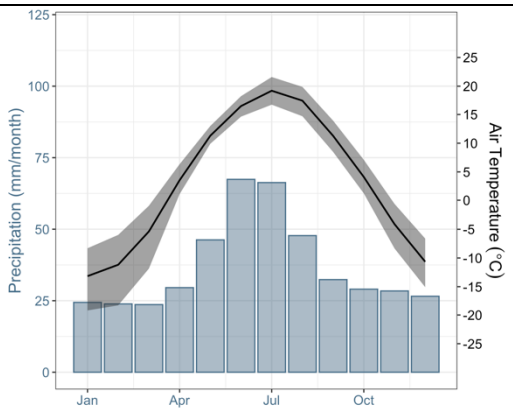
Lower North Saskatchewan River

Natural Ecoregions
Parkland, Boreal, and some Grassland

Headwater Source
North Saskatchewan River, Battle River

3.1.1.25 Climate

Period	Average Air Temperature	Annual Precipitation
1986-2005	3.2 °C	446 mm
2021-2040	4.6 °C	468 mm
2041-2060	5.4 °C	470 mm

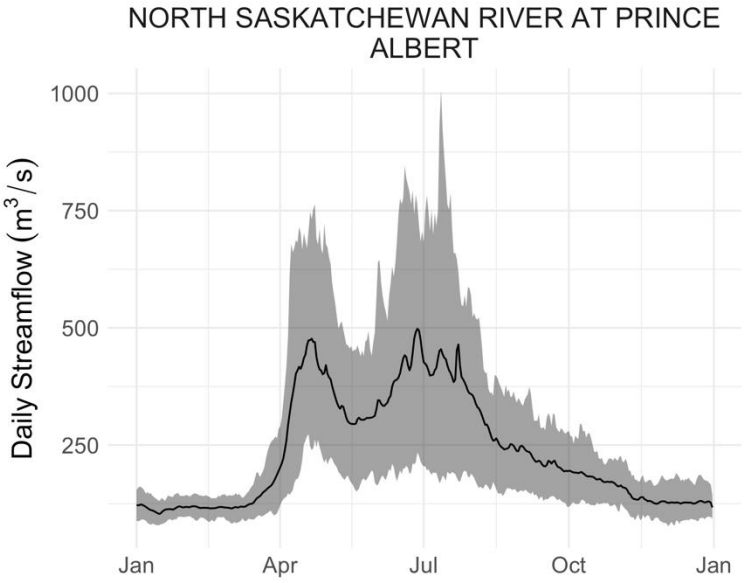


The climate in the lower North Saskatchewan sub-region is continental, with the sub-region classified as having a warm-summer humid continental climate (*Dfb*). The region has relatively cool air temperatures, with monthly averages below freezing from November through March, and warm summers. The sub-region has low precipitation. Winter months are arid in the region, with an average monthly precipitation of less than 30 mm/month from October through April. Precipitation is highest during the summer, with June precipitation peaking at approximately 70 mm/month on average. Much of the land cover in this sub-region is agricultural (48%) or native grassland (17%), with sparse forested areas, primarily in the north, and low population-density (SWA 2007). The region is projected to become substantially warmer (up to 1.8°C by 2040) with a modest annual increase (5%) in precipitation.

3.1.1.26 Hydrology

Streamflow in the lower North Saskatchewan sub-region predominantly originates from its headwaters in the upper North Saskatchewan River in the Rocky Mountains. This is demonstrated by its moderate total runoff (57 mm) but low incremental runoff (6 mm), indicating that most streamflow originates west of Edmonton, AB. Streamflow in the sub-region follows a largely snowmelt-dominated pattern, very closely following the upper and middle North Saskatchewan sub-regions. In addition, a second peak is discernible in late April/early May, coinciding with snowmelt within the lower elevations of this and the middle North Saskatchewan sub-regions. These areas are much warmer and drier than in the western mountain headwaters and therefore melt much earlier in the spring. Inter-annual flow

variability is 23% in the sub-region, which is slightly higher than the upper and middle North Saskatchewan River sub-regions. Since little runoff originates in this sub-region, it is likely that inter-annual variability on tributaries in this sub-region are much more variable than on the mainstem. In addition, many tributaries experience zero flow during part of the year (SWA 2007). Only approximately 55% of the total drainage area contributes to streamflow, meaning much of this sub-region is non-contributing.



Flow Statistics	
Regulation Level	*Regulated*
Gross Drainage Area	131,000 km^2
Contributing Area	55%
Runoff	57 mm
Incremental Runoff	6 mm
Inter-Annual Flow Variability	23%
Allocated Water	2,128,432 dam^3

3.1.1.27 Licensing and Regulation

The lower North Saskatchewan sub-region has approximately 2,128,432 dam^3 of its water allocated, which includes two large licenses with high return flows in the Battle River, qualifying as "Medium" water stress (OECD 2019). Unlike its headwaters, this sub-region generates little water and has substantial allocations, meaning it relies on streamflow from upstream to satisfy water demand. Licenses in the sub-region are largely designated as 'Habitat Enhancement' for wetland restoration, though the sub-region also contains substantial agricultural, irrigation, and water management demand (SWA 2007).

Streamflow is regulated by two upstream dams (Brazeau and Bighorn) located in the upper North Saskatchewan River sub-region, which have a combined live storage capacity of about 25% of the mean annual flow of the river (SWA 2007). While there are no major dams on the mainstem in this sub-region, there are twelve significant water infrastructure projects in the sub-region which are largely used for water storage, flood control, and lake level stabilization (SWA 2007). None of these projects substantially impact flow patterns on the mainstem, though they could have important local effects.

3.1.1.28 Summary and Future Outlook

Streamflow in this sub-region is determined primarily by upstream inputs and little flow is generated within this arid and primarily non-contributing area. Although the North Saskatchewan River maintains relatively high streamflow throughout the year, major tributaries like the Battle River, and smaller tributaries such as the Sturgeon River and Pipestone Creek, experience high flow variability and very low streamflow in the late summer (SWA 2007). Given this dynamic, water demands that are not associated with the mainstem could experience much higher scarcity than is captured in the sub-region wide statistic. Many of the small storage facilities in this sub-region are used to stabilize water levels and mitigate flooding in relatively low-relief areas. Under future climate change, precipitation is projected to increase marginally on an annual scale. However, limited increase in summer precipitation combined with a substantial increase in air temperature is likely to increase evaporation rates and decrease the reliability of streamflow, particularly on tributaries in the sub-region. In addition, this dynamic will likely lower water levels in lakes and wetlands. Overall, climate change is likely to bring about more local water shortages and additional water stress in the coming decades in the sub-region.