Virtual basins modelling approach to assess effects of climate change and wetland drainage on streamflows in the Prairie

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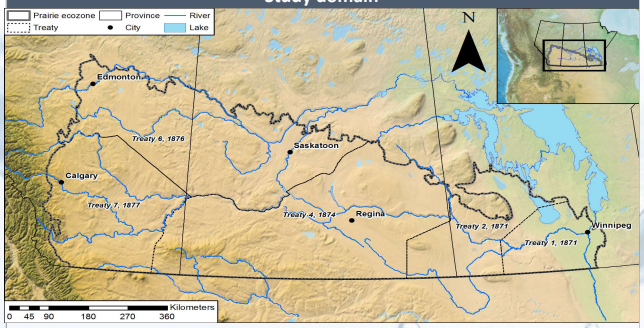
Motivation

- Hydrological models have been emerged as essential tools for successful implementation of regional to continental scale river basin planning initiatives.
- To date, there has not been an integrated regional level model developed for the Prairie.
- Prairie Water, which is part of the Global Water Future, aims to provide recommendations for water management that will improve the resilience of Prairie communities via improved understanding of water cycling.
- As part of the Prairie Water programme, this study is motivated by the need to understand how the Canadian Prairie Region functions hydrologically.

Objectives

- The broad aim of this study is to determine how the water cycle is partitioned across the diversity of Canadian Prairie watersheds under a range of land management and climate scenarios. More specifically, it aims:
  - To model the Canadian Prairie Pothole Region in a virtual manner using CRHM;
  - To assess effects of wetland management scenarios on Prairie streamflows; and
  - To assess effects of climate change on Prairie streamflows.

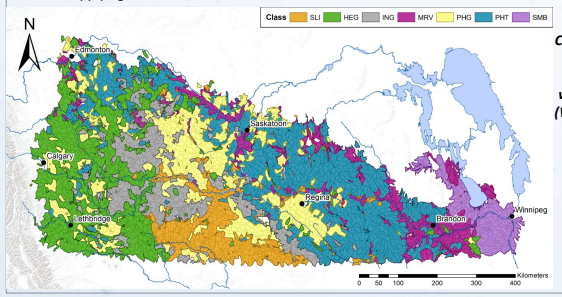
Study domain



Map of the study domain: the Prairie ecozone in western Canada (Wolfe et al., 2018).

Virtual basins modelling approach

- How to model the whole Canadian Prairie Pothole Region?
  - Developing a locally parameterized model for each watershed across the region: time and cost intensive
  - Modelling the region in a virtual manner: develop a model that works well for wider areas that are similar in hydrological responses
- Main steps in implementing the virtual basins modelling approach include:
  - Identifying hydrologically similar areas through cluster analysis;
  - Developing a virtual model for each cluster using the Cold Regions Hydrological Modeling platform (CRHM); and
  - Applying the model to different watersheds within the cluster.



Classification of Prairie ecozone watersheds (Wolfe et al., 2019).

Modelling High Elevation Grasslands (HEG) and Pothole Till (PHT) clusters using CRHM

WATERSHED CLASSIFICATION

- **Identify Clusters**
- **Identify HRUs**
- **Estimate parameter values**
  - Slope
  - Elevation
  - Wetland parameters
  - And others

FORCING CLIMATE DATA

- **Processing forcing climate data**
  - Temperature
  - Precipitation
  - Wind speed
  - Relative humidity

CRHM-PHM SETUP

- **Physical Processes**:
  - Blowing snow
  - Canopy Interception
  - Energy-balance snowmelt
  - Infiltration
  - Stream routing
  - And others
- **Parameterization**
  - Watershed area: 100 km^2
  - Most parameters were over the cluster
  - Only latitude and solar time shift are locally defined
  - Forcing climate data is also allowed to vary within a cluster

