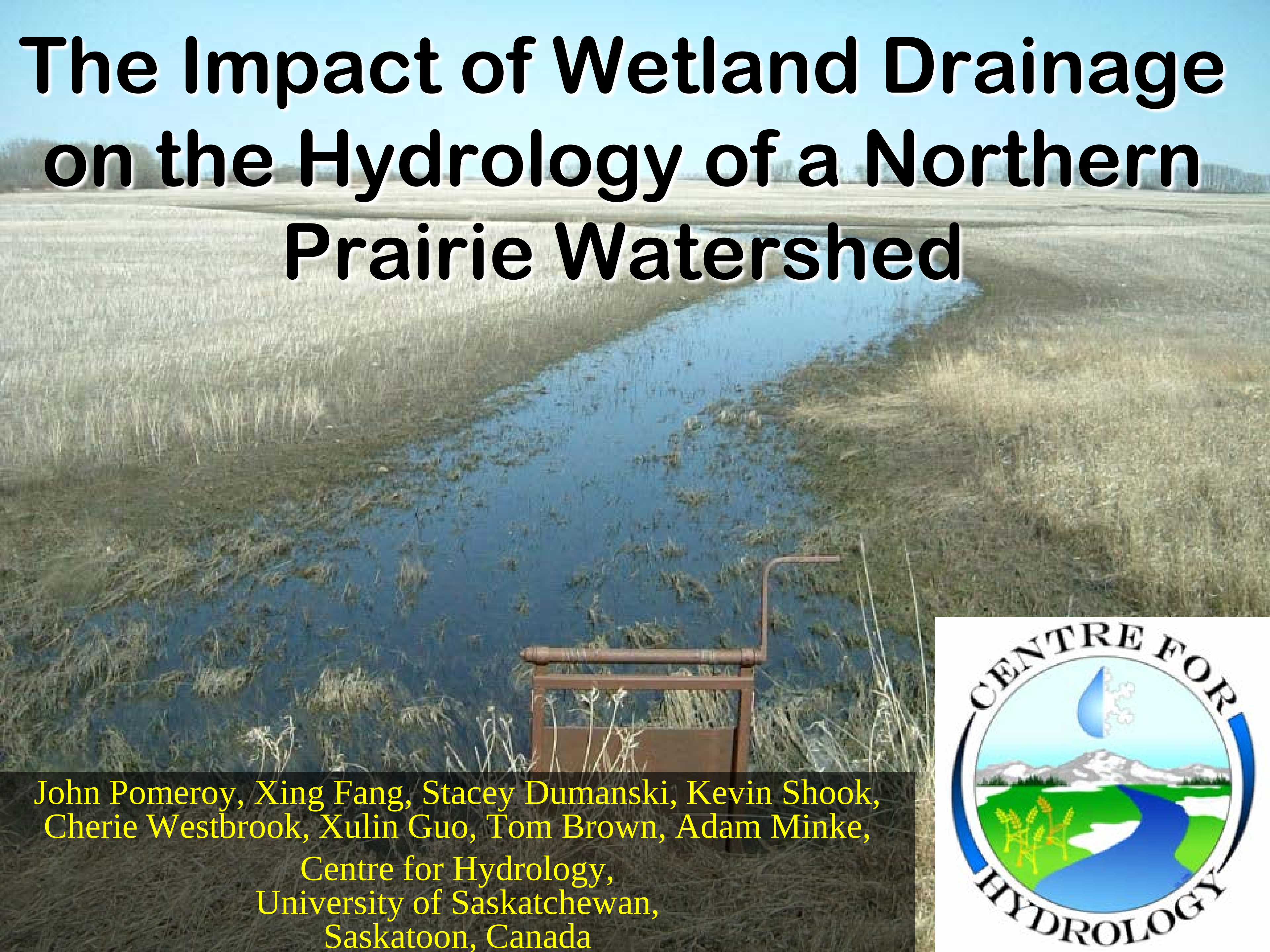


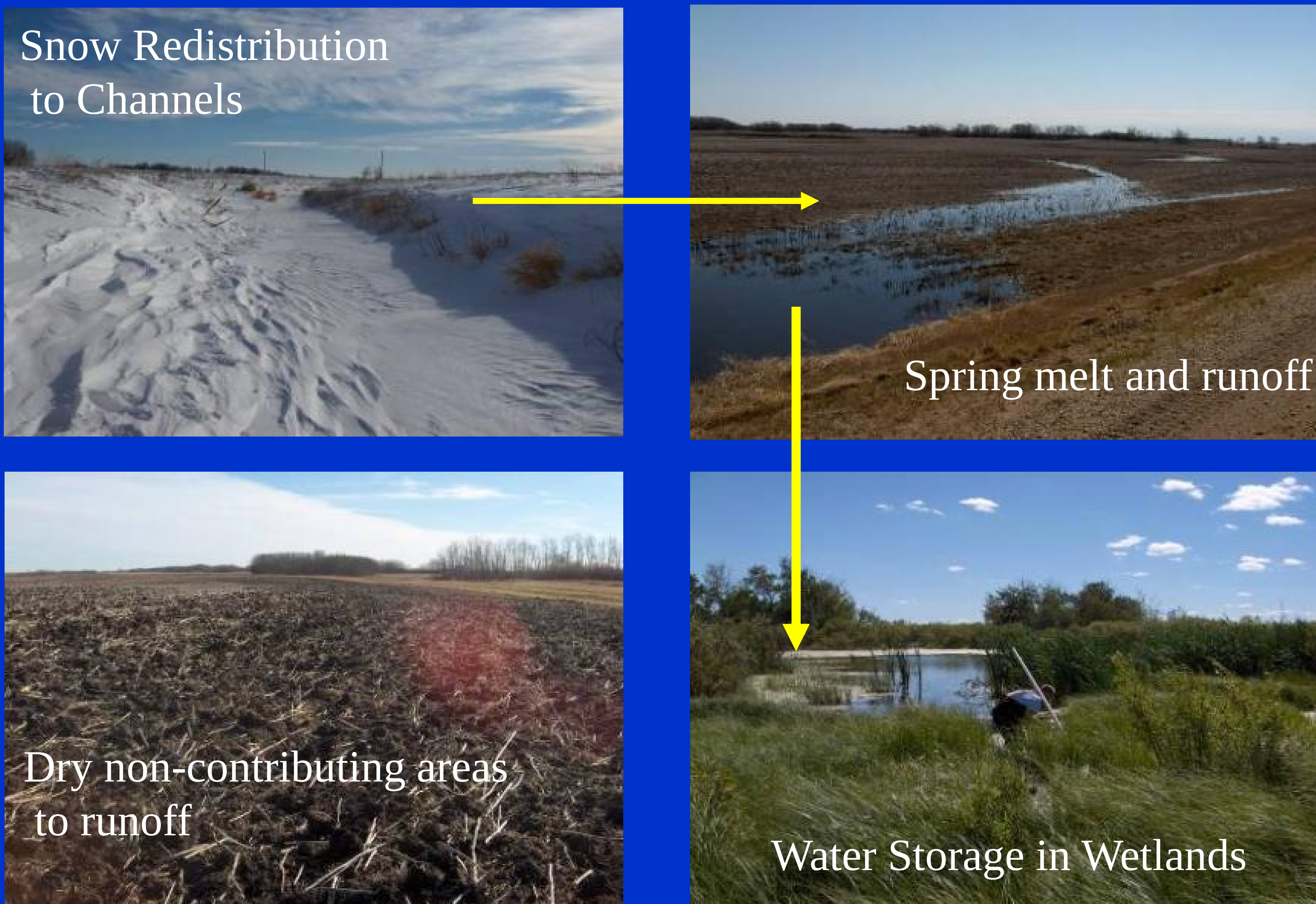
The Impact of Wetland Drainage on the Hydrology of a Northern Prairie Watershed

John Pomeroy, Xing Fang, Stacey Dumanski, Kevin Shook, Cherie Westbrook, Xulin Guo, Tom Brown, Adam Minke,
Centre for Hydrology,
University of Saskatchewan,
Saskatoon, Canada

Northern Prairie Hydrology

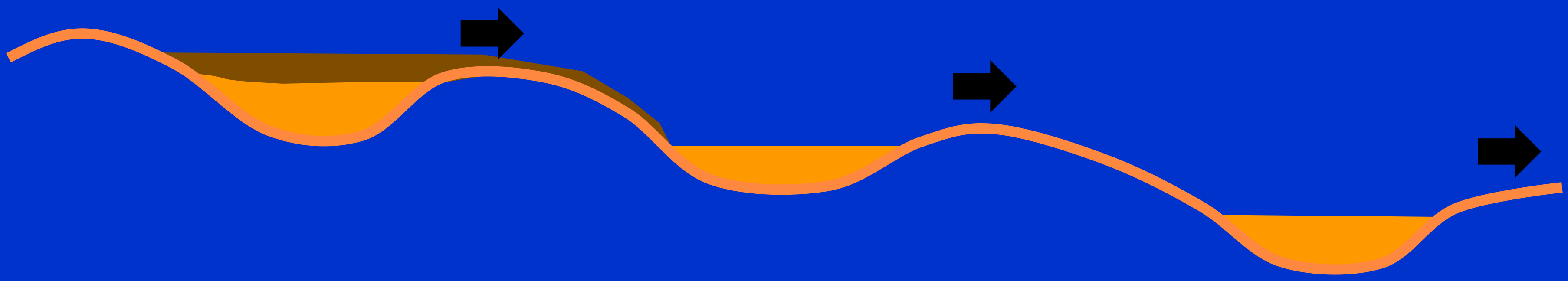
- Prairie runoff supplies smaller rivers, streams, sloughs and lakes
- Prairie Runoff
  - forms in internally drained (closed) basins that are locally important but non-contributing to river systems that drain the prairies, OR
  - drains directly to small prairie rivers (Battle, Souris, Assiniboine) >80% of runoff occurs during snowmelt period
- Blowing snow from fields to form snowdrifts in wetlands, woodlands and stream channels is critical to spring streamflow generation.
- Streamflow often ceases completely in summer when evapotranspiration consumes most available water.
- Baseflow (winter and dry season flow) from groundwater is often nonexistent.

