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Considering the Riverscape When Developing eFlows Frameworks for Deltaic Ecosystems: Exploring the Mackenzie and Saskatchewan River Systems

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Introduction

Across Canada, a key question challenging river scientists is "how much of the natural flow can be removed from a river without affecting critical ecosystem services?" Significant scientific effort has been invested in understanding the relationships between streamflow, geomorphology and aquatic ecology; however, more targeted research is needed to develop scientifically-based environmental flows (eFlows) criteria that are applicable to the wide-ranging ecoregions, including deltaic ecosystems downstream of human-dominated riverscapes exhibiting altered flow regimes.

Simply stated, eFlows seek to balance water resource development needs (eg, supporting agricultural or industrial water demands) and the need to protect freshwater-dependent ecosystems. According to the Brisbane 2018 Declaration, "eFlows describe the quantity, timing, and quality of freshwater flows and levels necessary to sustain aquatic ecosystems which, in turn, support human cultures, economies, sustainable livelihoods, and well-being" (Athington et al. 2018). In addition to including people, recognition of water levels within this latest definition as an equally relevant metric to flows is paramount for low elevation, deltaic floodplains that rely on critical water levels to trigger connection with adjacent lakes and wetlands. For instance, the Saskatchewan and Mackenzie River deltas are influenced by cold-regions processes, such as ice jam floods that are largely ignored in current eFlows approaches.

The goal of this poster is to outline preliminary thoughts on: 1) The implications of upstream hydrological alterations (eg, hydropower production and water withdrawals) for downstream deltaic ecosystems, 2) Outlining the common hydrological stressors and issues found in the Saskatchewan River Delta and the three deltas within the Mackenzie River, 3) Establishing timelines and indicators of hydrological change that allow for calculation of baseline conditions and links to hydrological and water resource management models, and 4) Outlining initial thoughts on a unified eFlow framework that can be applied to cold-regions deltaic environments. Although this work is directed at the Integrated Modelling Program for Canada, it is envisioned that such a framework would address cross-cutting challenges/opportunities and enhanced decision making for water and ecosystem management.

Study Region

The Mackenzie and Saskatchewan River systems originate in the ice/snow fields of the Rocky Mountains in western Canada. The Mackenzie River flows ~4200 km to the Beaufort Sea and drains ~1.8 M km2. Deltaic systems formed at the confluence of the Peace and Athabasca Rivers at the west end of Lake Athabasca (Peace-Athabasca Delta; PAD; ~5500 km2), Slave River entering Great Slave Lake (Slave River Delta; SRD; ~400), and Mackenzie River spilling into the Beaufort Sea (Mackenzie River Delta; MRD; ~10 000 km2) (Figure 1). The Saskatchewan River flows ~1900 km to Cumberland Lake where the Saskatchewan River Delta (SaskRD; ~10 000 km2) formed the largest inland freshwater delta in North America.

These low topographic relief deltas are some of the most productive ecosystems in the world, with main waterways that split into complex active/inactive flow systems that can link to floodplains containing a vast number of small lakes and wetlands that provide habitat for fish, waterfowl and mammals, as well as traditional trapping/hunting areas for Indigenous Peoples. The PAD is a Ramsar Wetland Site of internal importance, with the large majority within the Wood Buffalo National Park which was inscribed on the UNESCO World Heritage list. The SaskRD is a designated Canadian Important Bird Area of global significance. All 4 deltas started forming with the retreat of glacial ice sheets via deposition of river-borne sediment into a standing body of water, and have experienced growing number of hydrologic stressors in the past 100 years.

