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Canada

Environment and Climate Change Canada Agency Report

Prepared for the Mackenzie River Basin Board

November 2020

Science, Monitoring and Information

<u>Water Quality Monitoring and Surveillance Report</u>

The Water Quality Monitoring and Surveillance (WQMS) Division of ECCC's Science and Technology Branch supports the Federal government's water quality-related obligations under various acts and agreements e.g. Canada Water Act; Canadian Environmental Protection Act, 1999 (CEPA); Fisheries Act; International Boundary Waters Treaty Act; Federal/provincial/territorial agreements; Canada-United States water quality agreements; and, Federal Sustainable Development Strategy. Responsibilities include transboundary waters, waters on federal land, and waters of national importance. WQMS main activities consist of water sample collection, data analysis and interpretation, scientific advice, and reporting on results.

<u>A risk-based adaptive management framework</u> (Contact: arash.shahsavarani@canada.ca)
ECCC's Freshwater Quality Monitoring and Surveillance (FWQMS) program provides water quality monitoring in Canada through a risk-based adaptive management framework. Decisions on where and how to monitor watersheds are based on the level of risk, helping to ensure focused and objective programming. Risk is assessed based on the nature, probability, frequency and severity of threats to the watersheds. Through this framework, and ongoing collaboration with our provincial, territorial, other government and non-governmental partners, the federal government provides targeted, adaptable and efficient monitoring to ensure quality of service delivery and value for money for Canadians. The FWQMS program framework includes three key components:

(i) A regular review of ECCC's roles and responsibilities to ensure that our activities are consistent with our departmental mandate;
(ii) A regular assessment of the level of risk for watersheds using three types of analyses:

- risk-based site-specific analysis (described below) of all monitoring sites in ECCC's current monitoring network, based on chemical and biological measurements, upstream human activities, and vulnerability of the ecosystem;
- risk-based basin-level analysis (described below) of all watersheds across Canada to identify areas where monitoring should be conducted or the scope of monitoring enhanced. The analysis is based on the aggregation of multiple point source and non-point source threats;
- statistical power analysis to assess the ability of the monitoring network to accurately detect change to ensure optimal sampling frequencies; and

(iii) A Quality Management System that focuses on continuous program improvement through a Plan-Do-Check-Improve model.

Risk-based analysis (RBA) is done at the monitoring site level to assess the likelihood, extent and potential severity of impacts from human activities on water quality and the aquatic ecosystem. For each monitoring site, risks are scored between 0 and 10, weighted by risk group based on a list of 14 criterion (e.g., point sources, guideline exceedances, water uses) and aggregated to obtain an overall score out of 100. The higher the score, the higher the potential risk to water quality is at the site (see Figure 1). The WQMS division aims to review RBA sites scores every 5 years.

The risk-based basin analysis (RBBA) is a spatial analysis tool used to quantify the relative risk to water quality from 16 human activities in 1138 sub-sub-drainage areas. These include stressors like point sources of pollution, various types of land use and changes, deposition of atmospheric contaminants and climate change. The RBBA tool aggregates these stressors and classifies basins on a relative risk scale (see Figures 1).