Prairie Runoff Generation



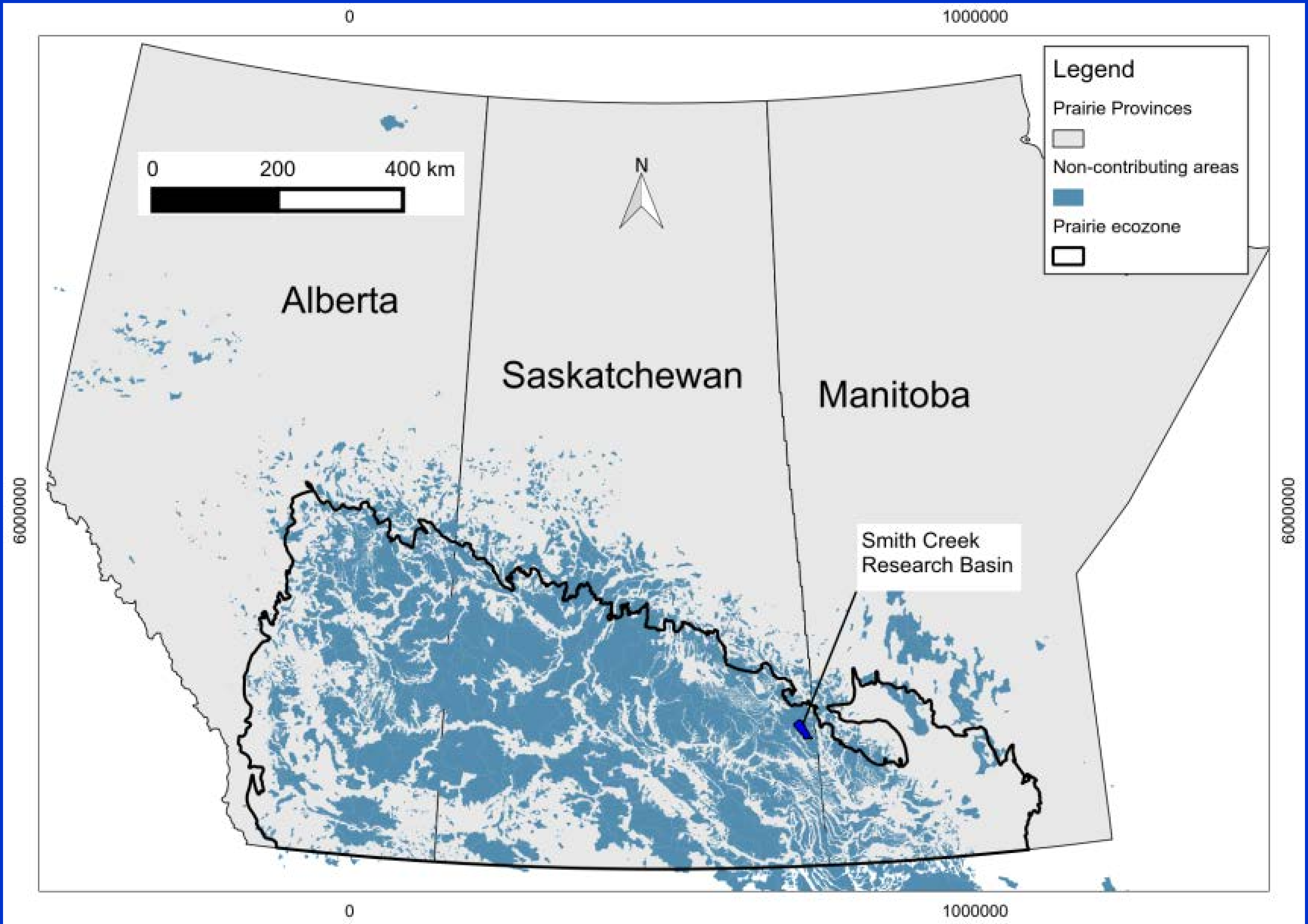
Prairie Hydrological Connectivity

The 'fill and spill' hypothesis

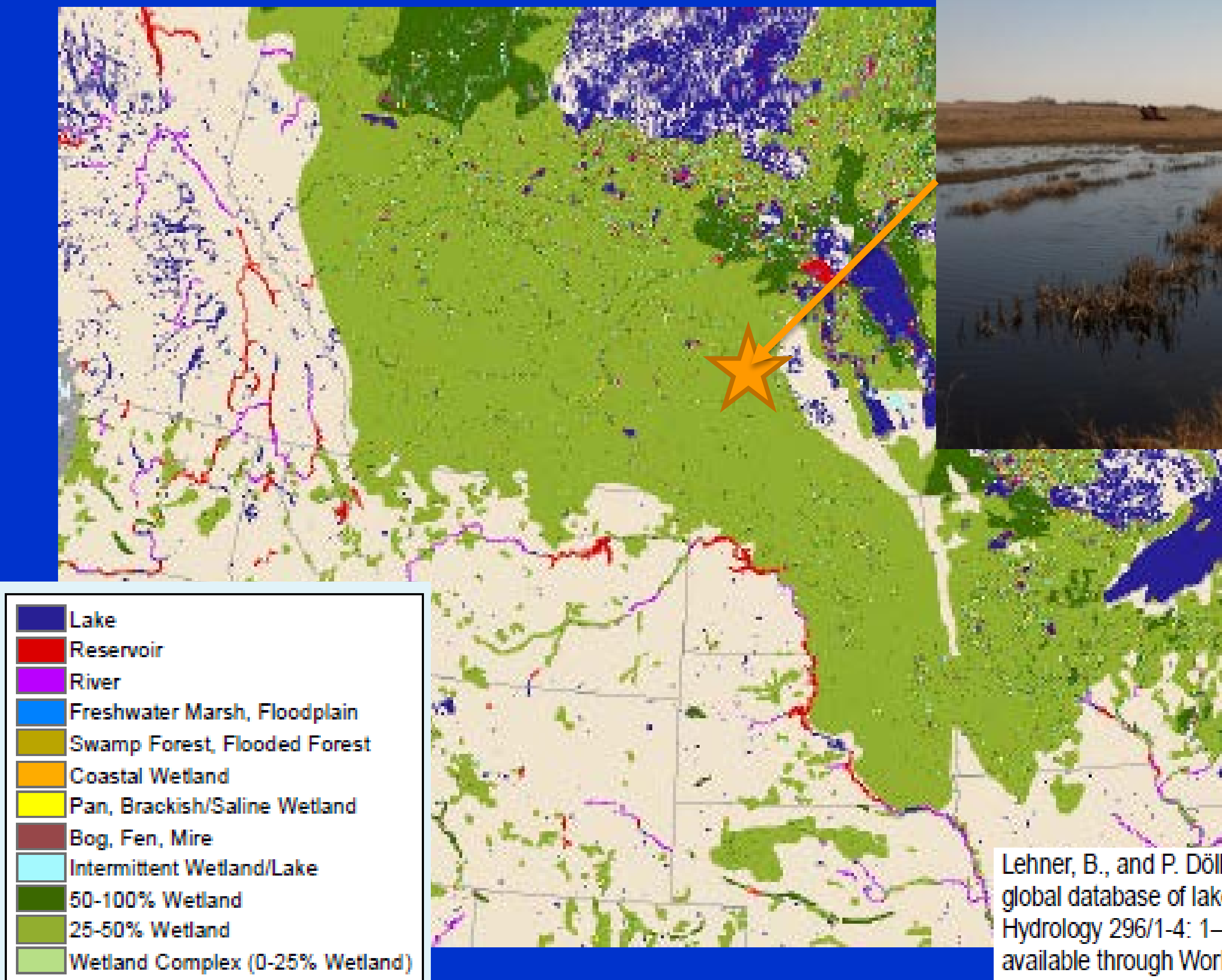


Lack of groundwater connections in this landscape – heavy tills

Canadian Prairie Non-contributing Areas



Smith Creek, Saskatchewan



Lehner, B., and P. Döll. 2004. Development and validation of a global database of lakes, reservoirs and wetlands. Journal of Hydrology 296/1-4: 1–22. Global Lakes and Wetlands Database available through World Wildlife Fund (WWF).

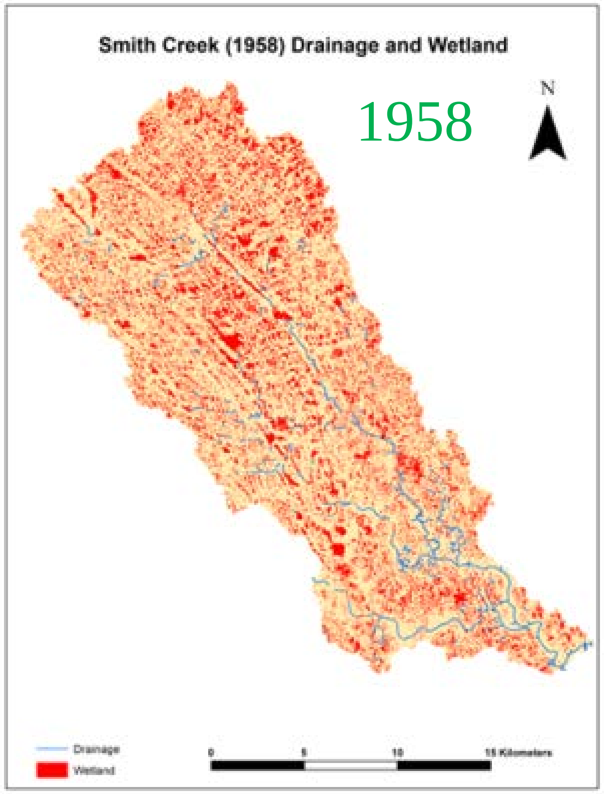
Smith Creek Hydrology Study

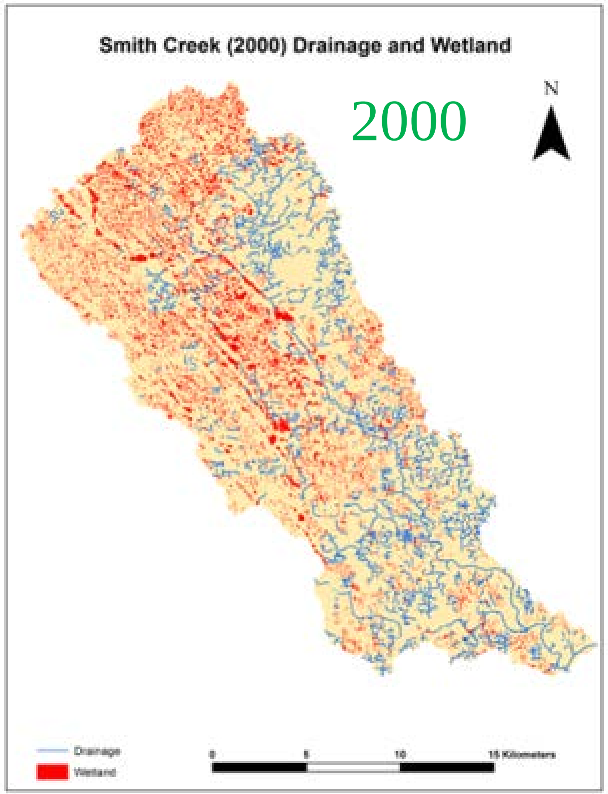
- **Problem 1**: Inability to reliably simulate streamflow in prairie basins where variable runoff contributing area, wetlands, and snowmelt play a major role in hydrology.
- **Problem 2**: Recent increase in streamflow volume and peak discharge in the area

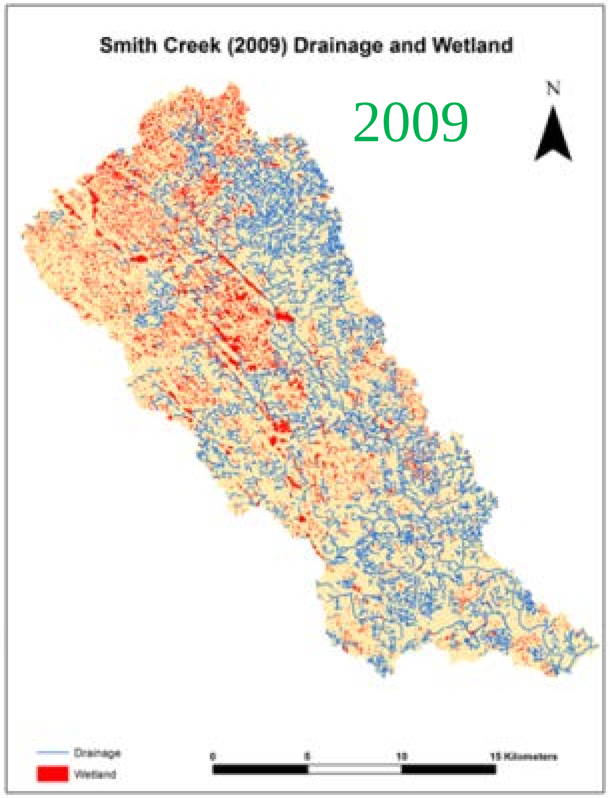
- Objectives
  - Examine changing climate, drainage and hydrology
  - Develop and test a hydrological model suitable for wetland dominated Prairie basins.
  - Use the model to estimate the sensitivity of recent high streamflows to wetland drainage

Smith Creek Research Basin

- 393 km²
- 60 km southeast of Yorkton, Saskatchewan, Canada
- Agriculturally dominated and partially drained
- Wetland extent reduced from 24% to 10% and drainage channel length increased 8-fold from 1958 to 2009