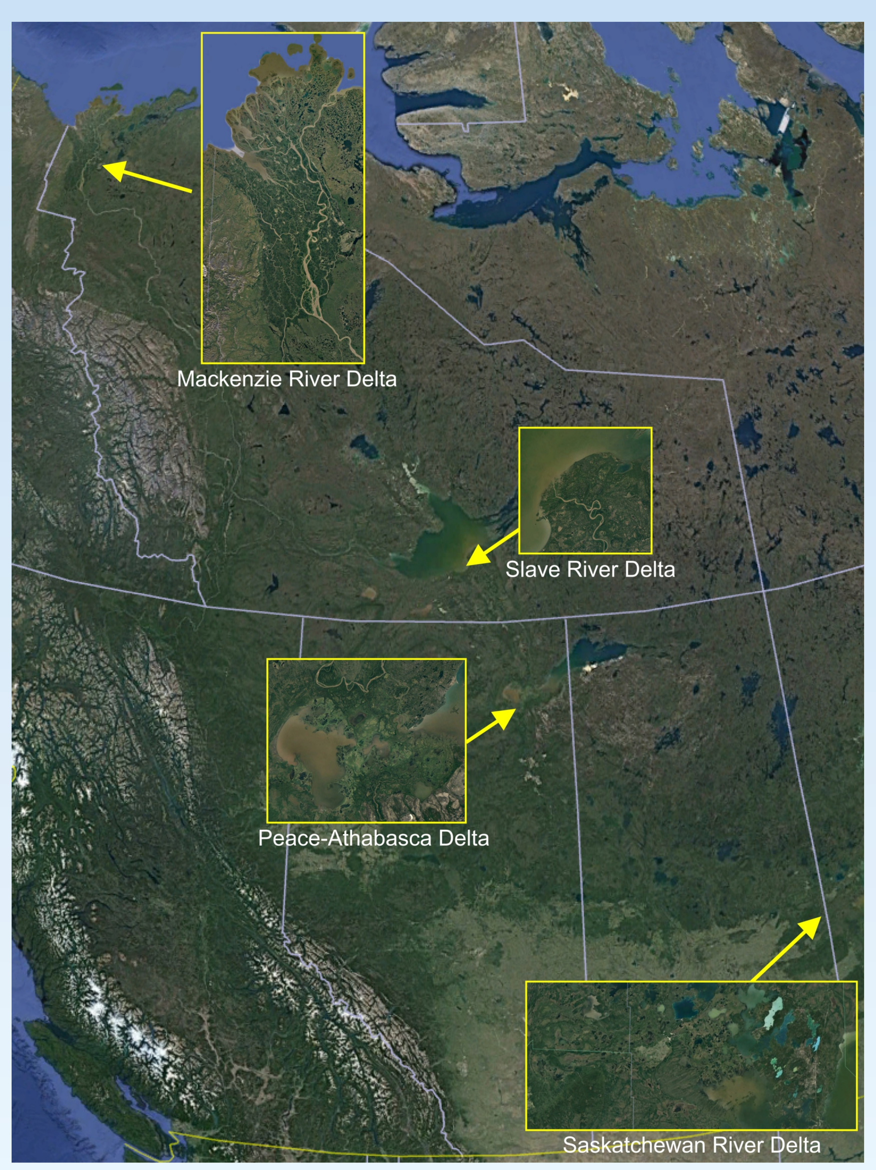

Figure 1: Location and zoomed in areas for the Peace-Athabasca Delta, Slave River Delta, and Mackenzie River Delta withing the Mackenzie River Basins, plus Saskatchewan River Delta.

Important Features of Cold-Regions Deltas

- Low topographic relief and complex connectivity to inland wetlands (open, restricted and isolated hydraulic connections)
- Open water and Ice covered periods influences the balance of water and connectivity
- Recharge of inland basins via spring ice jam and summer stormflow induced highwaters on major and smaller connecting channels, plus expansion of large lakes into surrounding floodplain
- Generation of flood conditions influenced by upstream contributing river basin and local condittions
- Spatially and temporally complex flood histories
- Multi-scale controls on the hydroperiod and persistence of water in connected and perched basins
- Relatively rapid changing geomorphology - eg, in-filling, formation of new channel connections following a large flood event
- Flow direction dependent on relative water levels - ie, reverse flow