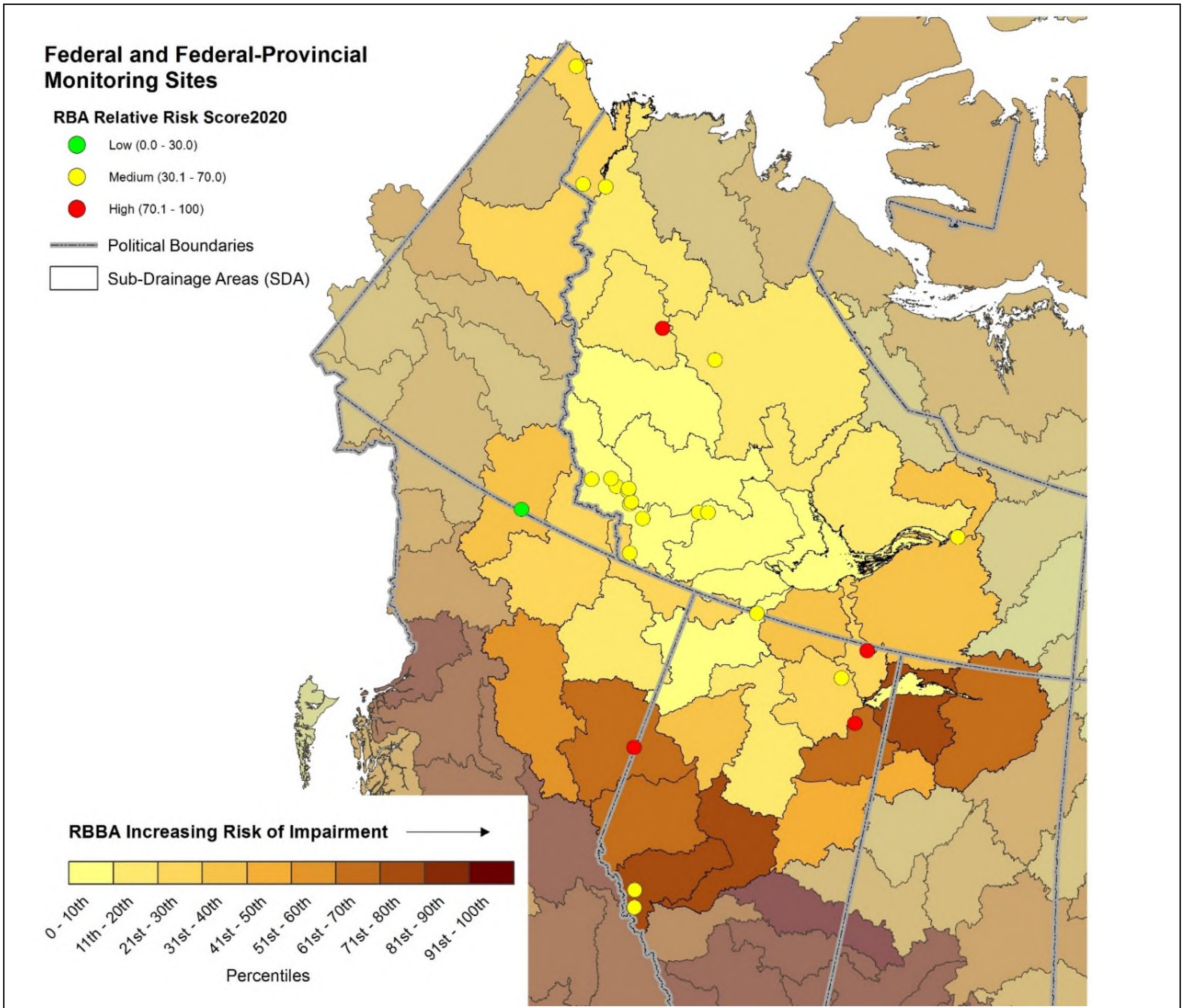


Figure 1: Results of RBBA and RBA analyses for basins of interest to MRBB, 2020.

Open Data (https://open.canada.ca/data/)

ECCC provides credible, scientifically sound information to support decision making. The public release of our water quality monitoring data supports the Government of Canada open data initiative by providing access to water quality data to Canadians. Since January of 2017, national long-term water quality monitoring data are made available to the public on the Government of Canada's Open Data portal, in both English and French. The datasets include data for nutrients, metals, major ions, and other physical-chemical variables from 2000 covering 22 basins across Canada. For the few monitoring sites located outside those basins, links are provided where the data are already available online or provided by partners. As of fall of 2017, these data files are refreshed on a monthly basis. In addition, ECCC is posting additional water quality datasets from programs such as automated monitoring and surveillance (e.g., pesticides) to Canada's Open Data Portal.

Other online water quality data sources from ECCC include:
Acid Sensitive Lakes Study and Turkey Lakes Watershed Study,
Clean Air Regulatory Agenda Freshwater Inventory and Surveillance of Mercury,
Great Lakes Basin (GLB) Monitoring and Surveillance,
National Water Quality Pesticides Surveillance Data,
Canadian Aquatic Biomonitoring Network (CABIN),
Canadian Environmental Sustainability Indicators (CESI).

Of particular interest to MRBB, data for the following basins are published and regularly updated:

- Lower Mackenzie
- Peace-Athabasca

In addition, the most recent data pertaining to the ongoing Oil Sands Monitoring Program are available online through both ECCC (http://data.ec.gc.ca/data/substances/monitor/surface-water-quality-oil-sands-region/) and Alberta Environment and Parks (https://aws.kisters.net/OSM/applications/public.html?publicuser=Guest) data web portals. (contact: nancy.glozier@canada.ca).

Support to the MRBB (Contact Nancy.Glozier@canada.ca)

The Government of Canada remains committed to the Mackenzie River Basin Transboundary Waters Master Agreement and to continuing cooperation on water monitoring in the region and sharing data.

Environment and Climate Change Canada (ECCC) currently operates 26 stations throughout the Mackenzie Basin as part of the federal long term water quality network. Table 1 includes information on these stations, some of which have been in operation since the 1960's. Planned sampling events for all sites total 125 per year as well as approximately 10% additional samples for Quality Assurance/ Quality Control. Samples are analyzed for a range of parameters including nutrients, metals, major ions, physicals and, at a subset of sites, organics (pesticides and Polycyclic Aromatic Hydrocarbons (PAHs)).