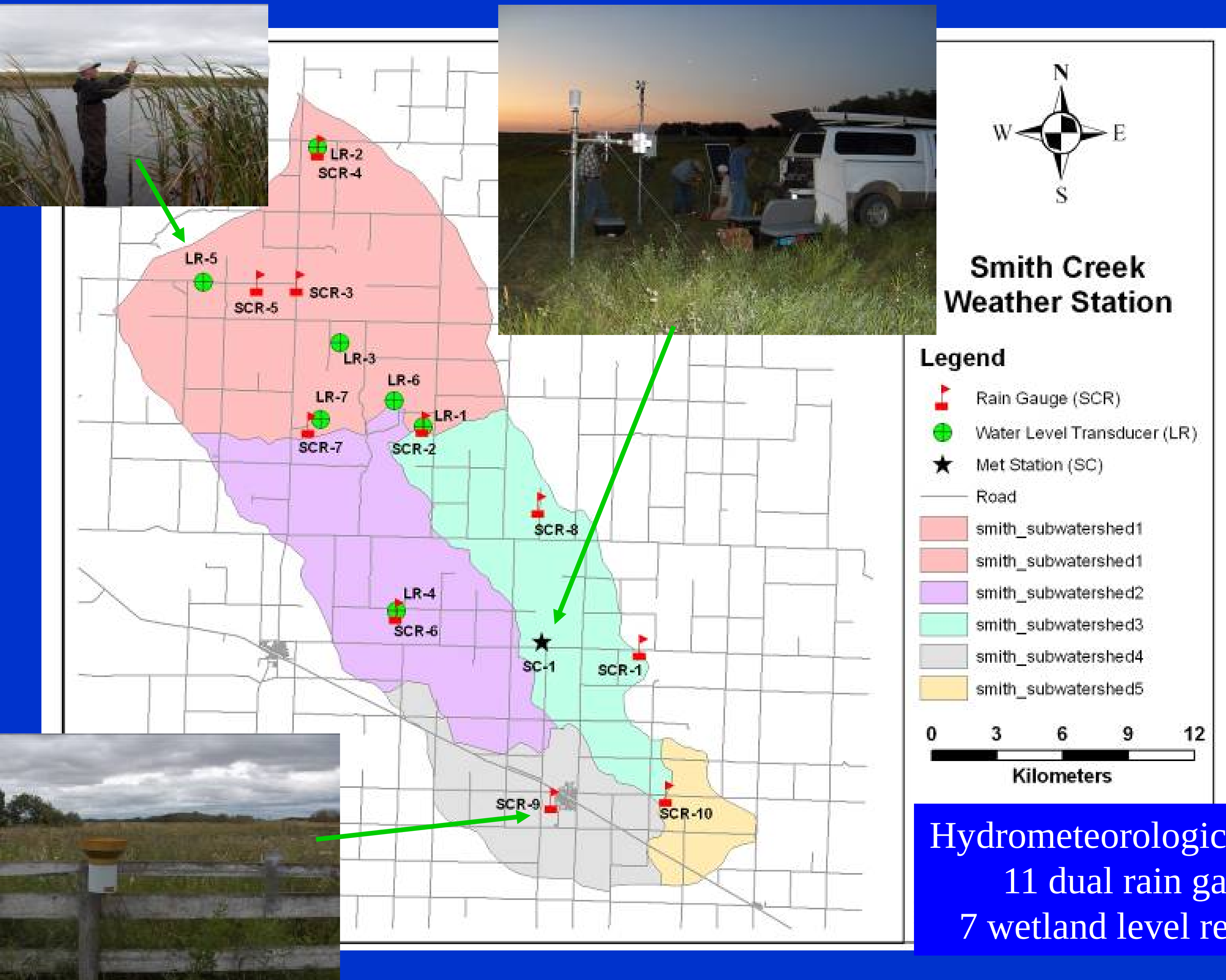
Smith Creek Pond Drainage

April 28, 2011

No Drainage

Artificial Drainage

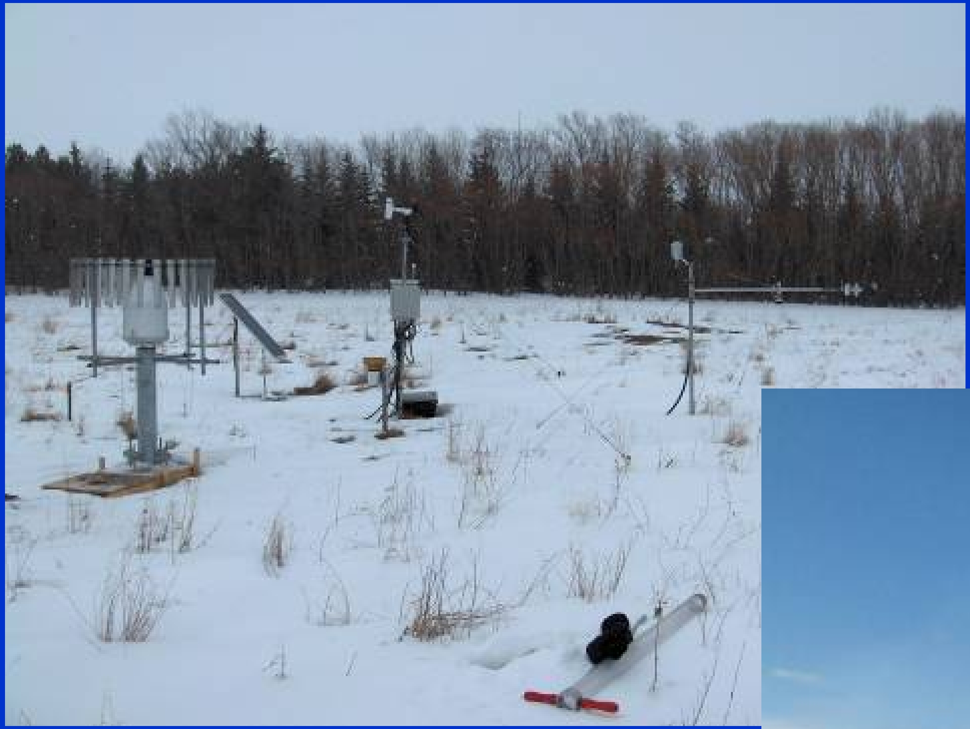
Instrumentation of Smith Creek



Completed
Summer 2007

Hydrometeorological Station
11 dual rain gauges
7 wetland level recorders

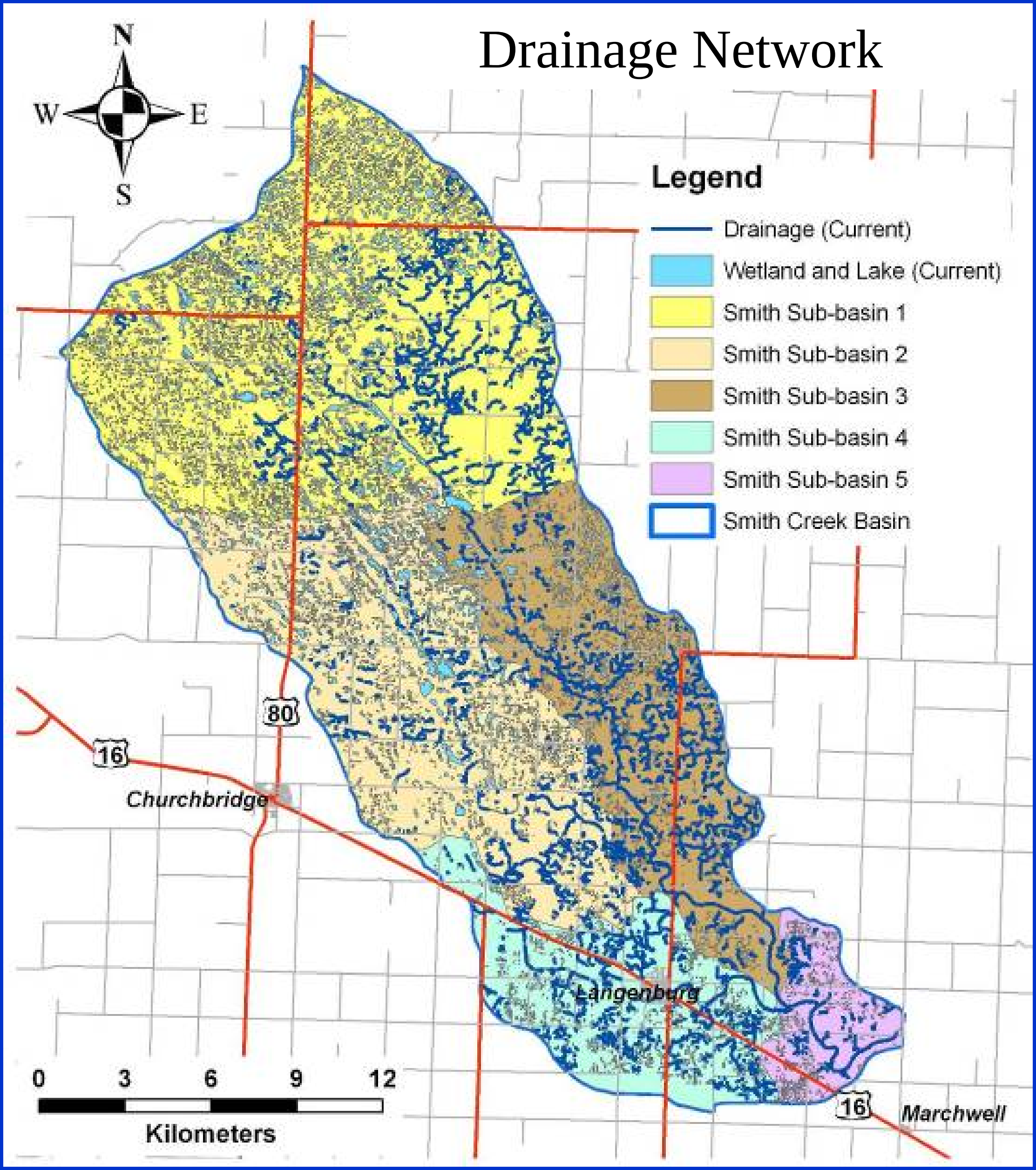
Main Weather Station



Temperature, humidity, wind speed,
shortwave radiation,
longwave radiation, soil moisture,
soil temperature,
soil heat flux, snow depth, rainfall,
snowfall

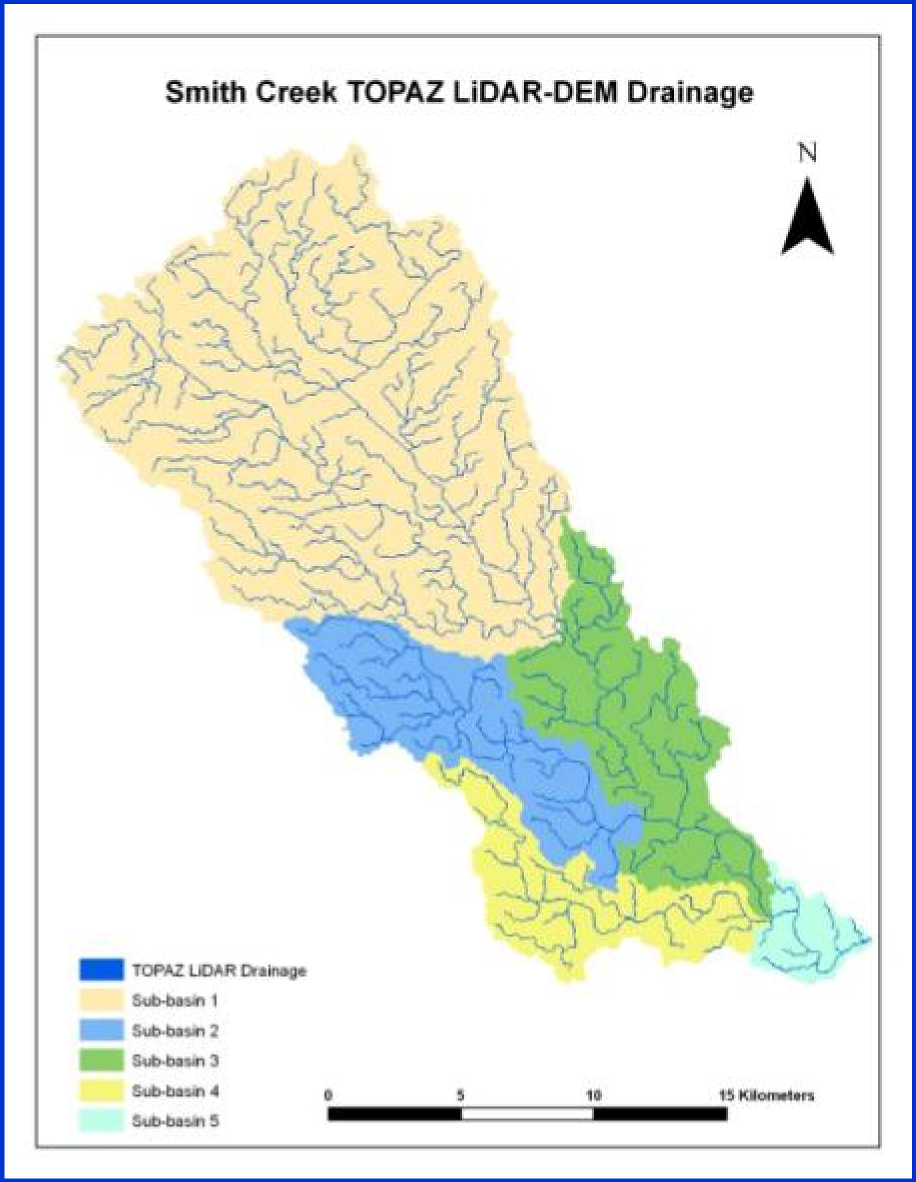
Snow and Soil Surveys

Smith Creek Basin Characteristics

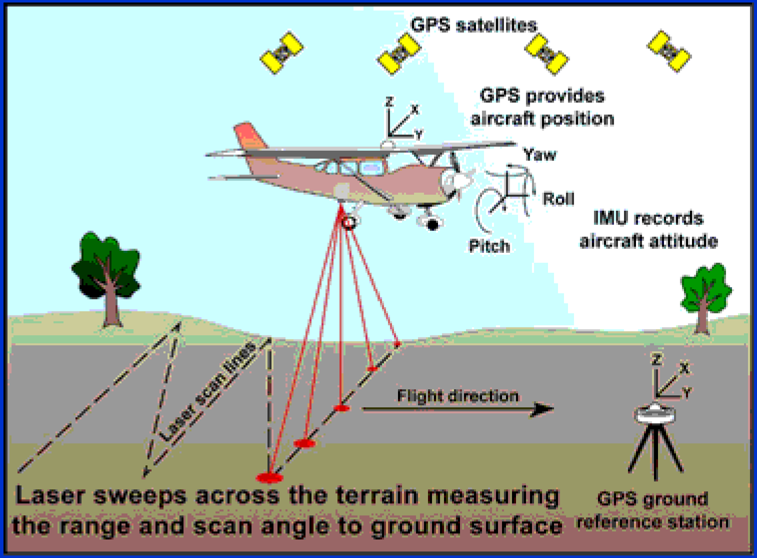


Spot Satellite Image

LiDAR-Derived Digital Elevation Model Drainage Network



LiDAR topography



Light Detection And Ranging

Derivation of Wetland Depressions

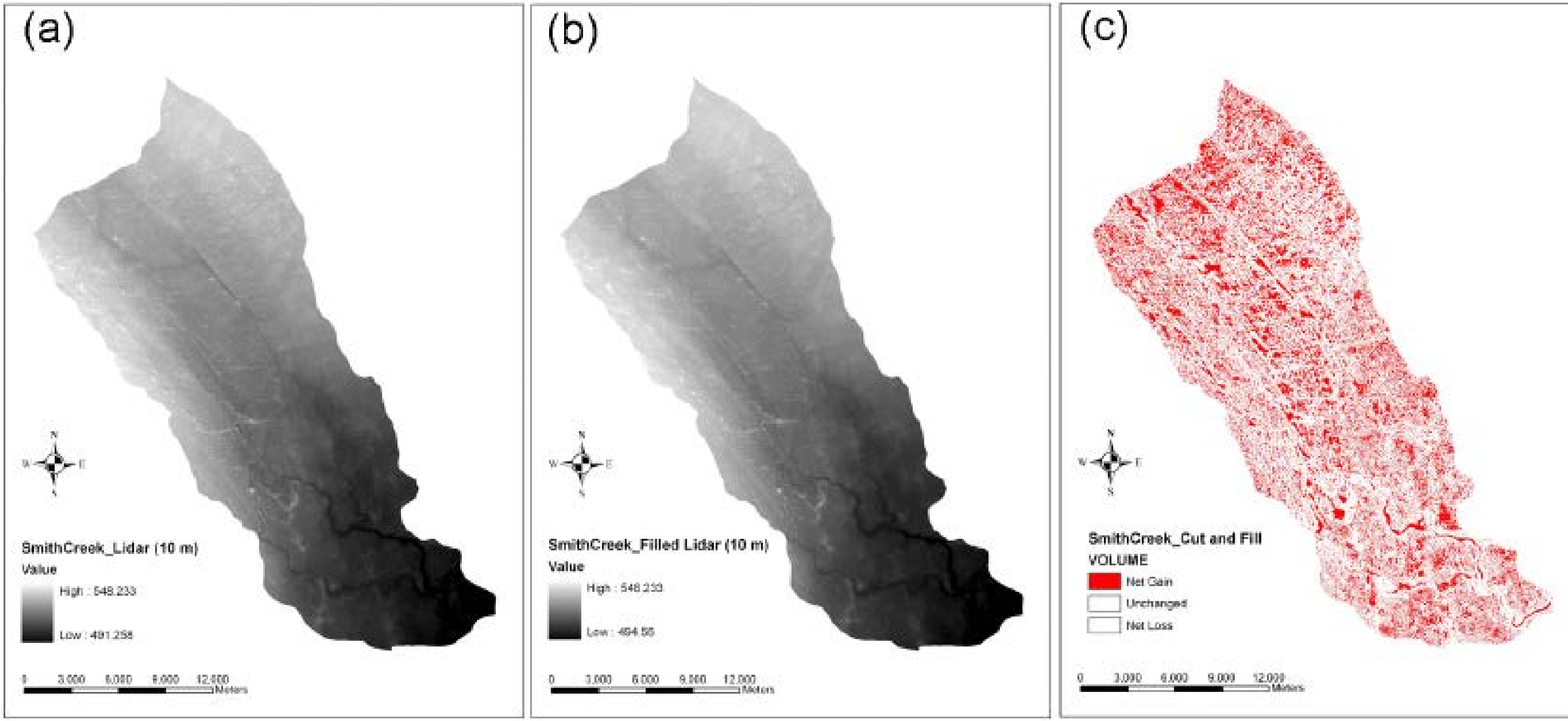


Figure 3. (a) Original 10-m LiDAR DEM, (b) filled depressionless 10-m LiDAR DEM, and (c) "cut/fill" output for Smith Creek basin.

