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Problem statement and objectives

- Currently, there are no tools which account for the complexities of prairie hydrology and hydrography available to hydrological practitioners for calculating return-period flows and flooding at small scales on the Canadian Prairies.
- The need for such tools is especially great due to non-stationarity from the effects of climate change and surface drainage.
- The Prairie Hydrology Design and Analysis Product (PHyDAP) uses the research results of the Global Water Futures Prairie Water Project to produce a spatial dataset which will allow practitioners to determine return-period flows and flooded areas in a scientifically defensible manner, while incorporating changes in the local climate and land use.

Methodology

- The development and intended use of the PHyDAP data sets are shown schematically in Figure 1.
- The PHyDAP data set consists of sub-daily (hourly or 3-hourly) outputs from CRHM models including:
  - rainfall depths (on lakes and depressions)
  - evaporation depths (from lakes and depressions)
  - snowmelt depths (on lakes and depressions)
  - runoff depths from cropped uplands
  - streamflow depths (from basins)
- The CRHM outputs can be applied by practitioners as inputs to local-scale hydraulic models.
- The CRHM models are run for long time periods (1950 – 2100) using gridded historical meteorology and downscaled future climate simulations.
- The hydraulic model outputs can be used to estimate *changes* in return-period flows and flooded areas due to changes in climate and local drainage.

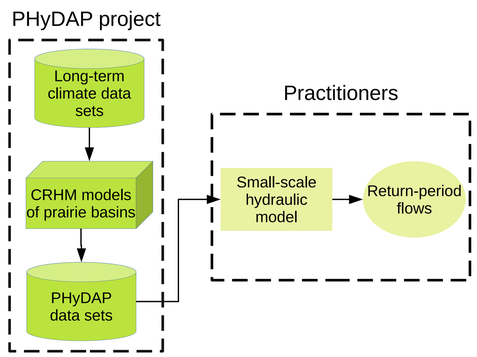

Figure 1: Schematic diagram of creation and use of PHyDAP data sets.

- Because developing CRHM models for each basin individually is very time-consuming, PHyDAP uses virtual basin models.
  - A virtual basin uses the same parameters for each basin of a given type, but local meteorological forcings.
- Each basin model developed for PHyDAP is based on the classification of prairie basin types undertaken by Prairie Water for 4175 basins classified by Wolfe st al (2019), as mapped in Figure 2.
- The development and validation of the virtual basin models is described in detail by Spence et al (2022a, 2022b) and He et al. (2023) .
- The hydrological basins are from the HydroSHEDS database (Lehner and Grill, 2013), each having an area of approximately 100 km².
- In addition to the virtual basins, PHyDAP also has CRHM models of 346 lakes in the Canadian Prairie ecozone. The lake models output sub-daily rainfall, snowmelt and evaporation depths.

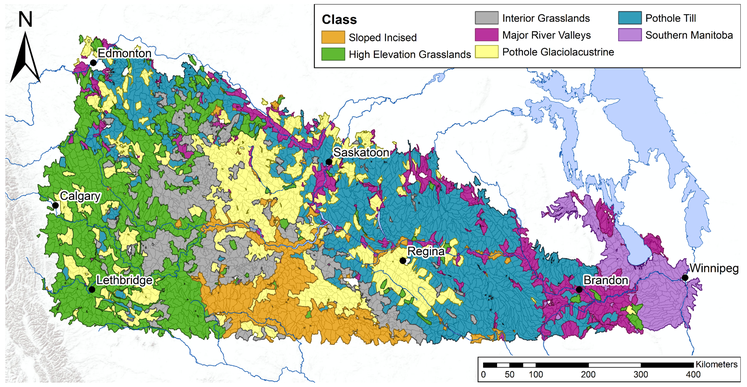

Figure 2: Prairie Water basin classes. From Wolfe et al. (2019).