Table 1. ECCC Water Quality Monitoring Sites in the Mackenzie River Basin

Station	Ter/ Prov	Latitude	Longitude	Start Date of Long Term Monitoring	Status	Frequency (planned samples/yr)
Great Bear R./Great Bear Lake	NT	65.1283	-123.5508	1969	Active	3
Liard River/Fort Liard	NT	60.2414	-123.4753	1998	Active	6
Liard River/Mouth	NT	61.7425	-121.2278	1960	Active	6
Lockhart River/ Artillery Lake	NT	62.8889	-108.4658	1969	Active	3
Mackenzie R./Norman Wells	NT	65.2739	-126.8442	1960	Active	6
Mackenzie R./Strong Point	NT	61.8164	-120.7917	1992	Active	6
Mackenzie River/Arctic Red R.	NT	67.4558	-133.7531	1960	Active	6
Peel River/Ft. McPherson	NT	67.2589	-134.8886	1960	Active	4
Hay R./NWT-Alta. Boundary	NT	60.0036	-116.9719	1969	Active	4
Slave River/Fitzgerald	AB	59.8575	-111.5987	1960	Active	9
Flat River/Mouth	NT	61.5297	-125.4106	1972	Active	3
Flat River/Pk. Boundary	NT	61.4278	-126.6299	1988	Active	3
Prairie Creek/ New park Boundary	NT	61.5219	-124.7126	2010	Active	3
Prairie Creek/above Cadillac Mine	NT	61.5583	-124.8125	2003	Active	3

Table 1. continued						
Station	**Ter/ Prov**	**Latitude**	**Longitude**	**Start Date of Long Term Monitoring**	**Status**	**Frequency (planned samples/yr)**
Prairie Creek/below Cadillac Mine	NT	61.5561	-124.8108	2003	Active	3
Prairie Creek/Mouth	NT	61.2844	-124.4456	1988	Active	3
Prairie Creek/Old Park Boundary	NT	61.3485	-124.4153	2001	Active	3
S.Nahanni R./Nahanni Butte	NT	61.0991	-123.5899	1988	Active	3
S.Nahanni R./Virginia Falls	NT	61.6361	-125.7969	1996	Active	3
Peace River at Peace Point	AB	59.1193	-112.4502	1967	Active	9
Athabasca River at 27th Baseline	AB	58.1743	-111.3664	1989	Active	9
Athabasca River at Highway 16	AB	53.0417	-118.0872	1973	Active	4
Athabasca River above Athabasca Falls	AB	52.6644	-117.8808	1972	Active	4
Liard River at Upper Crossing	YT	60.0477	-128.9018	1983	Active	12
Peace River above Alces River	BC	56.1260	-120.0600	1984	Active	12
Petitot River below Hwy 77	BC	59.98421	-122.92784	2012	Active	4

Update to MRRB on Whirling Disease - Operational Impacts to Field and Laboratory Operations (Contact: Paul.Klawunn@canada.ca; Nancy.glozier@canada.ca)

While Whirling Disease has only been recently introduced and detected in Canada, it has been present in the USA for more than 20 years and follows a cycle of activity and relative dormancy. This parasite will eventually infect many prairie river systems leading into Lake Winnipeg, Hudson's Bay and potentially north through the Athabasca and Peace rivers. Whirling disease has no known human health effects (WDI 2006) and is an infectious disease of finfish caused by a parasite, *Myxobolus cerebralis*. There are no treatment options currently available and containment and prevention are the focus for minimizing the spread of the parasite. Conventional wastewater treatment practices are not totally effective at deactivating the parasite.

To date, the Bow, Oldman, Red Deer and North Saskatchewan River watersheds have been officially declared as whirling disease impacted (https://www.alberta.ca/whirling-disease.aspx). Watersheds not officially declared affected but logically implicated as being impacted may include:

- Milk River Watershed– receives water from the St. Mary's diversion which is in the Oldman River Watershed.
- South Saskatchewan River Watershed – both the Bow River and the Red Deer River join the South Saskatchewan River. The Bow River joins upstream of the PPWB sampling site, the Red Deer River downstream.

Other watersheds that may be implicated and are listed as at risk include:

- Athabasca River Watershed – with headwaters in Jasper National Park and outflows into the Peace Athabasca Delta (PAD), Lake Athabasca and eventually through to the Slave River.
- Peace River Watershed – with headwaters in British Columbia and outflows into the Peace Athabasca Delta (PAD), Lake Athabasca and eventually through to the Slave River.

In response to this new threat, WSTD has liaised and reviewed protocols with Alberta Environment and Parks Canada to implement field and laboratory processes to mitigate spread of this parasite (for more information: https://www.alberta.ca/whirling-disease.aspx. In the field, personnel use a combination of dedicated field equipment and sampling equipment decontamination between sites and risk areas to mitigate the spread of the organism. For all samples from Alberta and the Alberta/Saskatchewan border, staff also are required to wipe down the interior of the shipping cooler and each individual sample bottle with a disinfecting wipe prior to shipping to the lab. Our labs have implemented a process whereby the instrument waste and any unused sample is collected and treated prior to disposal into municipal sewage. Currently these modifications for field and laboratory processes have been applied to 6 of the 12 PPWB water quality monitoring sampling sites (all sites on the AB/SK border) and all of the sites in the Lower Athabasca River during sampling for Oil Sands related water quality and biomonitoring sampling.