Historical Data

Precipitation & Temperature

1942-2012

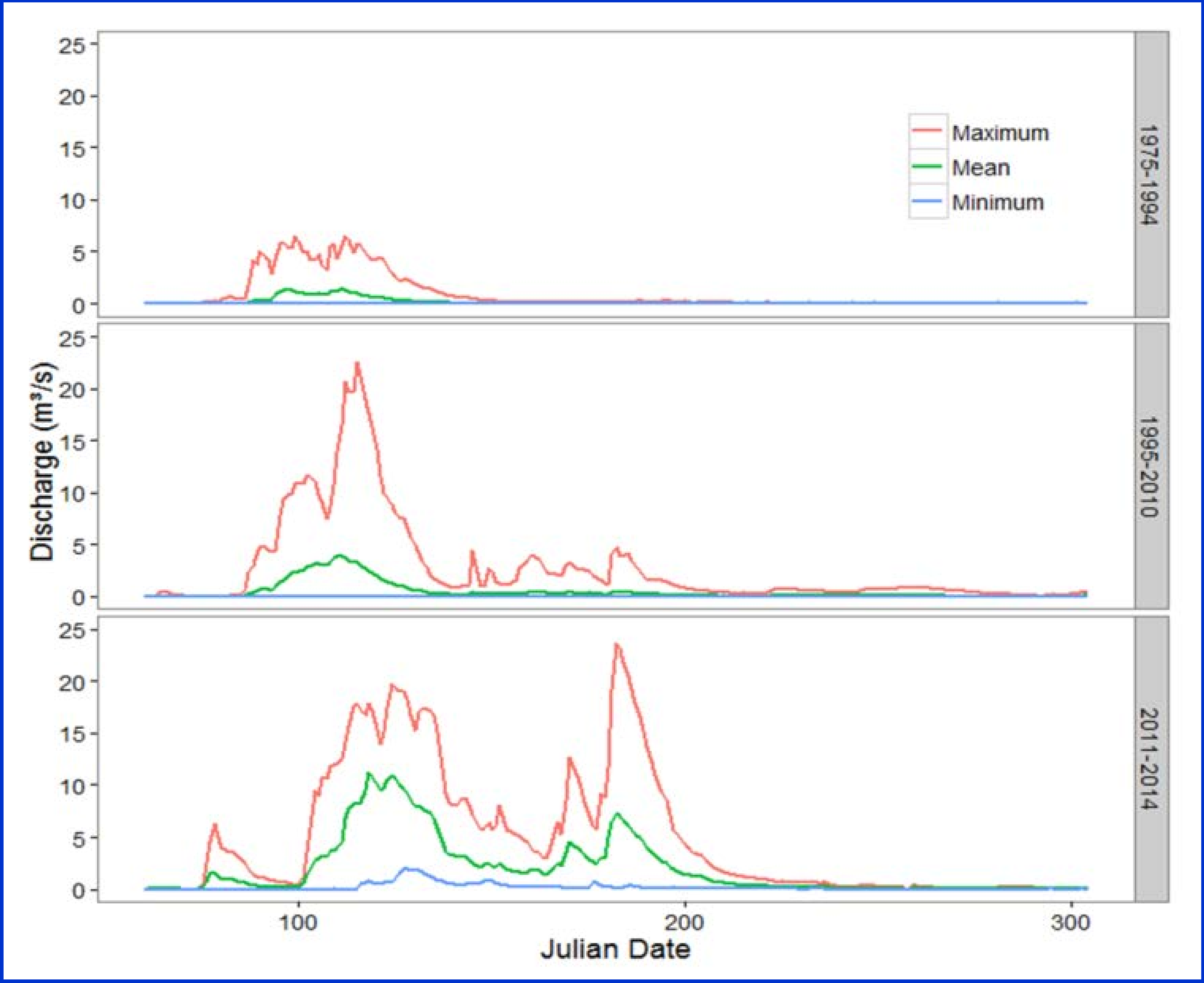
- Environment Canada & Centre for Hydrology
- Precipitation data adjusted for spatial variability

Streamflow

1975-2012

- Water Survey of Canada

Changing Hydrology – Smith Creek



Smith Creek near Marchwell, Water Survey of Canada Gauge, May 3, 2011

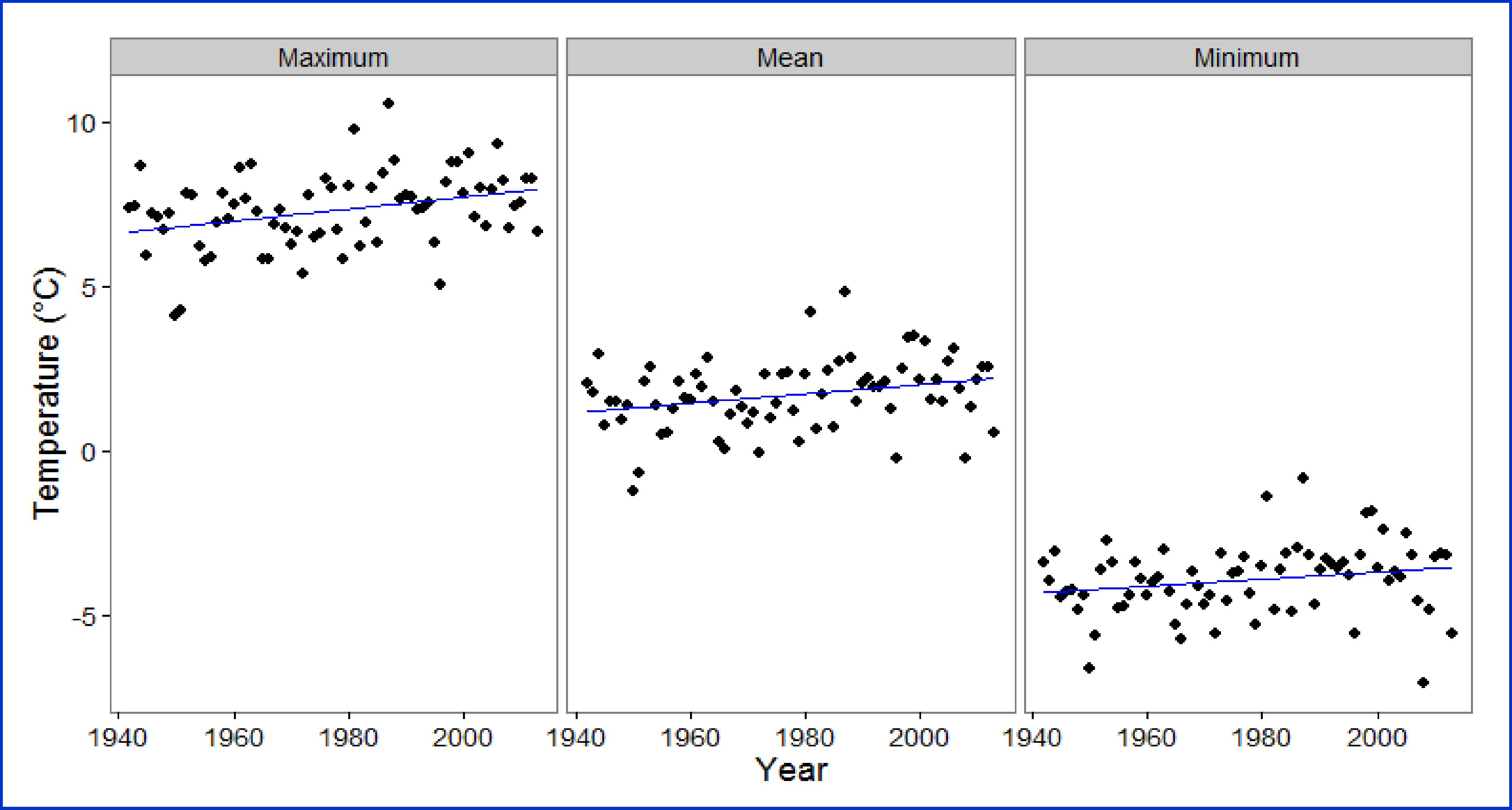
Note that the culvert that the rating curve is based upon is somewhere under the whirlpool…….

Smith Creek near Marchwell, Water Survey of Canada Gauge, May, 2011

Note that the culvert that the rating curve is based upon is somewhere under the whirlpool…….