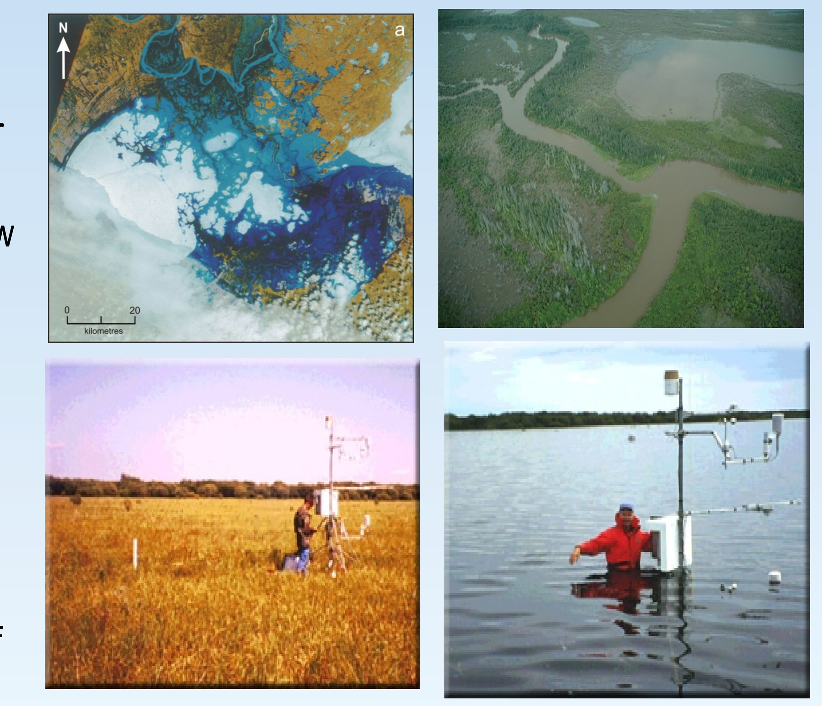

Figure 2: Examples of ice jamd and open water flooding. Modified from Peters et al. (2006; 2016)

Drivers of Hydrological Change in Deltaic Ecosystems

- Climate Variablity and Change
- Agricultural activities
- Hydropower generation
- Oil and gas exploration and extraction
- Forestry activities
- Urbanization

Associated with the above contributing basin drivers are the following pressures :

- Landscape disturbance
- Regulation of water ways via contruction of hydraulic structures (weirs and dams)
- Water use, withdrawal, storage, diversion and consumption

Figure 3: Examples of drivers of hydrological alteration affecting

Hydrological Stressors on Deltaic Ecosystems

Hydrological stressors can cause a number of impacts on aquatic ecosystems and services. eg babitat alteration and loss - organisms are adapted to specific hydrological regimes, and alterations to the following may cause a loss of suitable habitat.

- Surface Water connectivity
- Magnitude of flow and water level
- Timing of flow and water level
- Flow and water level range
- Duration of open water and ice influenced periods
- Frequency of flooding and drought periods

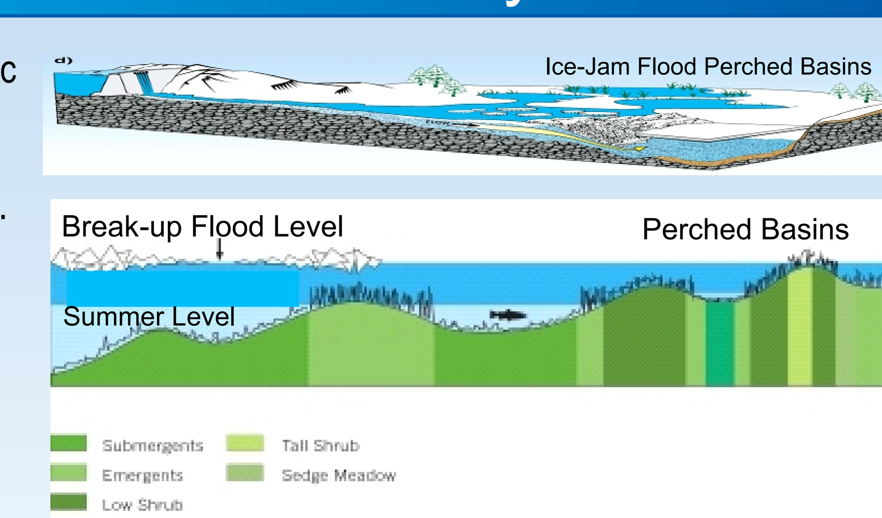

Figure 4: Diagrams of floodwater connection in cold regions deltas. Modified from Prowse and Conly (2002).

Cold-Regions Hydrological Indicators of Change

- 33 annual hydrological variables that form the Indicators of Hydrologic Alteration (IHA; TNC 2007) suite of variables that characterize intra- and inter-annual variability in flow conditions based on the work of Richter et al. (1996, 1997) are described and summarized in TNC (2007) and Monk et al. (2012).
- However, need to acknowledge that low and high water conditions can occur during both ice and open-water seasons in cold regions.
- An important first modification to the IHA approach is to identify the period of the year affected by both ice-influenced and open-water conditions.
- Extraction of B flag dates in Environment Canada HYDAT archive enables the identification of the water year (i.e. 1 October to 30 September) when open-water channel hydraulics prevailed and when the flows were affected by ice conditions.
- Timing and magnitude of the annual spring freshet resulting from snowmelt and heavy rainfall, which generally follows an extended low-flow period over the winter months, is also a crucial addition.
- Associated with the spring freshet onset and river-ice break-up condition in many is the generation of the annual high water level with considerably less flow than generated under open-water conditions via ice .
- We thus combined a review of the published literature on cold-regions hydrology and hydro-ecology with available hydrometric information for sites across Canada, to produce a suite of indicators specifically designed for cold regions. See Peters et al. (2014) for details on CHIC approach.