Hydrometric Monitoring in the Mackenzie River Basin

Environment Canada and Climate Change (ECCC) monitors water level and flow at 348 hydrometric stations in the Mackenzie River Basin (MRB) through its water collection and dissemination branch, the Water Survey of Canada (WSC). Table 2 indicates the number of stations located in the MRB from each province or territory. The vast majority of these stations provide real-time data to the public through WSC's real-time website (https://wateroffice.ec.gc.ca/search/real_time_e.html). WSC operates these stations in support of provincial bilateral agreements, flood monitoring, power generation, climate studies and other scientific research.

Table 2 Hydrometric Stations Monitored by ECCC

Province / Territory	Hydrometric Stations
Yukon	14
Northwest Territories	95
British Columbia	45
Alberta	185
Saskatchewan	9

A summary of WSC monitoring operations in the Mackenzie River Basin from provincial and territorial jurisdictions follows:

Saskatchewan

Saskatchewan experienced high spring flows, especially north of Lake Athabasca. High flows were also experienced from summer through fall due to rainfall. Flows are expected to remain high through winter. One trip to the area was cancelled in April due to COVID-19. COVID-19 also limited trips to Douglas River near Cluff Lake until September. As of September, all stations in the Mackenzie River Basin area have been visited. Discharge measurements were collected, discharge rating curves have been validated and all stations are transmitting data.

Alberta

Ice jams and overland flooding impacted several stations from April through to late July. WSC recorded some of the highest water levels on record. Gauges at Athabasca River Upstream of Grande Rapids (07CC908) and Peace River at Peace Point (07KC001) were destroyed by ice jams. Real-time data transmission was lost at these sites until temporary gauges were installed in their place. COVID-19 restrictions impacted field/office delivery of programs. Only critical work continued through the year since mid-March, incorporating Personal Protective Equipment and safety protocols. The cancellation of major employee training camps presented a challenge to staff development.

British Columbia

British Columbia experienced a wet summer and high flows were recorded during the summer as a result. The wettest August on record was experienced in the town of Smithers. Above normal flows were experienced at most stations this year. Nation, Parsnip, Halfway and Pine Rivers experienced particularly high flows. Despite COVID-19 constraints on technician mobility, hydrometric stations were effectively managed through the spring freshet and summer.

Northwest Territories and Yukon

Flows in the north, especially in southeast Yukon and southwest Northwest Territories (NWT) were well above average for the open water period. Snowpack in the eastern portion of the Yukon, and western portion of the NWT were above, or well above normal. Ice jams occurred at Hay River and a minor jam occurred at Fort Simpson. COVID-19 resulted in border restrictions that prevented pre and post break up visits for stations located in British Columbia but operated Yukon-based staff as well as for stations located in Alberta but operated by NWT-based staff. Alberta staff were able to conduct some visits during critical periods to critical gauges. Remote control boats were used during high flows to conduct discharge measurements. NuPoint satellite cameras were also used to capture daily images at select locations.

Meteorological Services Canada (MSC) Activities

Environment and Climate Change Canada's Canadian (ECCC) Meteorological Centre (CMC) launched the National Surface and River Prediction System (NSRPS) in Summer 2019. This system focuses on analyses and forecasts of near-surface (temperature, winds, humidity), surface (temperature, moisture, snowpack depth, density and Snow Water Equivalent (SWE), and surface runoff) and sub-surface (soil moisture) variables as well as precipitation, river flows and water levels. NSRPS consists of 5 component systems. Precipitation analyses are provided by the High Resolution Ensemble Precipitation Analysis (HREPA). HREPA runs the CaPA algorithm (Khedhaouiria et al., 2020).

At the surface, the Canadian Land Data Assimilation System – Satellite (CaLDAS-Sat) produces analyses while the High Resolution Deterministic Land Prediction System (HRDLPS; Deacu and Bélair, 2019) provides forecasts. CaLDAS-Sat and HRDLPS both include the new land surface scheme Soil Vegetation Snow (SVS; Alavi et al., 2016, Husain et al., 2016). The Deterministic Hydrological Prediction System (DHPS) simulates flow through the river network using the river routing model WATROUTE (Kouwen, 2010). DHPS also simulates the water level of major lakes. Finally, the Système de simulation Hydrodynamique Opérationnel (SHOP; Matte et al., 2017a, 2017b; Morin & Champoux, 2006) runs the hydrodynamic model, H2D2. H2D2 is implemented on a finite element domain with a variable mesh. This component provides water levels and velocities. The component systems are linked by 1-way coupling. Articles describing NSRPS in greater detail are in preparation.