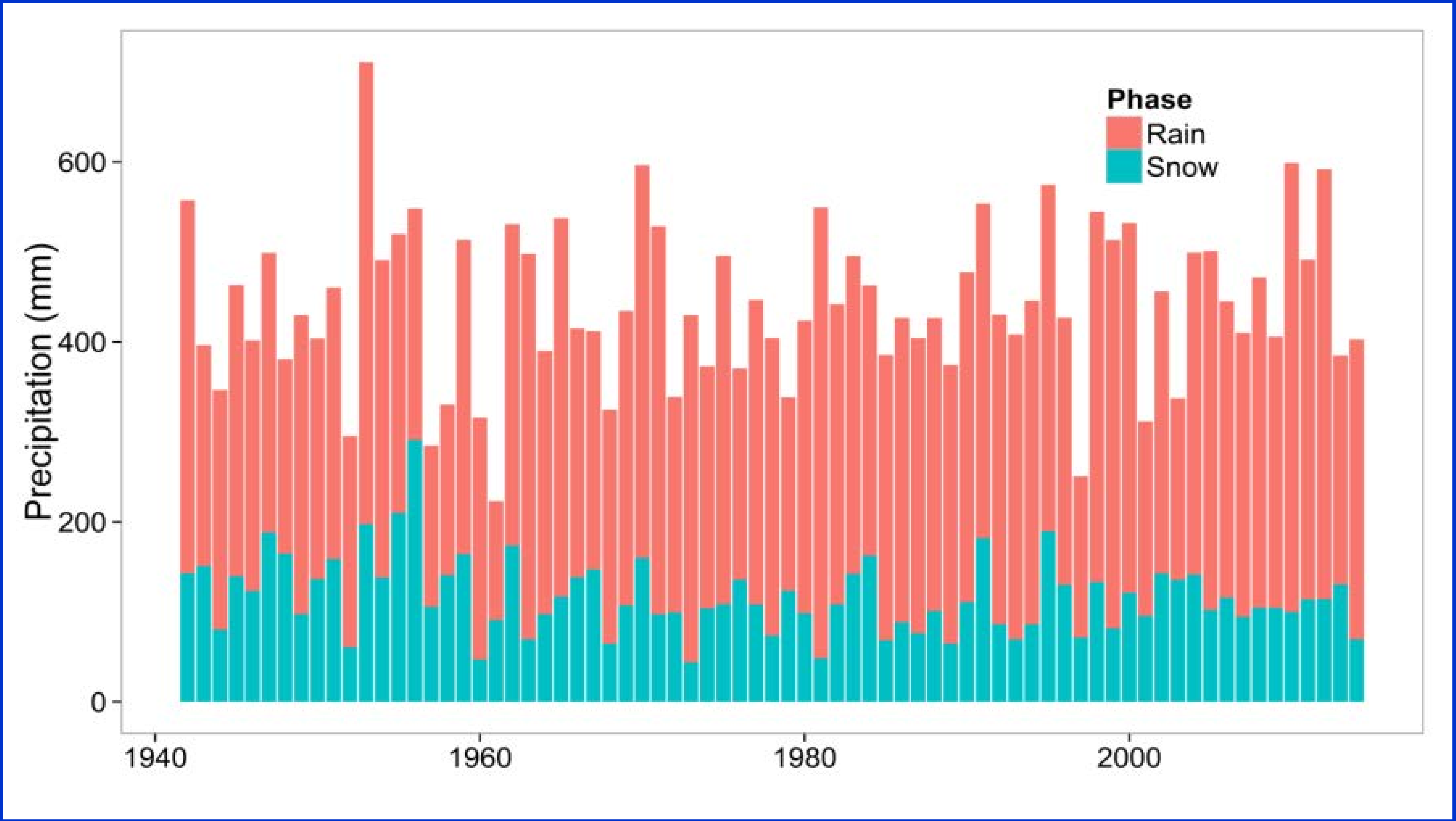
Temperatures Warming

- Annual max, min and mean temperatures increasing

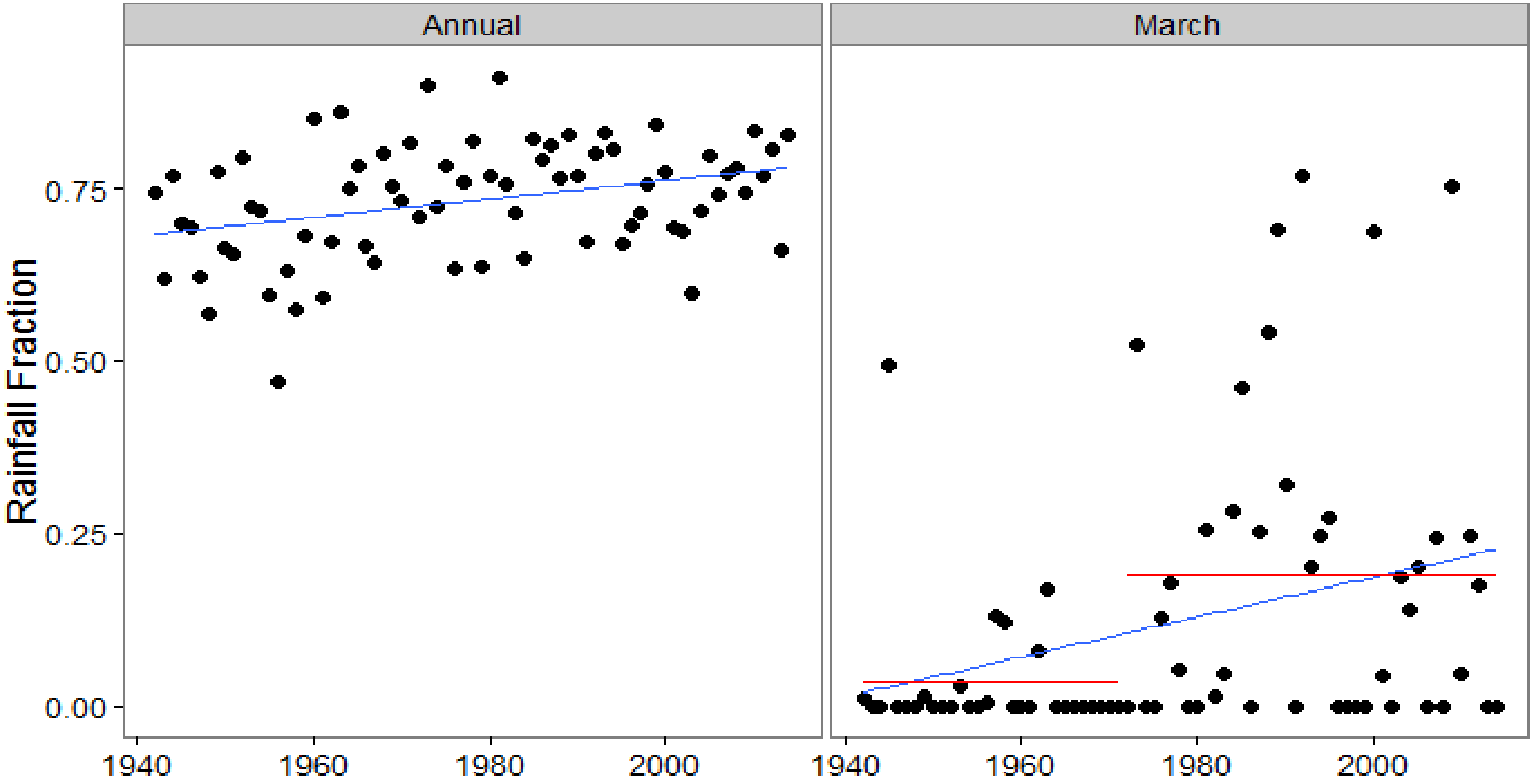


Annual Precipitation

- No significant changes in annual precipitation

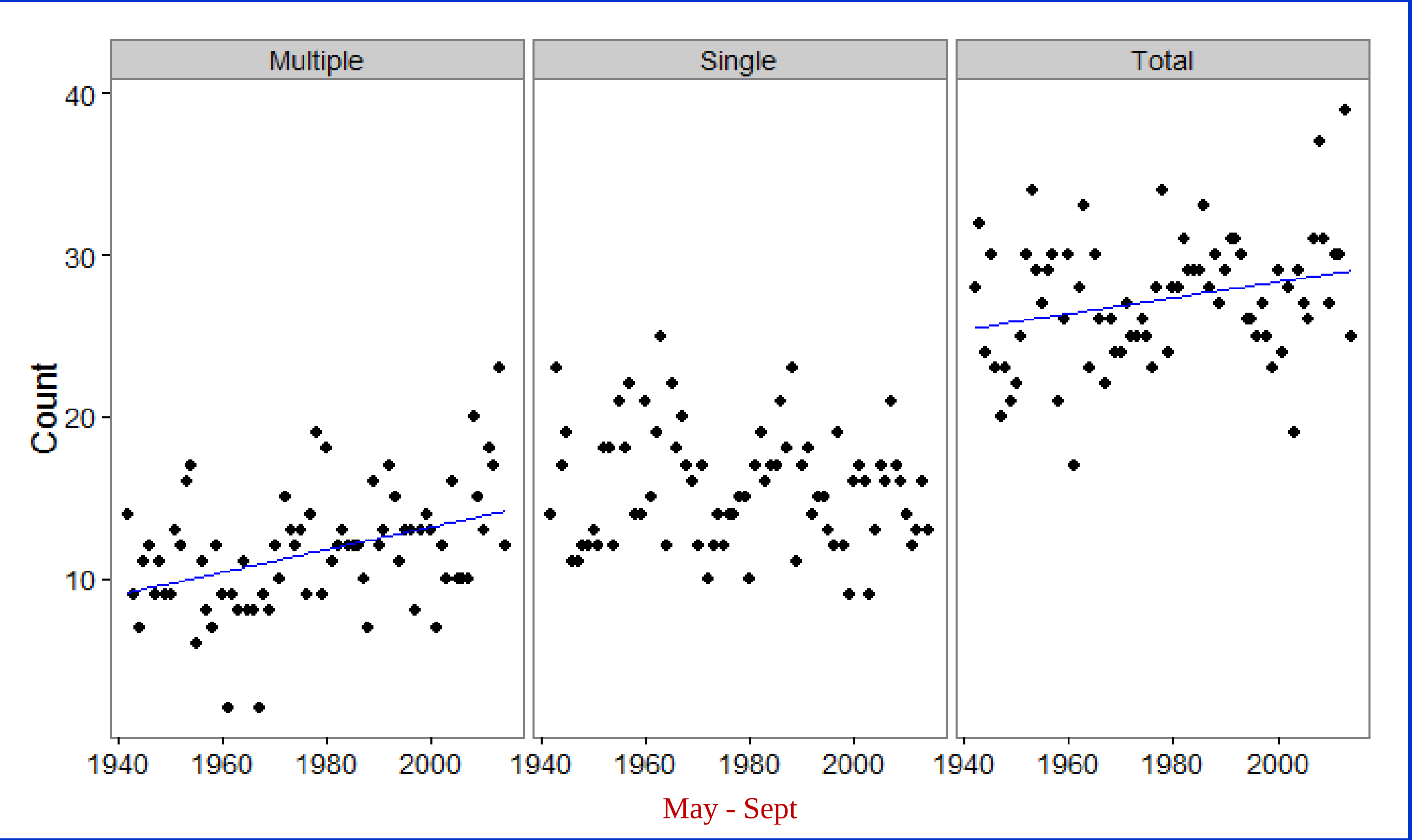


More Rainfall, Less Snowfall



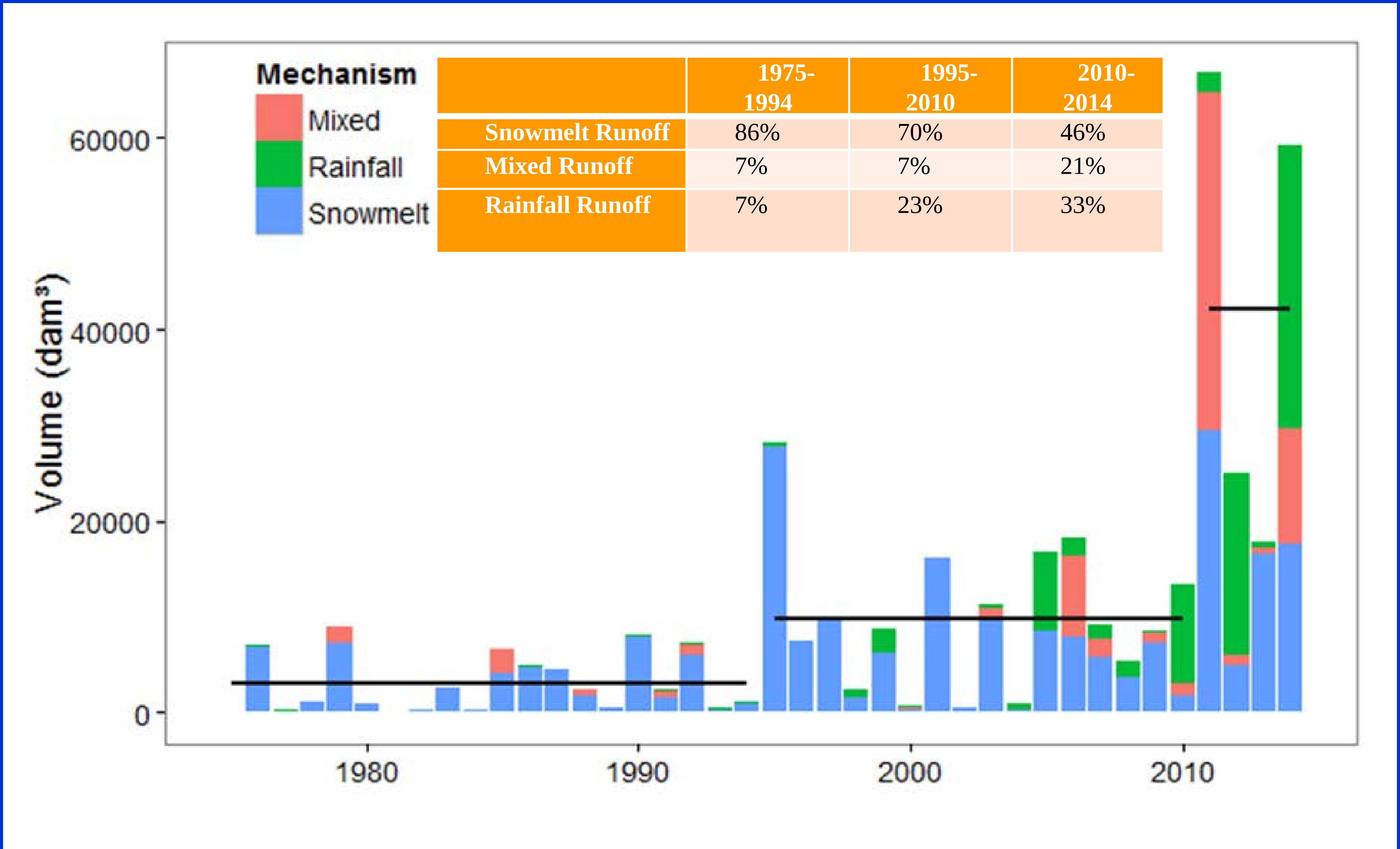
Duration of Rainfall Increasing

- Frontal (multiple day) vs. Convective (single day)
- Increasing number of multiple day and total rain events



Streamflow Volume Increasing

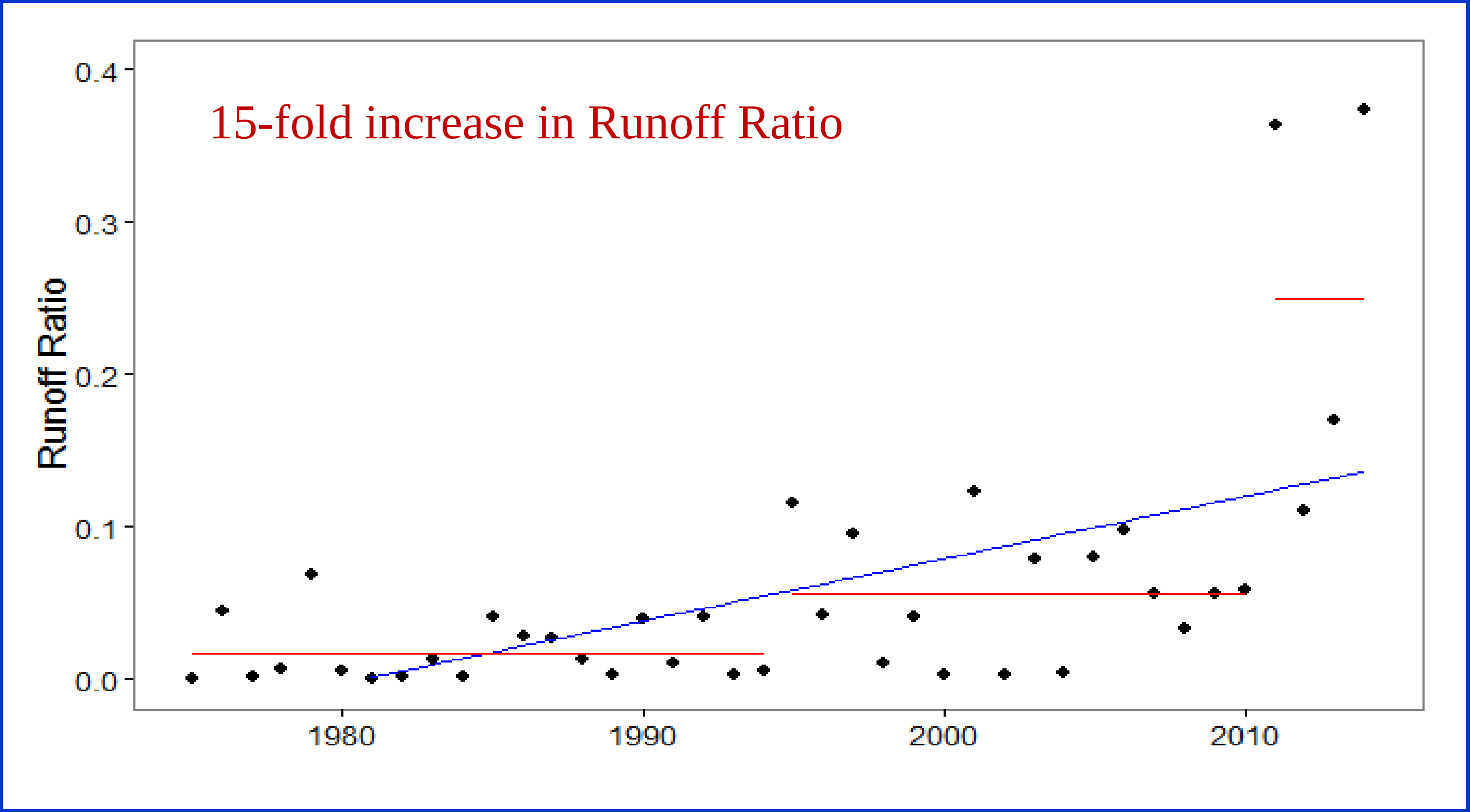
- Streamflow volume increased 12 fold 1994 to 2011
- Large mixed rainfall & snowmelt contribution to 2011 flood.



	1975-1994	1995-2010	2010-2014
Snowmelt Runoff	86%	70%	46%
Mixed Runoff	7%	7%	21%
Rainfall Runoff	7%	23%	33%

Runoff Ratio Increasing

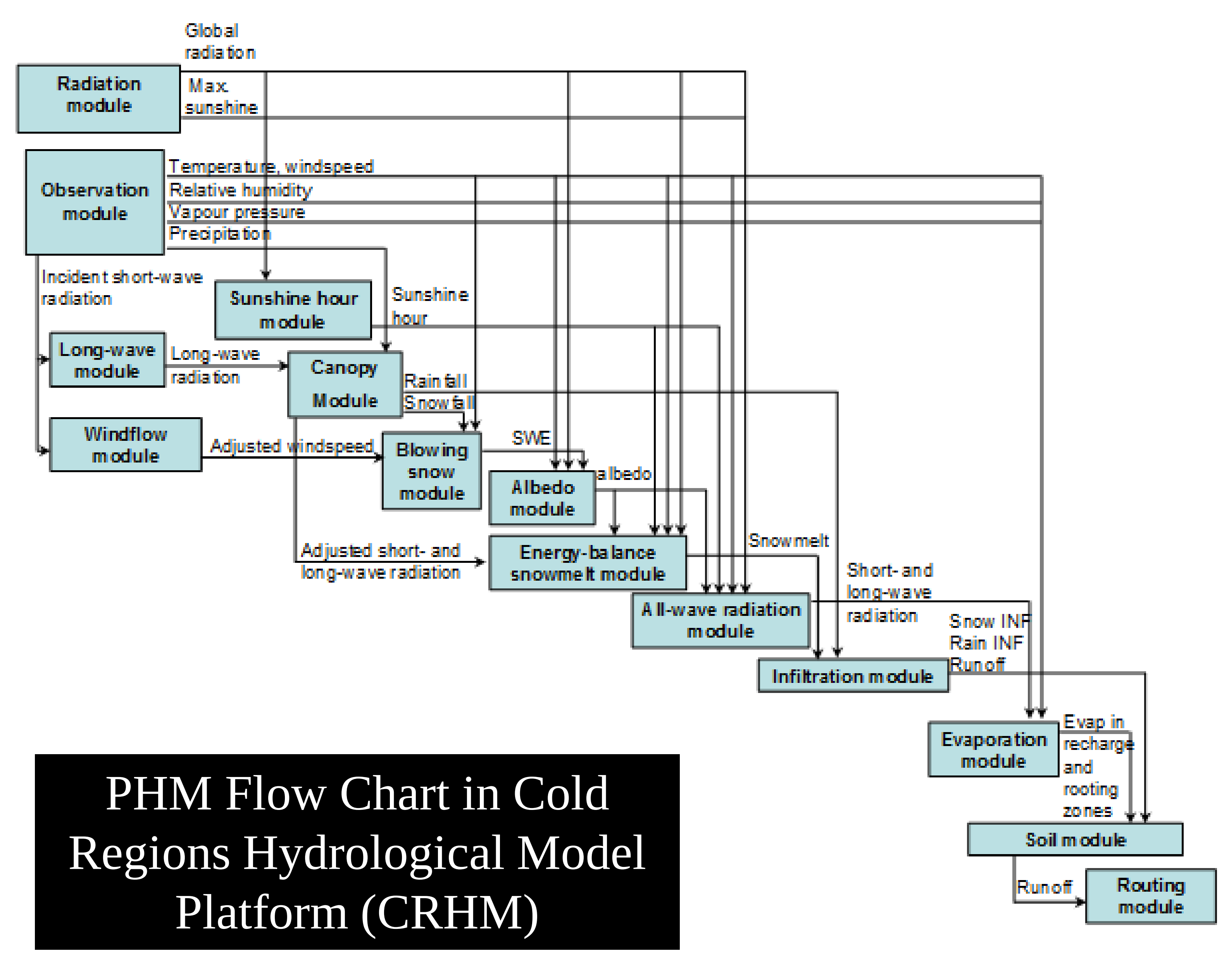
$$Runoff\ Ratio = \frac{Runoff\ (mm)}{Annual\ Precipitation\ (mm)}$$