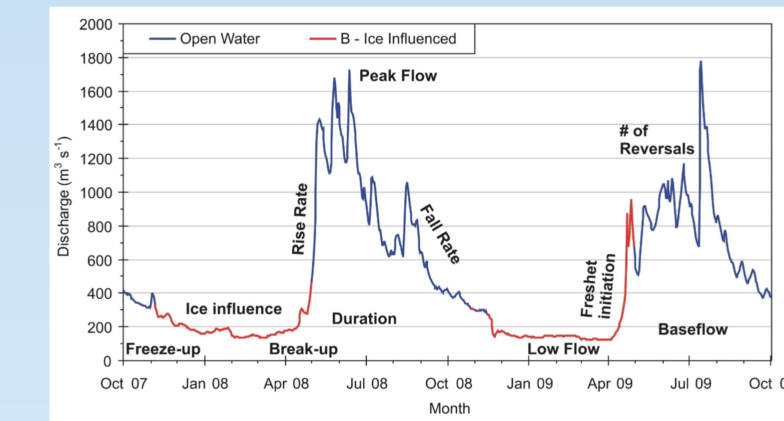

Figure 5: Streamflow hydrograph showing open water and ice-influenced conditions observed on the lower Athabasca River.

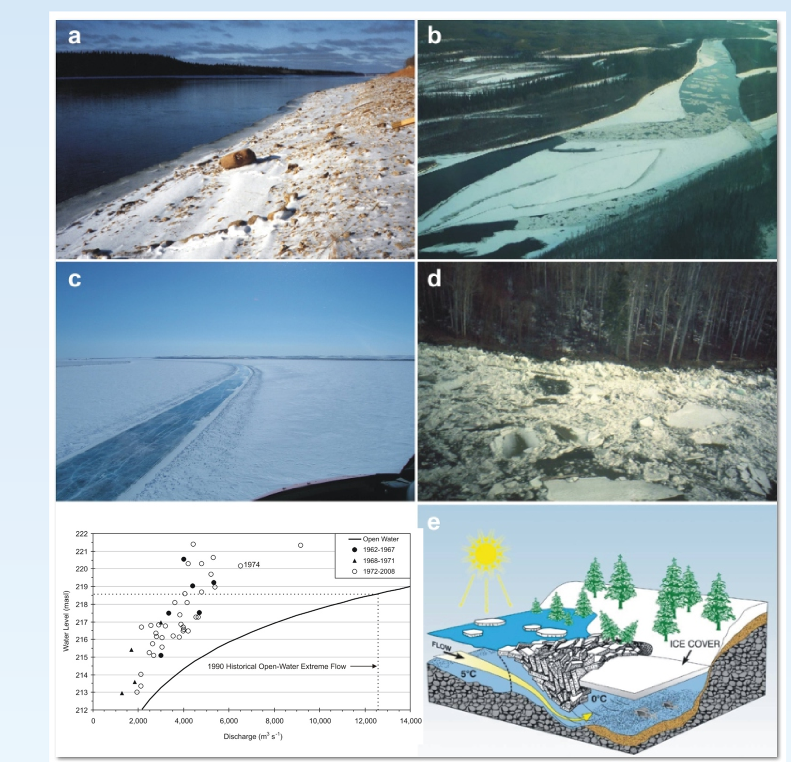

Figure 6: Examples of river conditions in the Mackenzie River Basin, northwestern Canada, as well as, annual peak water level vs discharge under break-up conditions in the lower Peace River.

Key Messaging and Future Work

- It has become clear in the literature that one must considering the riverscape when developing an eFlows framework for deltaic ecosystems as hydrological changes in upstream areas may be translated downstream.
- Deltaic ecosystems are comprised of a maze of channels, lakes, and wetlands with varying connectivity to main flow system.
- Work is ongoing to adapt the cold-regions hydrological indicators of change for deltaic environments – capture not only rivers and channels but also wetland and lake hydrology/hydraulics that are relevant to specific aquatic processes and species.
- Specifically, work has began on an eFlow framework for the Peace-Athabasca Delta as part of the Wood Buffalo National Park UNESCO Action Plan.
- It is planned that this ongoing eFlows framework will be applied to the Saskatchewan River Delta and other cold regions deltas in Canada.
- Work is also ongoing to incorporate the deltaic suite of indicators into hydrological/hydraulic platforms, such as the Integrated Modelling Program for Canada.

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