HREPA, CaLDAS-Sat and HRDLPS are implemented over Canada at a 2.5-km resolution. Currently, DHPS is implemented at a 1-km resolution over six watersheds including the Mackenzie River basin. SHOP is implemented on the St. Lawrence. In the near- to mid-term, new domains for SHOP will be added on Lake Champlain/Richelieu River, on the Great Lakes connecting channels, and on the Peace-Athabasca delta.

Analyses are provided by HREPA (6-hourly), CaLDAS-Sat (6-hourly), DHPS (hourly), and SHOP (6-hourly). Twice-daily forecasts of 6 days are provided by HRLDPS and DHPS while SHOP provides 2-day forecasts four times per day. Ensemble versions of HRDLPS, DHPS and SHOP that provide daily 16-day forecasts with a 32-day forecast once per week will be available in the near- to mid-term.

In the Mackenzie River basin specifically, DHPS represents flows through the river network and water levels of 41 major lakes. In the near future, DHPS will also provide analyses and forecasts every 12 hours of precipitation landing on (P) and evaporation from (E) certain lakes (currently Lake Athabaska, Great Slave Lake and Great Bear Lake), as well as the total terrestrial runoff into the lake (R). The combination of P-E-R explains the simulated change in the lake's water level. The DZTR model (Yassin et al., 2019) to represent flows from regulated reservoirs has been implemented on Lake Williston (Bennett Dam). A novel method of data assimilation that propagates upstream information derived from observations is applied to near real-time data from 102 stations from ECCC's National Hydrological Service (NHS) and 96 stations from Alberta Environment and Parks (AEP). No diversions are represented in the Mackenzie River basin. However, 10% of the outflow from Lake Wollaston is directed towards this basin, as occurs naturally, with the remaining 90% flowing to the Churchill River basin.

In the Prairies, DHPS represents flows through the river networks of the Nelson and Churchill Rivers. Our representation of the Nelson River basin includes the Saskatchewan River as well Lake Winnipeg and its tributaries. The water levels of 54 major lakes are simulated. The DZTR model for regulated reservoirs has been implemented on 11 reservoirs. Observations are assimilated from 64 stations from ECCC's NHS, 53 stations from AEP, and from 88 USGS stations. In the near- to mid-future, calculations of P-E-R will be added for large lakes including Lake Winnipeg. In the Churchill River basin, 38 major lakes are represented, with the DZTR model implemented on Reindeer Lake. Observations are assimilated from 22 stations from NHS and 5 from AEP. As per the Nelson River basin, calculations of P-E-R will be added on major lakes in the Churchill River basin in the near- to mid-term. Five diversions are represented in the Nelson River Basin as well as the diversion of water from the Churchill to the Nelson River basin.

NSRPS is being actively developed. For instance, SVS does not yet represent freeze-thaw. A representation of these processes is expected to be added in the near- to mid-term. A representation of permafrost will then be added. For the snowpack, the first estimate is provided by model output. In the near-term, the horizontal limits of the snowpack will be guided by satellite data. Additionally, a correction will be applied to reduce the bias in the amount of snow over mountainous regions.

A 40-year surface and precipitation reanalysis (article in preparation) is under construction at CMC. Simulations for 2000-2018 are now available at a 10-km resolution while the period 1980-2000 is in production. The numerical analysis and prediction systems producing the reanalysis includes atmospheric (GEM), land surface (CaLDAS) and precipitation (CaPA) components. This reanalysis provides a historical context for near real-time analyses and forecasts. Furthermore, it permits the generation of hindcasts by various surface, hydrological and other models, by providing the required piloting fields.

Products

Products are in development to package the information provided by NSRPS. Currently, the anomalies of analyses SWE are available as an experimental product to a limited number of clients including NHS personnel. Separately, an image of the risk of user-specified amounts of surface runoff is calculated based on output from CMC's Global Ensemble Prediction System; the thresholds can be set to locally relevant values. The risk level is determined by the amount of runoff predicted as well as its degree of certainty. Furthermore, a dashboard is under discussion to present analyzed and forecast variables of interest, their historical context, and their verification against observations as the estimates are produced in near real-time. The possible variables might include precipitation, near-surface temperature, winds and humidity, snowpack depth and SWE, and river flows, and water levels, temperatures and velocities. Finally, precipitation is currently available as an average over the drainage area of a multiple river gauges.