Hydrological Modelling

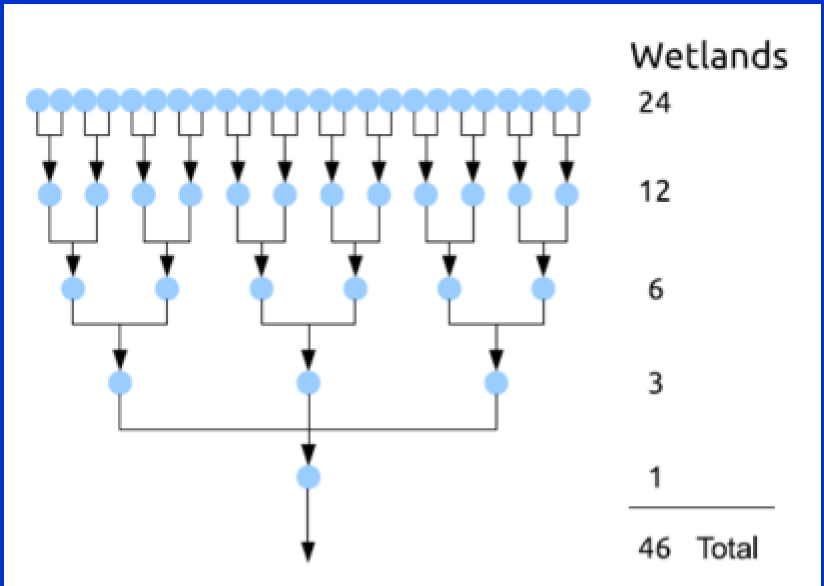
- Prairie Hydrological Model (PHM) developed using the modular, object-oriented, physically-based Cold Regions Hydrological Modelling Platform (CRHM)
- PHM set up to describe hydrological processes operating in the basin.
  - Snow redistribution, sublimation, accumulation and melt
  - Pond storage, drainage
  - Soil moisture storage, evapotranspiration and runoff
  - Stream routing
- Satellite and LiDAR information used to describe Smith Creek as it was in 2008
- Hourly weather data to run the model from 2007 to 2013

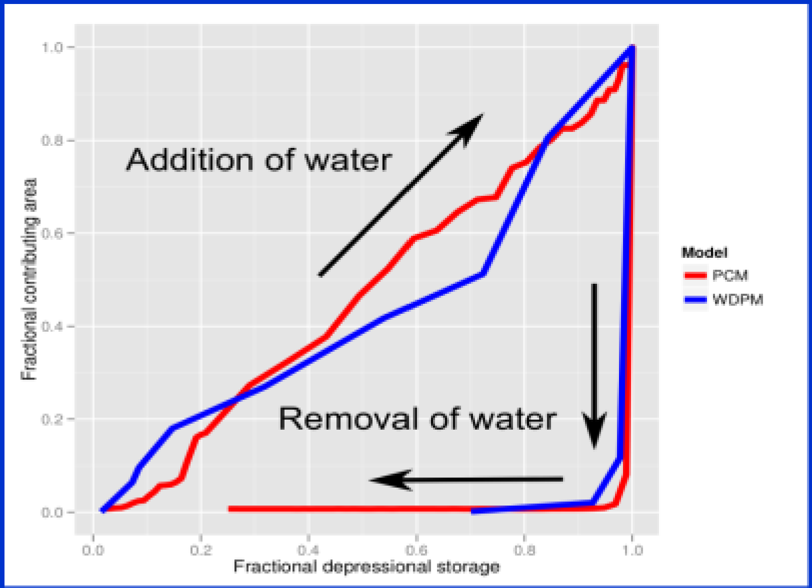
CRHM – Prairie Hydrological Model Configuration

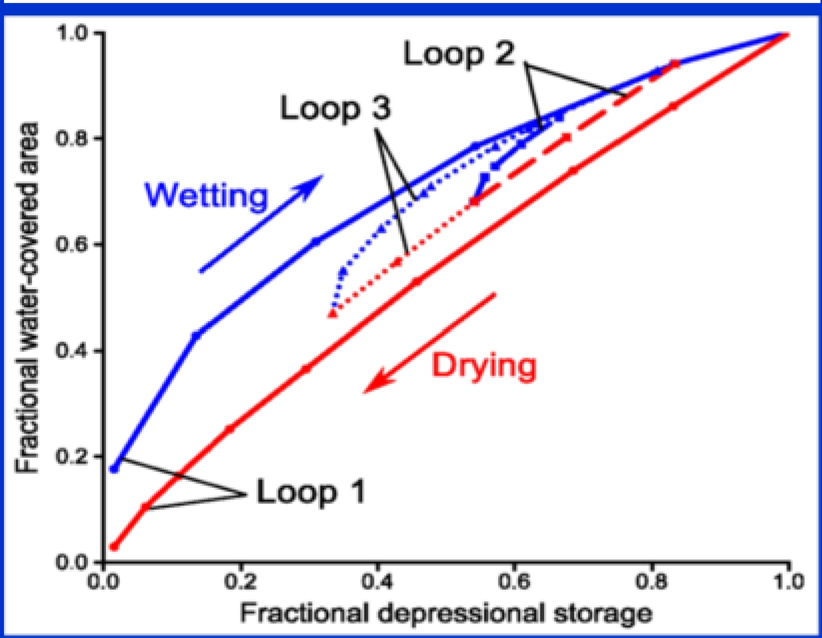


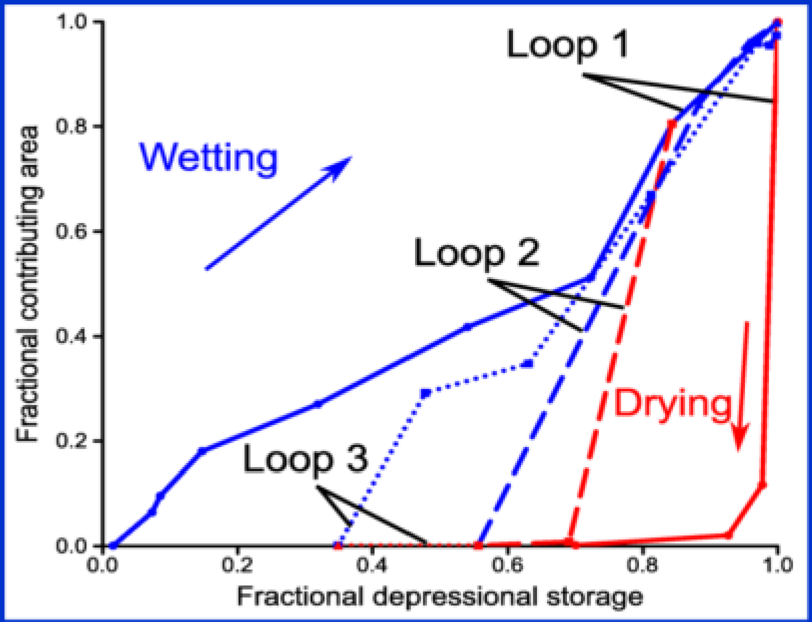
PHM Flow Chart in Cold Regions Hydrological Model Platform (CRHM)

Wetland Representation in PHM





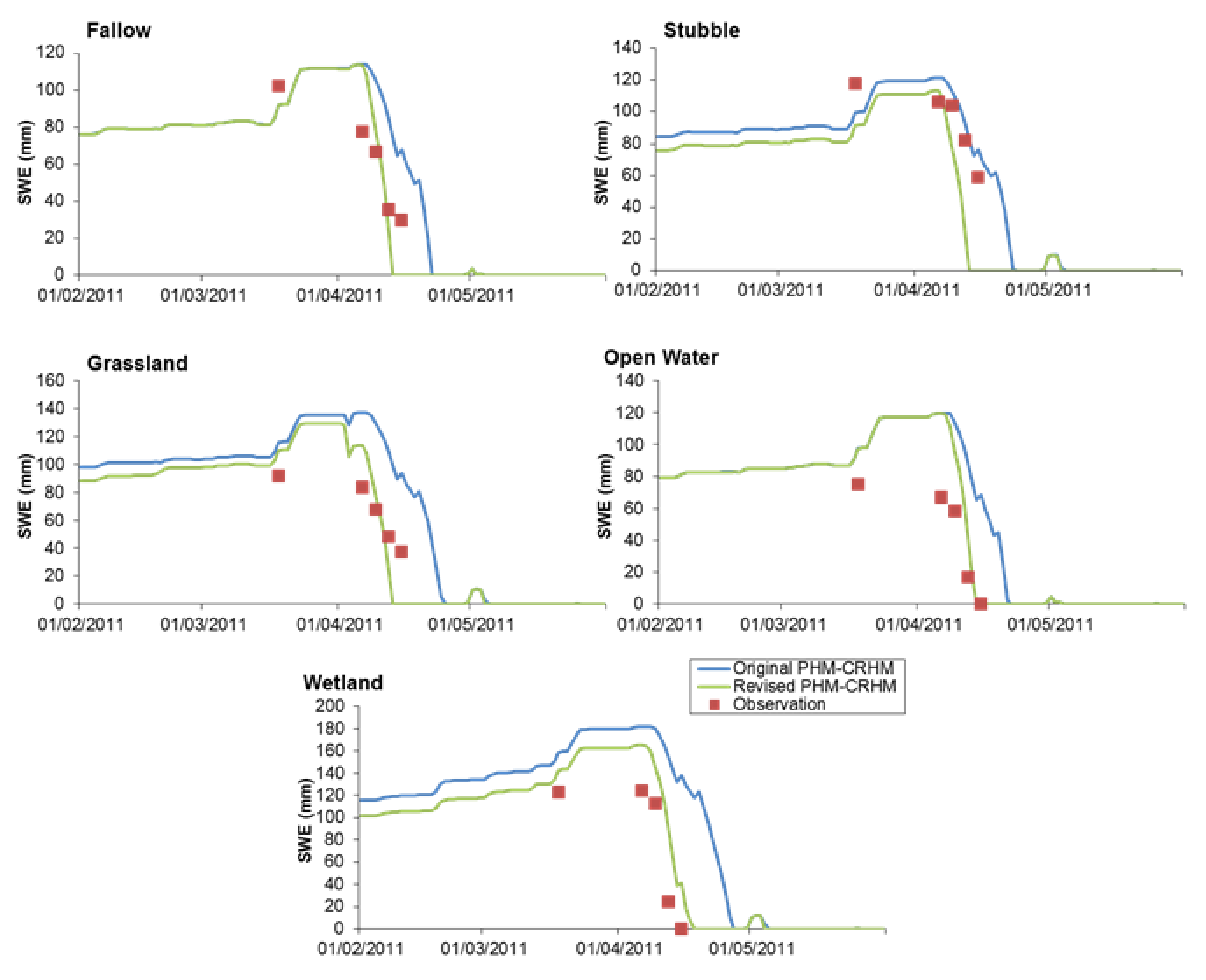




PHM Runs

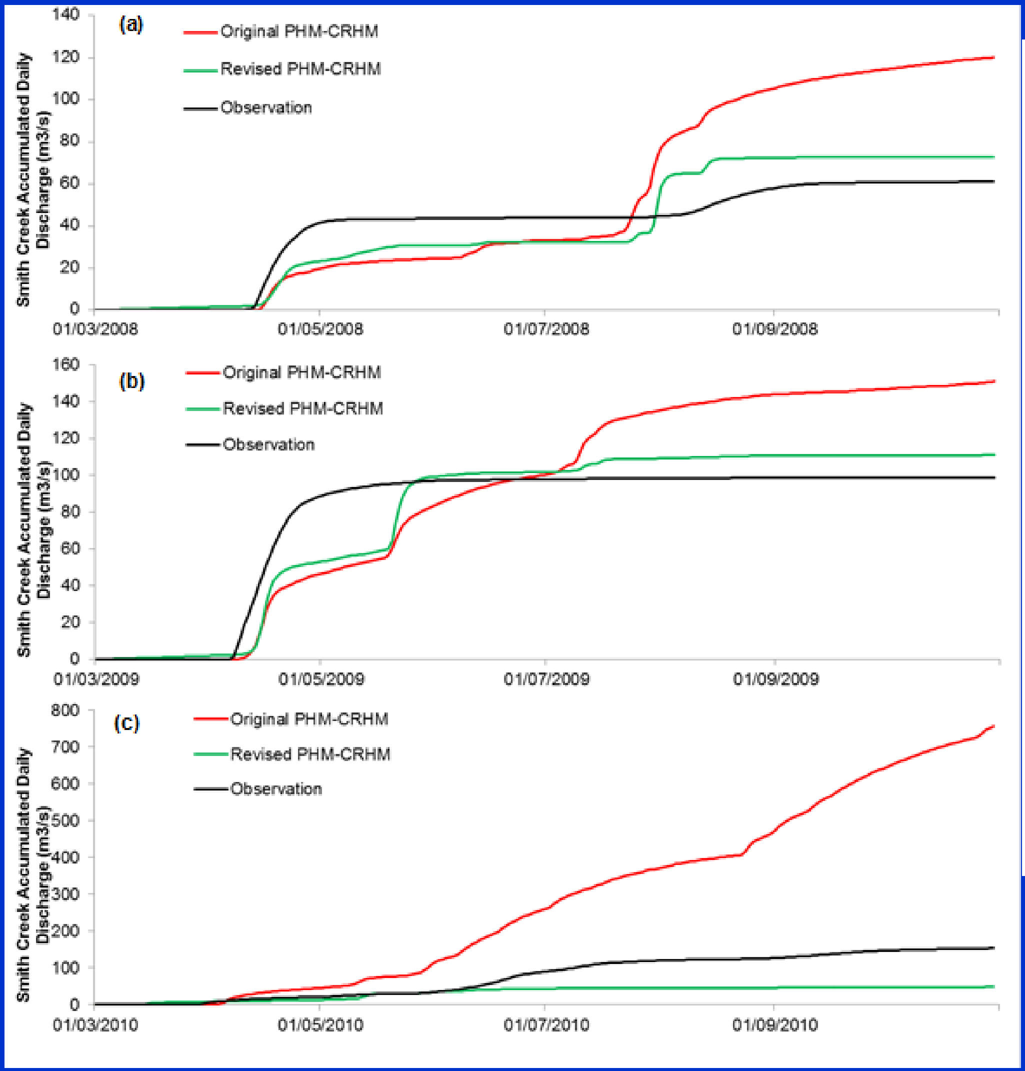
- 2008 LiDAR DEM for stream drainage network and depressional storage capacity,
- 2007 satellite classification of land use
- Meteorological data from U of S weather station from 2007-2013:
  - Air temperature
  - Humidity
  - Wind speed
  - Solar radiation
  - Precipitation (snowfall & rainfall)