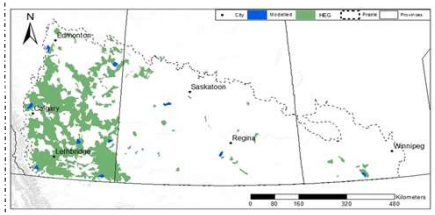
MODEL VALIDATION

- **Streamflows**
- **Soil moisture**
- **Snow Water Equivalent (SWE)**

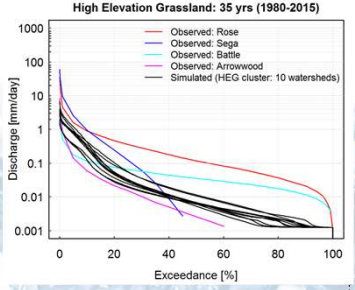
MODEL APPLICATION

- **Intra-cluster comparisons**
  - Streamflows at different locations
- **Scenario simulations**
  - Wetland drainage
  - Climate change
    - ΔT and ΔP

Procedure for implementing the virtual basins modelling approach for the Prairie region.



Map of the High Elevation Grasslands cluster and 10 watersheds modelled within the cluster.



Flow duration curves for High Elevation Grasslands cluster.

Scenarios

Wetland scenarios:

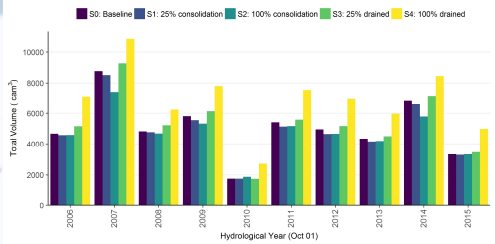
- Baseline: current wetland condition;
- Draining 25% of wetlands;
- Draining all wetlands;
- Replacing 25% of wetlands by a single wetland; and
- Replacing all wetlands by a single wetland.

Climate change scenarios:

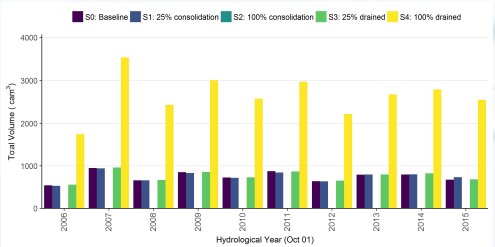
- Baseline: Current climate condition;
- Warm conditions: temperature increased by +2;
- Warm conditions: temperature increased by +4;
- Drought condition: precipitation decreased by 20%;
- Drought conditions: precipitation decreased by 40%; and
- Warm and drought conditions: temperature increased by +4 and precipitation decreased by 40%.

Results

Wetland management scenarios

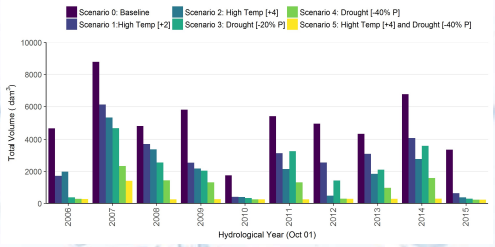


Response of annual flow volume to wetland scenarios for High Elevation Grasslands cluster.

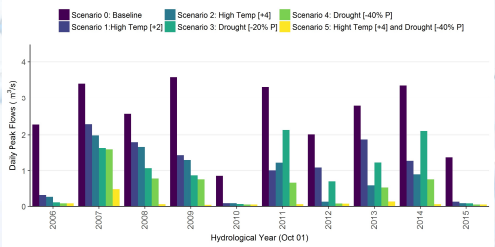


Response of annual flow volume to wetland scenarios for Pothole Till cluster.

Climate change scenarios



Response of annual flow volume to climate change scenarios for High Elevation Grasslands cluster.



Response of peak daily discharge to climate change scenarios for High Elevation Grasslands cluster.

Conclusion

- The Cold Regions Hydrological Modelling platform (CRHM) was setup in a virtual manner and tested over two clusters across the Prairie.
- The simulated annual streamflow volumes in both Clusters have a remarkably strong sensitivity to fully wetland drainage condition.
- The greatest hydrological sensitivity to wetland drainage was in the Prairie Pothole Till, which has had substantial wetland coverage (20%) compared to High Elevation Grasslands (7%).
- Results also indicate that wetland consolidation may be a promising way to offset wetland drainage effects on Prairie watershed streamflows.

References

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