Figures

a) b)

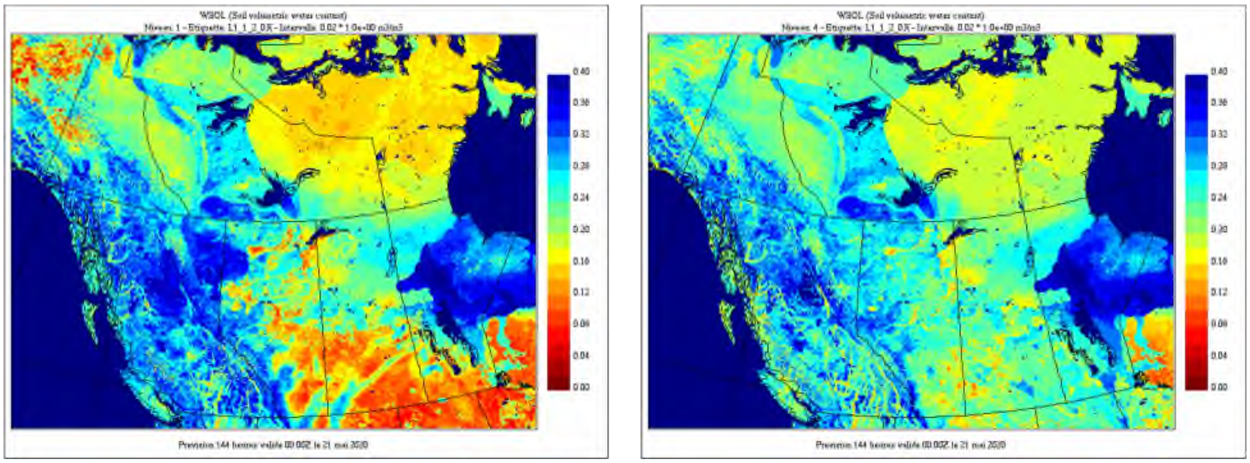


Figure 2: Day 6 forecast of soil moisture content from HRDLPS at a) 0-5 cm and b) 20-40 cm.

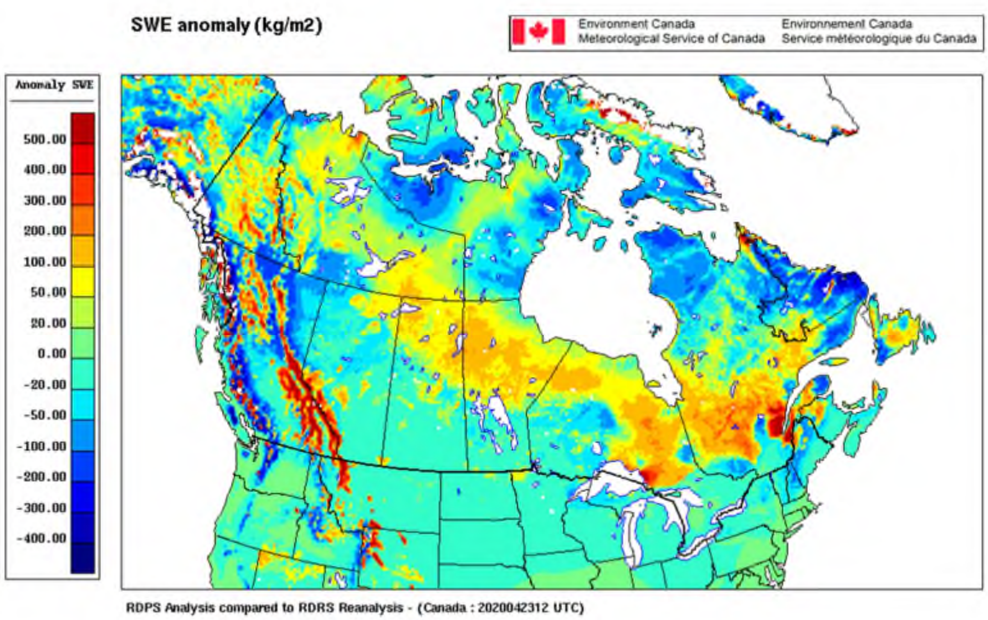
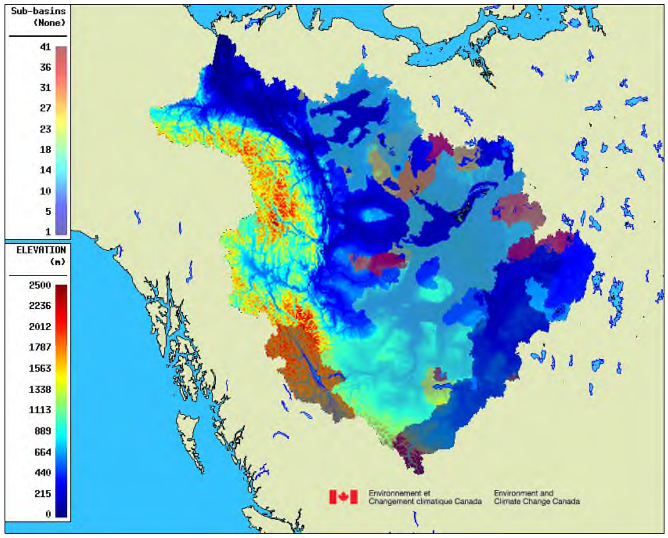
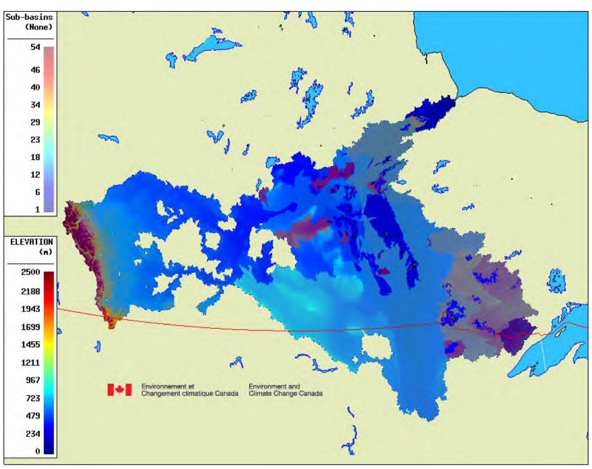


