Complexity of Prairie Hydrology

Prairie Hydrology, Flood Modeling and GIS

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Distinctiveness of prairie hydrology

- **Dry** - relatively small precipitation, water deficit, low moisture reserves
- **Cold** - long frozen season, snow cover, frozen soils
- **Flat** - gentle topography, poorly defined drainage
- **Extreme** –
  - Inter-annual – sequences of drought and floods
  - Intra-annual – dry and wet years
  - Episodic – intense snowstorms, snowmelt and rainfall, intense heat, rapid growing season, unreliable
Prairie hydrological practice

- Difficult to do operational hydrology on the prairies:
  1. Complex hydrological processes
  2. Challenging hydrography
  3. Lack of tools
1. Prairie hydrological processes
Prairie hydrological processes

- Transport of water in liquid, vapour and frozen states (runoff, percolation, evaporation, sublimation, blowing snow)
- Phase changes in snow & soils (snowmelt, infiltration in frozen soils, soil freezing and thawing)
- Snow and rain interception in forest canopies
- Episodic flow between soil moisture, groundwater, ponds and streams.
- Variable storage, drainage and contributing areas
- Land use changes
Blowing snow is water transport
2. Prairie hydrography
Typical prairie “basin”
Limited contributing areas for streamflow

Non-contributing areas for streamflow extensive in Canadian Prairies

Localized hydrology affected by poor drainage, storage in small depressions
Because of the presence of wetlands, the contributing area of prairie basins is difficult to estimate.

Historical rainfall/streamfall records show that the contributing area is not constant, but varies with storage of water in the wetlands.
Complexity of flood processes

- Rainfall-runoff methods widely used for design of hydraulic structures in prairie “basins”
- Typically only small convective cells produce sufficient intensities to cause runoff
- NOT the cause of most prairie peak flows
Frontal rainfall

- Capable of covering larger basins than convective storms
- May have greater accumulations, but generally lower intensities
- May cause runoff if soils already saturated/frozen and/or wetlands connect
Fraction of prairie peak flows
89 unregulated basins < 1000 km²
Spring snowmelt

- Many prairie streams only flow during spring melt
- Runoff increases if soil is wet pre-freezup
  - Rain in fall
- If ice layer at bottom of snowpack, almost all snowmelt may runoff
  - Can be caused by rain on frozen soil in early winter
  - Can also be caused by rain in spring
# Increase in rain fraction of monthly precipitation

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<td>Sites tested</td>
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<td>Number of sites having a significant* trend</td>
<td>Number of sites having a significant* trend</td>
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* Mann-Kendall test, 5% level of significance
Calculating prairie high flows

- Snowmelt runoff is much harder to estimate than rainfall runoff
  - Accumulation of snow depends on relocation and sublimation caused by wind
  - Snowmelt is driven by solar radiation
  - Infiltration to frozen soils is complex: coupled heat and mass-transfer processes
  - All prairie runoff depends on the state of wetlands
3. Lack of tools
Tools (procedures and models) developed in other locations are NOT suited for the prairies.

“The Canadian prairies are the graveyard of hydrological models” - D.M. Gray

Not for lack of research on prairie hydrology.
Division of Hydrology (1964-2001)

SRC

NHRC

Centre for Hydrology

GIWS

Research has resulted in several research models
Cold Regions Hydrological Model

Modular, based upon 50 years of prairie hydrology research at University of Saskatchewan

Only program to reproduce prairie hydrological processes

Physically-based model

- Reproduces physics of hydrologic processes
- Can work under changed conditions – changing climate and/or landuse
Wetland DEM Ponding Model

- Simulates spatial distribution of runoff from LIDAR DEM of a prairie basin
- No time step
- Very slow: 12+ hours per run
- No physics
- Validated by remote sensing
Pothole Cascade Model

- Simulates spill and fill of flows among prairie wetlands
- Gives results similar to WDPM, but much faster
- No spatial information
- Working on incorporation in CRHM
The gap

Researchers (develop new techniques)

Practitioners (need new tools)
Who will bridge the gap?

- Researchers?
  - Research tools aren’t operational tools
  - Aren’t able to support users

- Practitioners?
  - Not in the business of development

- Government?
  - Cut to the bone

- Private companies?
  - Very small market / large potential liabilities
Potential development path

- Open source software
  - All source code is available to all users
  - Licence protects developers
  - Generally free of charge
  - Works best when there is a strong community
  - Many jobs to do:
    - Programming
    - Testing program and reporting bugs
    - Helping users / writing documentation
    - Advocacy
  - Can work well with other programs
“Do one thing, and do it well”

- One type of program will not meet all needs
- Need to incorporate many types of data
  - Historical
  - Realtime
  - Gridded/reanalysis
  - Future climate simulations
- Need to work with other programs
  - Statistical analysis
  - Large-scale hydrological models
  - Hydraulic models
Open MI

- Open Modeling Interface
- Way to connect hydrological models with each other and with data sources
- Models and data can be interconnected by user without any programming
- www.openmi.org
Prairie hydrology is unique

Prairie hydrography is unique

Methods and programs developed elsewhere don’t work

Research has resulted in improved understanding of prairie hydrology

If you want new tools, then you are going to have to participate in their development