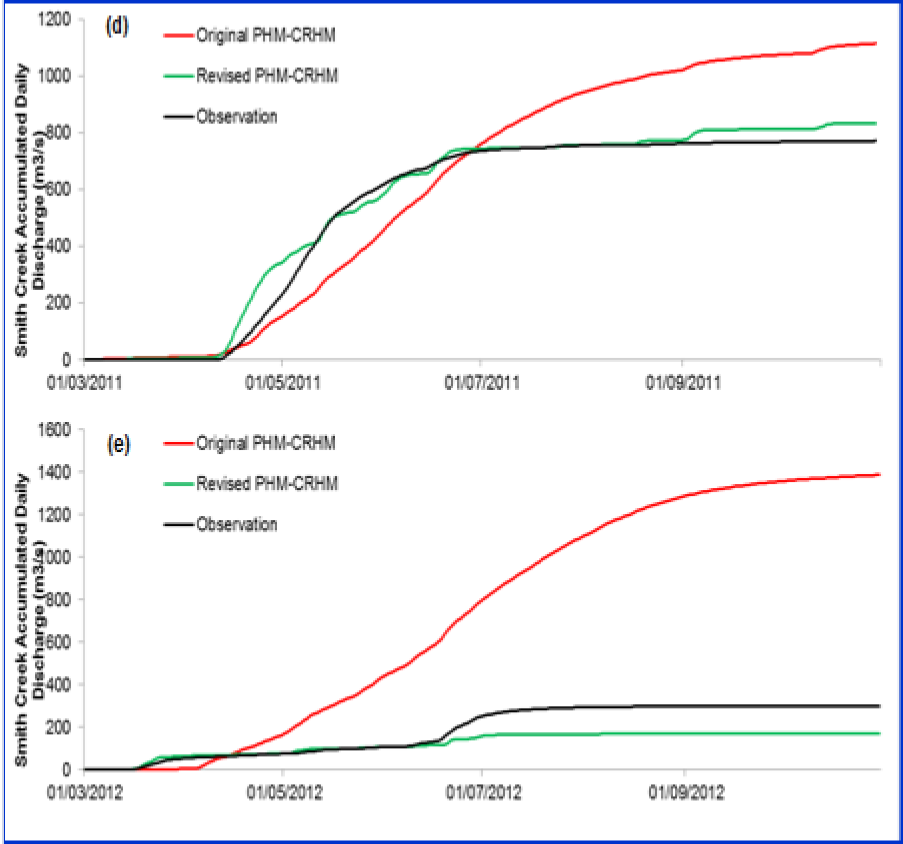
Testing the PHM - Snowpack



RMSD = 28 mm

Testing the PHM - Streamflow





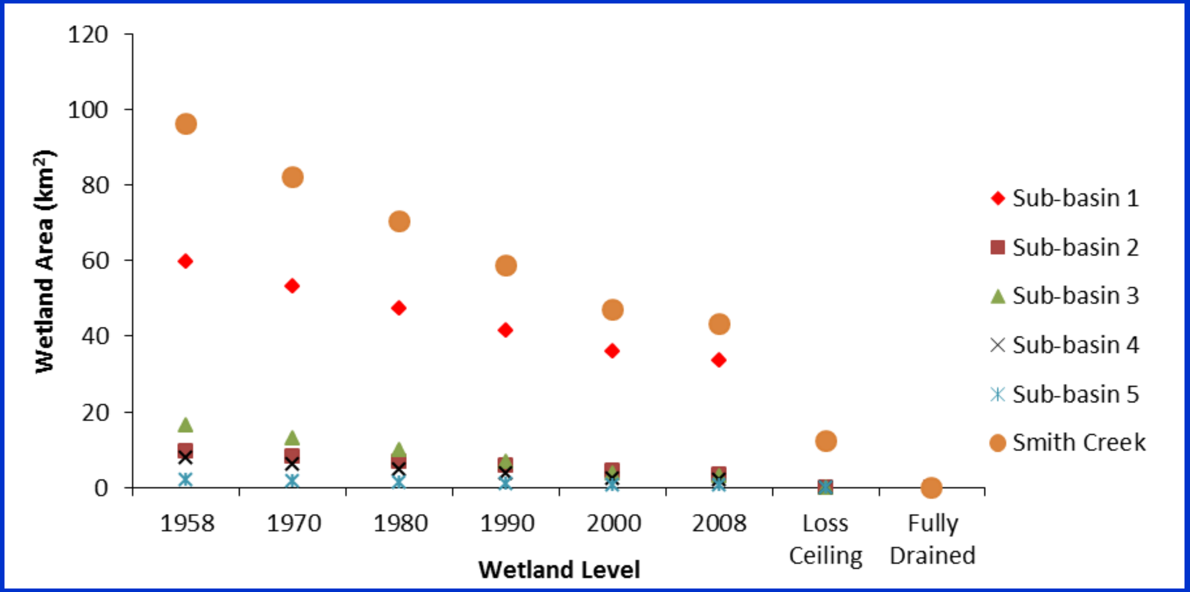
RMSD = 1.8 m^3/s

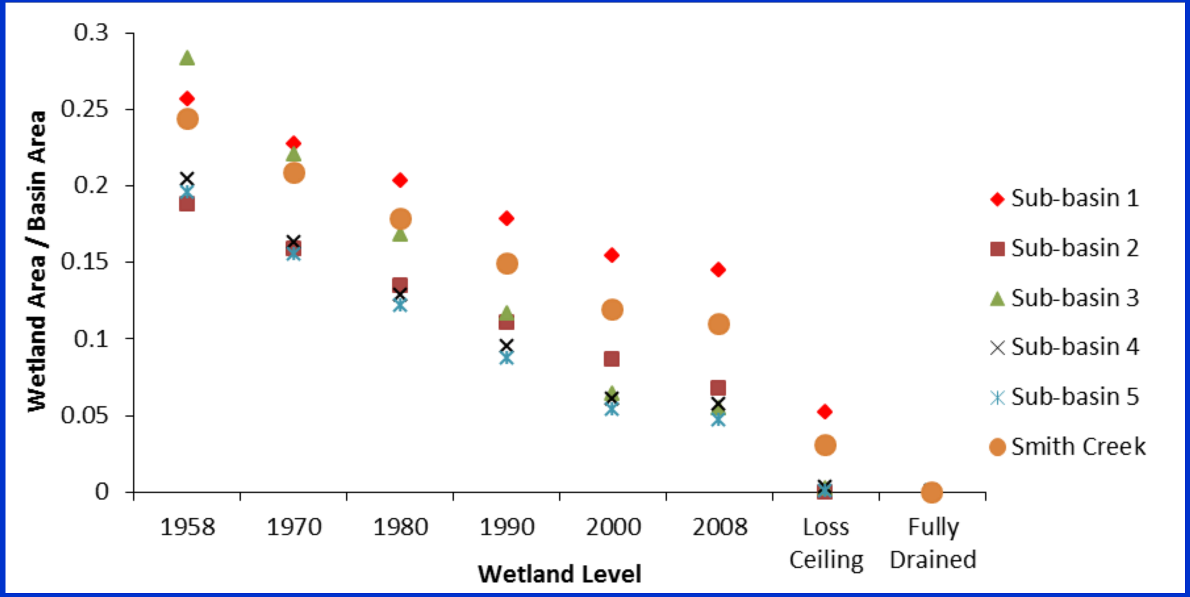
MB = -0.14

PHM Wetland Scenarios

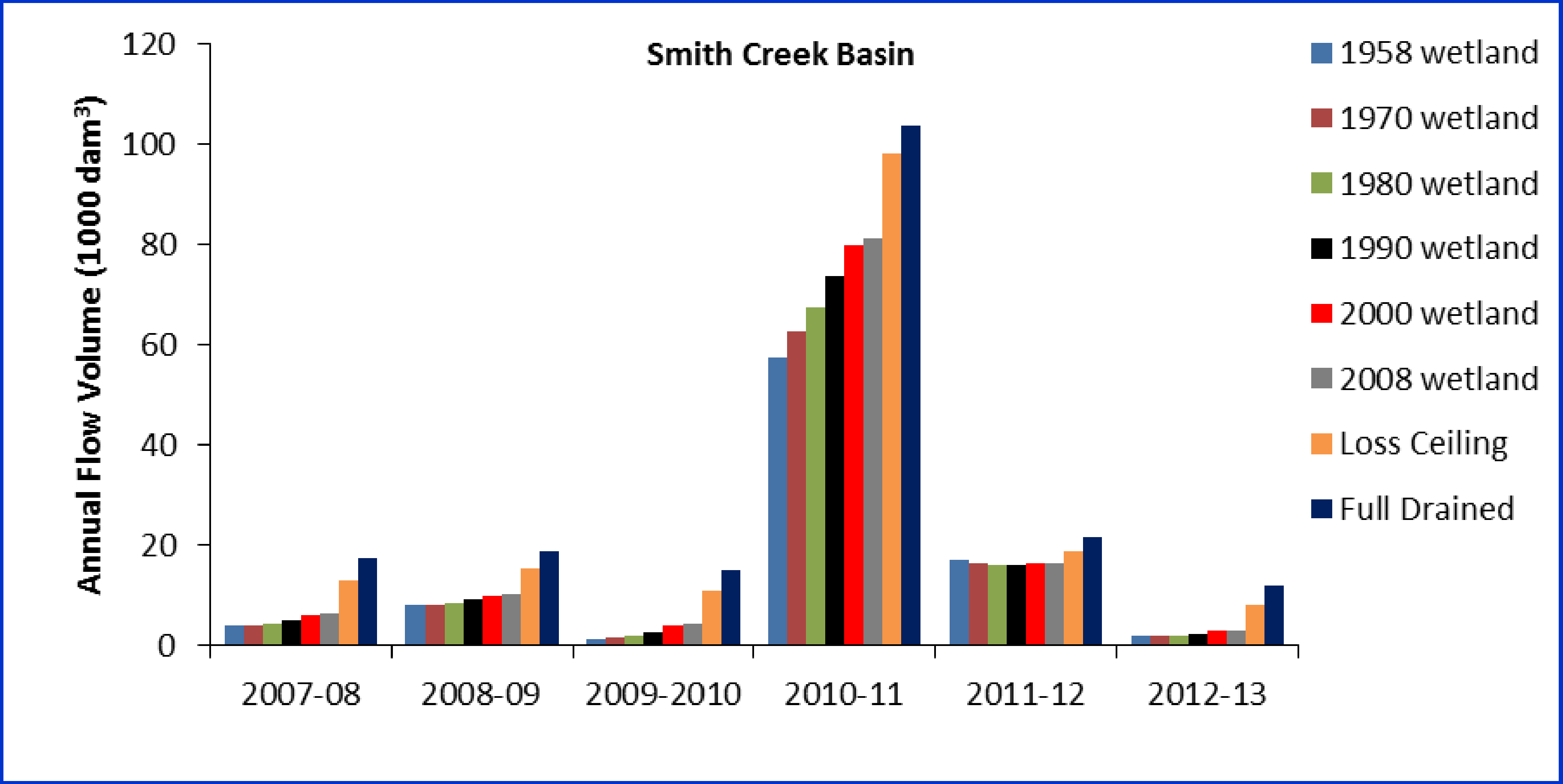
1. **1958**: Maximum known wetland extent and storage volume.
2. **1970**: Derived by linear interpolation of wetland areas between 1958 and 2000 along with area-volume relationships
3. **1980**: Derived by linear interpolation of wetland areas between 1958 and 2000 along with area-volume relationships
4. **1990**: Derived by linear interpolation of wetland areas between 1958 and 2000 along with area-volume relationships.
4. **2000**: 2000 DUC wetland extent was used to estimate wetland storage volumes.
5. **2008**: 2008 LiDAR DEM was used to determine the area, storage capacity and connectivity: considered “current”.
6. **“Loss Ceiling”**: All wetlands that occur outside of conservation lands in a sub-basin were drained.
7. **“Fully Drained”**: All wetlands were drained.

Smith Creek Wetland Drainage



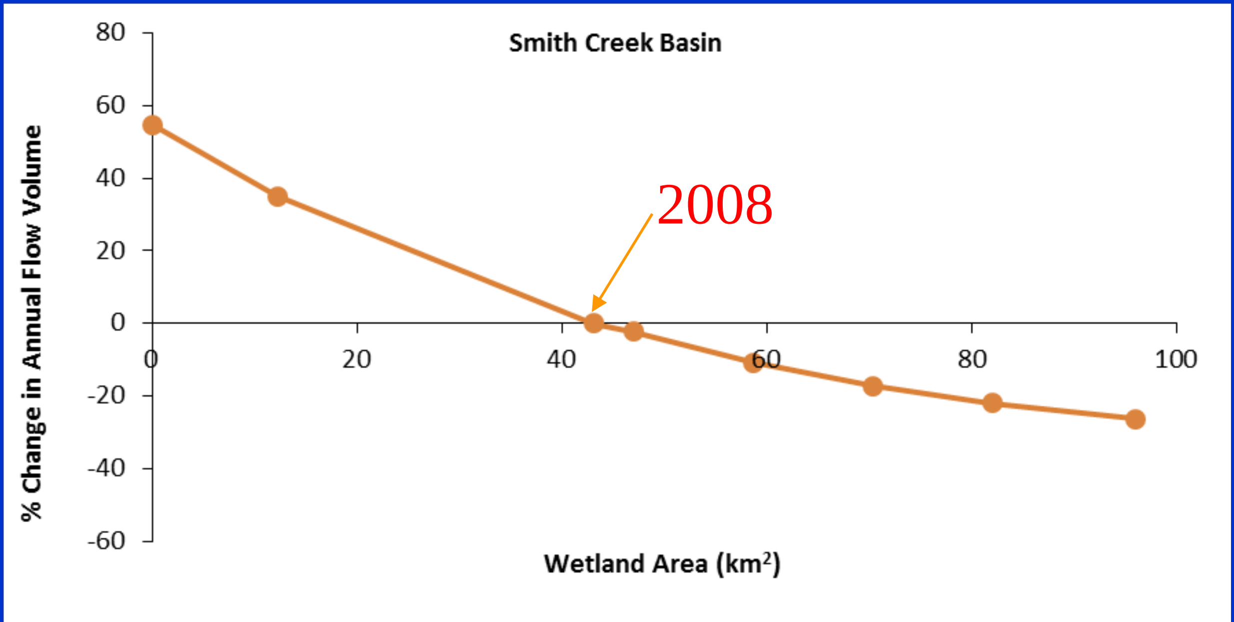


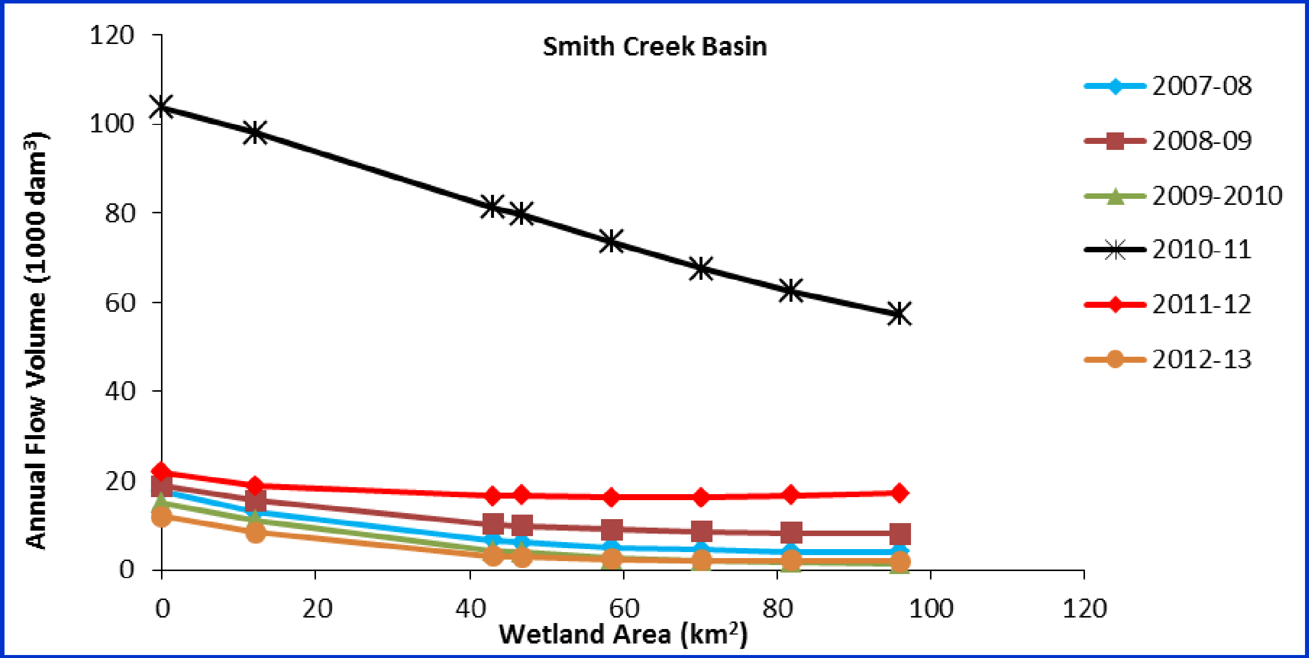
Impact of Drainage on Annual Flow Volume