Figure 3: Anomaly of SWE for 23 April 2020 based on the analysis from the Regional Deterministic Prediction System and CMC's surface and precipitation reanalysis.

a)



b)



c)

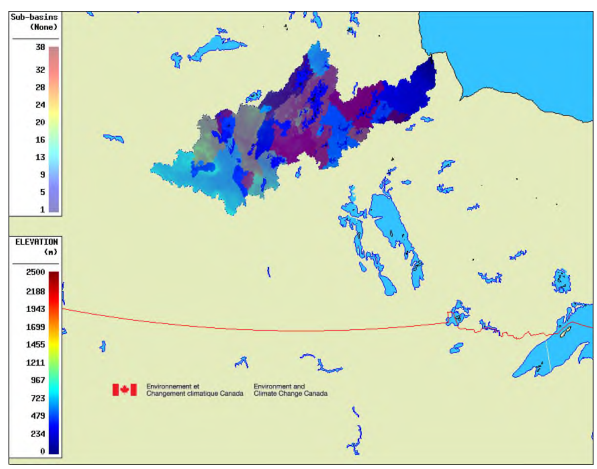


Figure 4: Modelling domains of the Deterministic Hydrological Prediction System and their defined sub-basins for a) the Mackenzie River basin, b) the Nelson River basin, and c) the Churchill River basin.

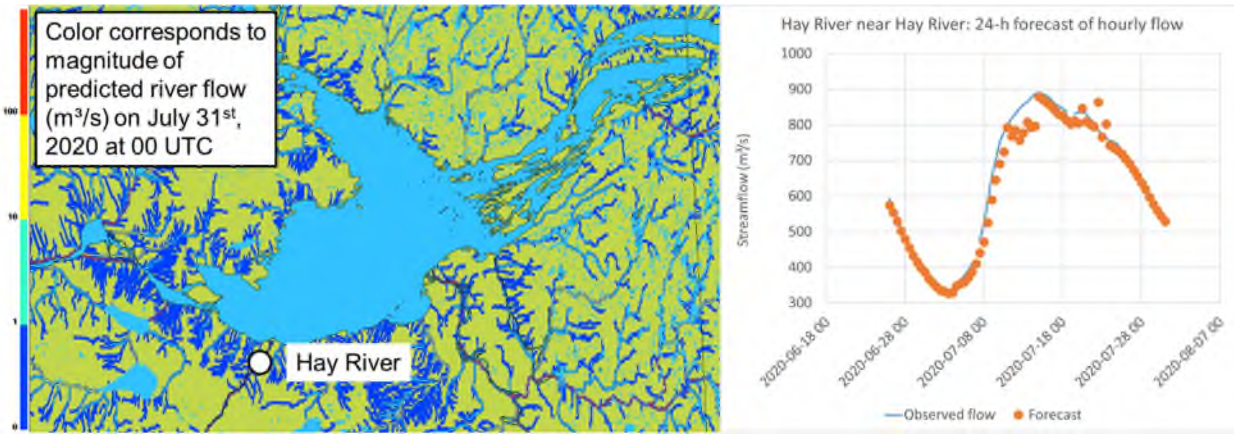
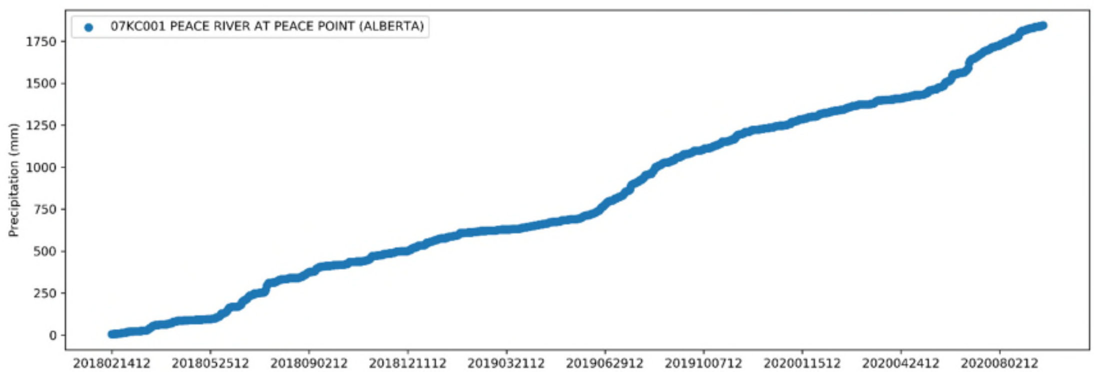