Climate forcing data

- The PHyDAP CRHM models require sub-daily inputs of precipitation, air temperature, humidity, wind speed and (optionally) incoming shortwave solar radiation.
- To allow for the assessment of uncertainties in the modelled outputs, the PHyDAP CRHM models were run using several sets of gridded climate forcings as inputs.
- The gridded data sets were clipped to the Canadian Prairie ecozone boundaries using the **datatool** script (https://github.com/kasra-keshavarz/datatool) and basin-averaged values were computed for each variable for each time interval using the Python program **EASYMORE** (pypi.org/project/easymore/).
- All PHyDAP CRHM models have now been executed using the following forcings, resulting in 17 data sets, as shown in Table 1.

Table 1: PHyDAP meteorological forcing data sets.

Dataset	Source	Duration	Interval
RDRS	Climate stations	1981 – 2018	Hourly
CanRCM4_Cor_WFDEI-GEM-CaPA - 15 ensemble members	Combined reanalysis (CanRCM4) and downscaled/bias adjusted future climate simulations (RCP 8.5 business as usual scenario)	1951 – 2100	3-hourly
ERA5	Reanalysis	1950 – 2020	Hourly

PHyDAP output data sets

- The PHyDAP model outputs are now freely available online at the Federated Research Data Repository (FRDR) at https://doi.org/10.20383/102.0694. Note that the data are distributed under the Creative Commons Attribution 4.0 International (CC BY 4.0) licence.

Limitations

- The PHyDAP outputs contain all the uncertainties of the a) the hydrological model algorithms, b) the hydrological model parameters and c) the model forcings.
- Although the virtual basin model parameters are believed to give reasonable values for the rainfall, snowmelt, evaporation and runoff (Spence et al., 2022a, 2022b), the basin discharge depths may be grossly in error in a given basin.
- The reason is that the depressional storage in a given basin may not agree with the value in the PHyDAP CRHM model, which is based on the median value for each class.
  - The distributions of non-effective fractions (the fraction which does not contribute flows to the outlet at least one year in two) of each basin class are plotted in Figure 3. The values in many classes vary widely from their median values.
  - In these cases, it may be necessary to replace the PHyDAP simulated basin discharges with values calculated using the Hysteretic and Gatekeeping Depressions Model (HGDM), which is under development.

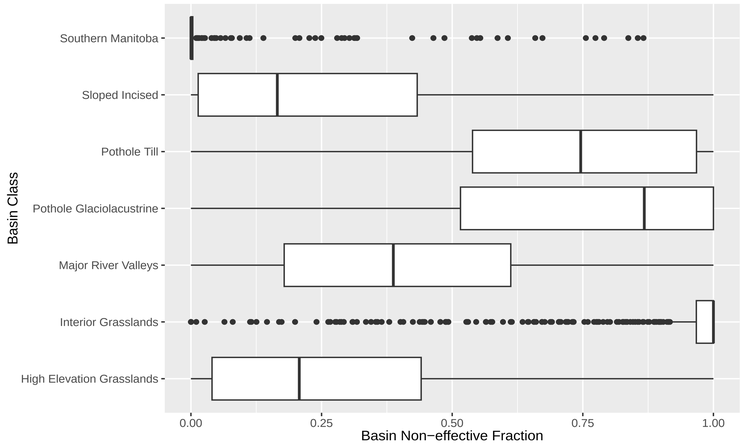

Figure 3: Box plot of distributions of PHyDAP basin non-effective fractions by basin class. The median value for each class is indicated by the vertical bar; the boxes encompass the upper and lower quartiles.

Conclusions

- It is believed that the PHyDAP model outputs may be useful, despite their many limitations as their purpose is to aid in the estimation of changes in return period flows and forcings.
  - When calculating the hydrological effects of climate change, many of the limitations in the PHyDAP modelled values will cancel. This will also be true when running a hydraulic model with varying drainage scenarios forced with the same PHyDAP data set.
- The basin discharge depths should be used with caution as they may not reflect the depressional storage within a given basin.

Acknowledgments

- The authors acknowledge funding support from Global Water Futures and Environment and Climate Change Canada.
- Early iterations of PHyDAP were used by practitioners from the Prairie Water user community to guide full-scale development of the product.

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