Figure 5: A comparison of the Day 1 forecast of river discharge at mouth of Hay River from the Deterministic Hydrological Prediction System versus observations.

a)



b)

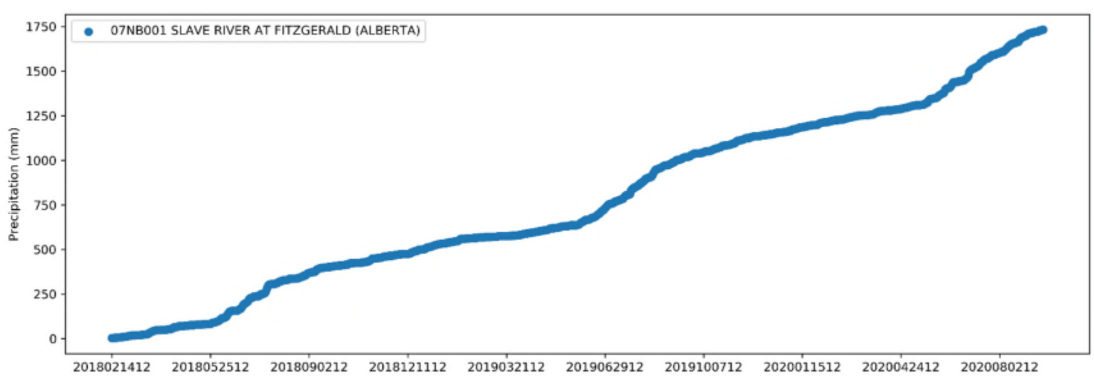


Figure 6: Precipitation from HREPA averaged over the drainage area of a river gauge on the a) Peace and b) Slave Rivers and accumulated over time.

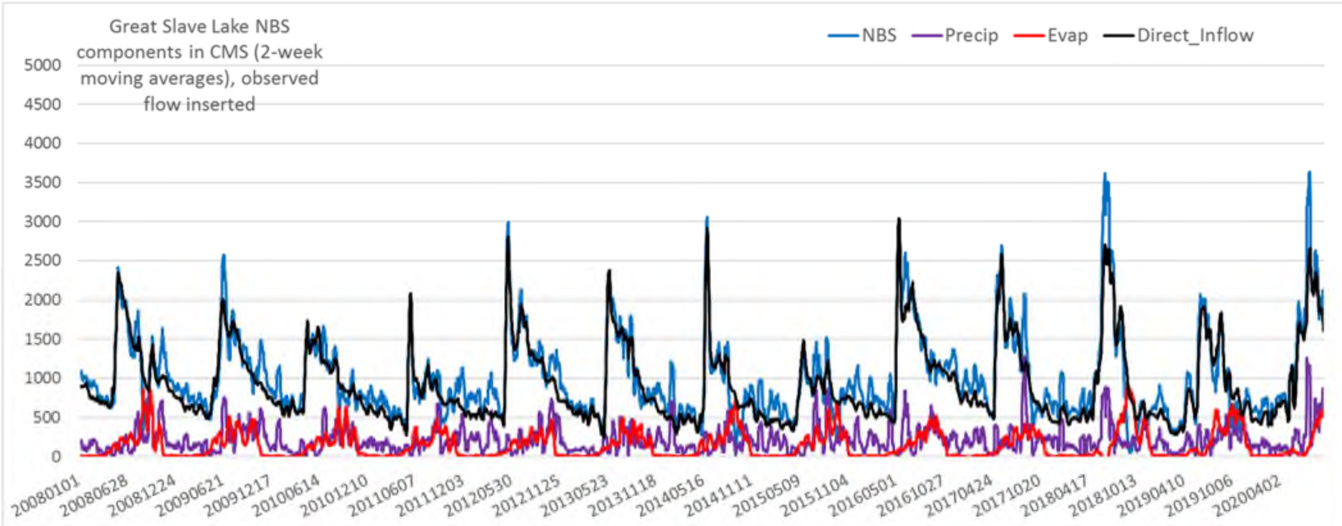


Figure 7: NBS component historical simulations for Great Slave. Simulations performed with GEM-Hydro (forced with ECCC's Regional Deterministic Reanalysis System) in open-loop mode and involving observed flow insertion. Direct Inflow is Great Slave Lake inflow from its direct watershed (not including Slave River inflow). Precip and Evap are overlake precipitation and evaporation, respectively.

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