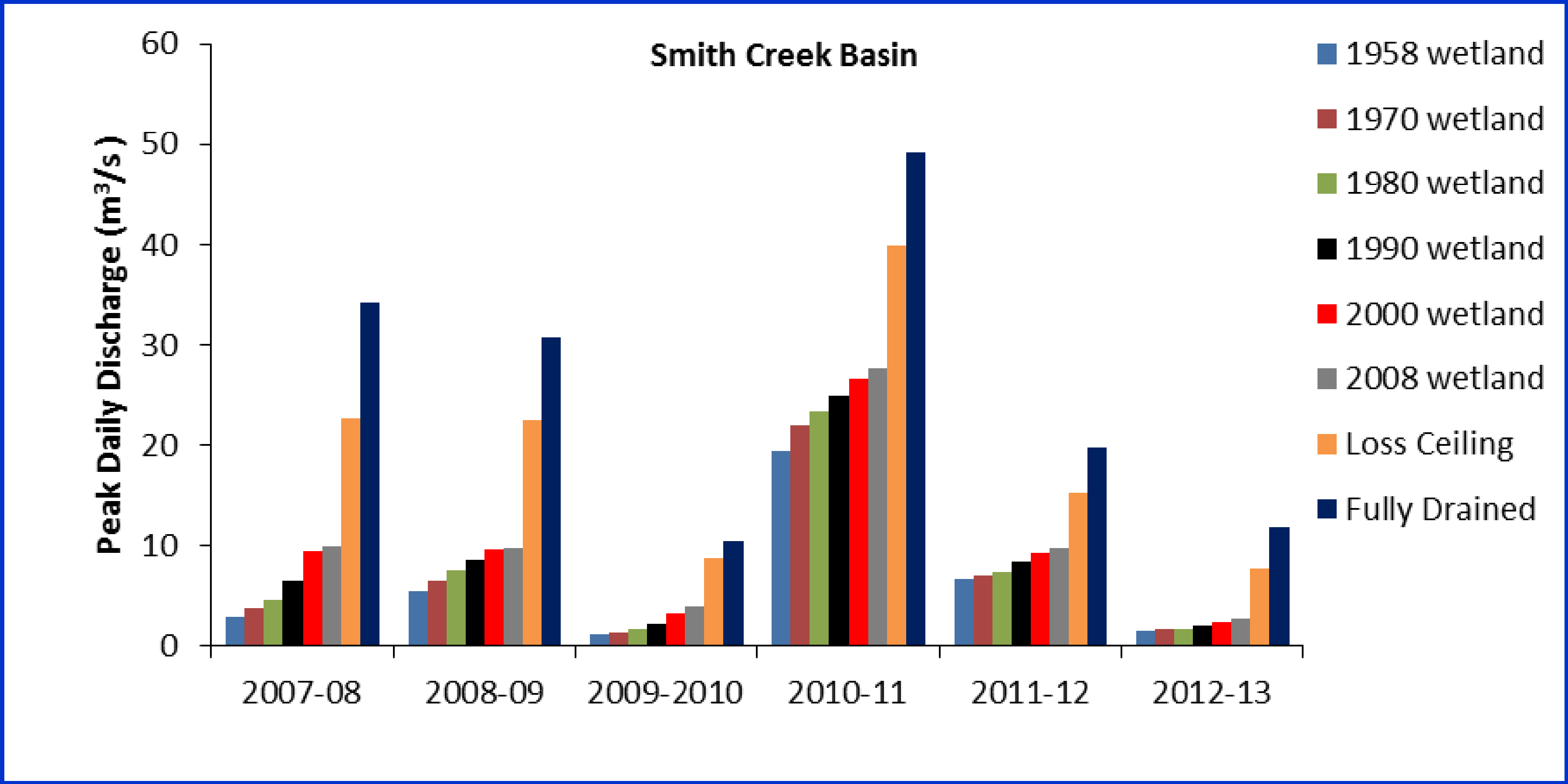
Impact of Wetland Area on Annual Flow Volume

% change from 2008

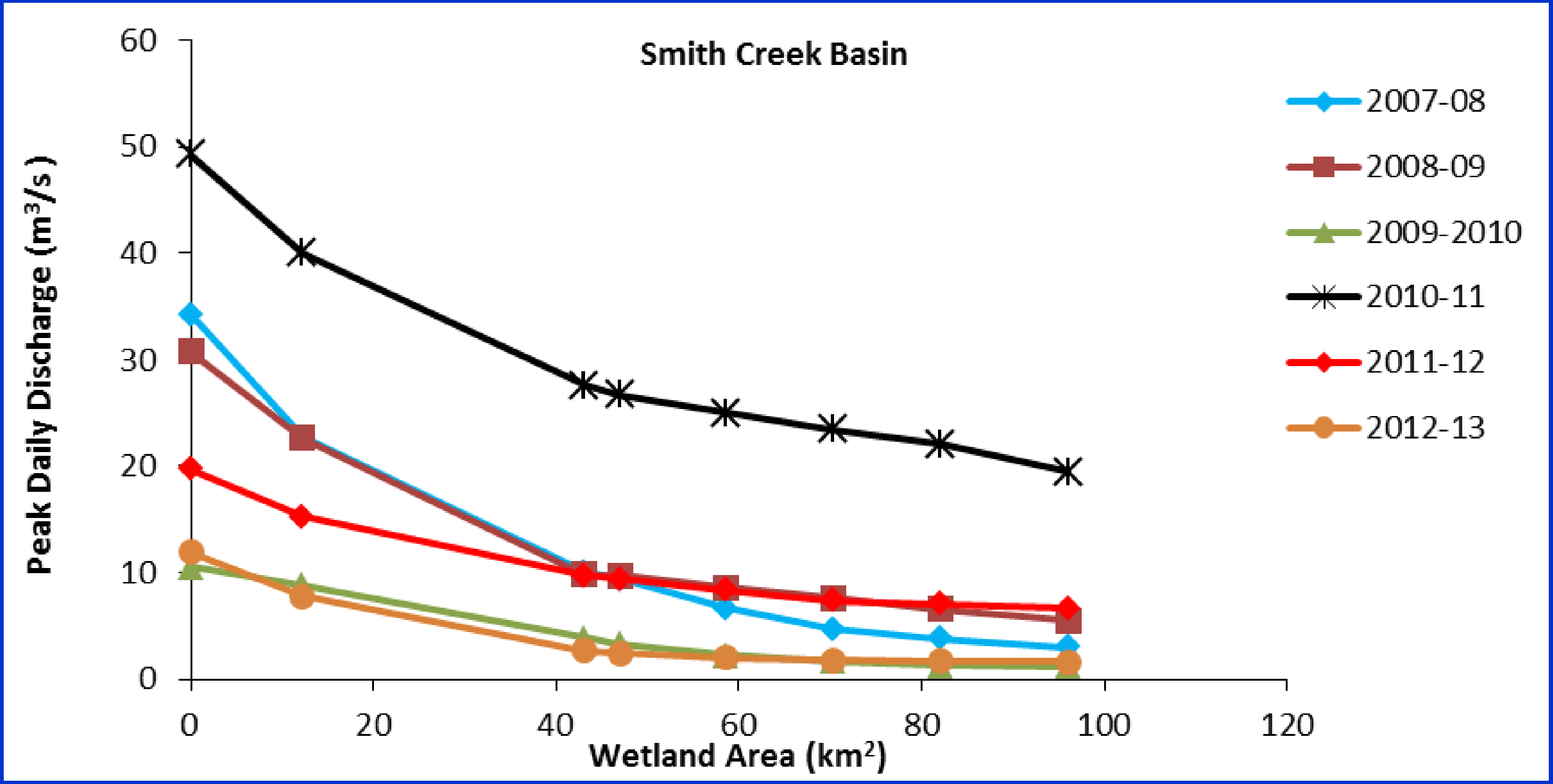




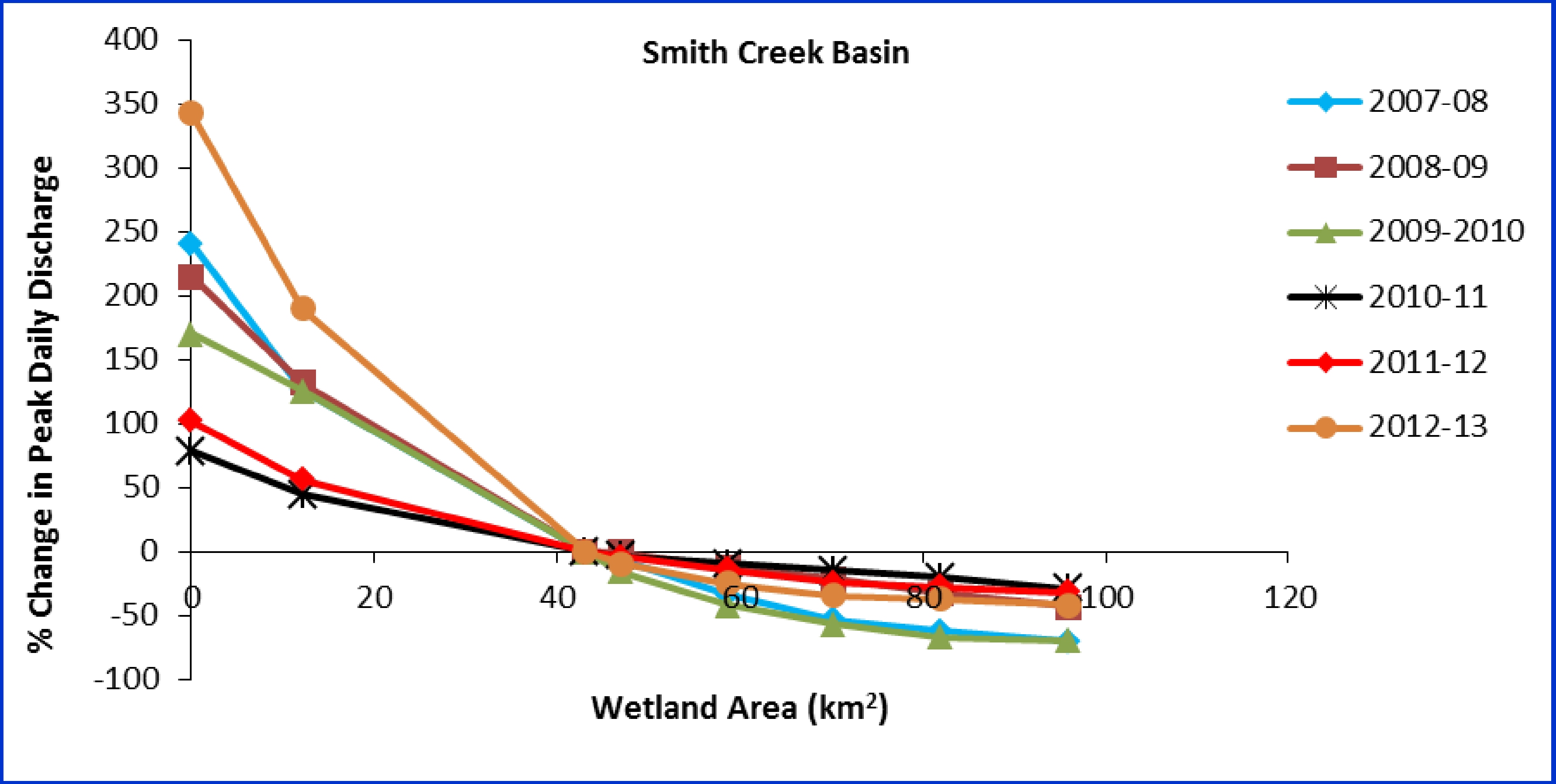
Impact of Drainage on Peak Daily Discharge



Impact of Wetland Area on Peak Daily Discharge



Impact of Wetland Area on Proportional Change in Peak Daily Discharge



Observed Changes in Smith Creek

- Over one-half of wetlands have been drained over the last 56 years.
- Climate in the basin shows signs of global warming
  - air temperatures have warmed substantially, especially in winter and spring
  - increase in rainfall fraction of precipitation
  - increased frequency of multi-day rainfall events
- Streamflow and runoff ratios have increased dramatically and disproportionately to climate
  - Greater contribution from rain-on-snow and rainfall runoff processes
  - Summer streamflow and flooding
- Gradual changes to the character of precipitation cannot fully explain the 12-fold increase in streamflow volumes and 15-fold increase in runoff ratios after 1994.
- The shifts after 1994 and 2010 are likely due to combinations of a changing climate, and recent increases in wetland drainage.

Wetland Drainage Model Outcomes

- **Wetland drainage increases the size of both snowmelt (2011) and rainfall-runoff (2012) floods.**
- **In 2011 snowmelt flooding, limited surface water storage capacity <u>did not</u> reduce the impact of wetland drainage on streamflow volume or peak flows.**
- **In 2012 rainfall-runoff flooding, lack of surface water storage capacity <u>did</u> reduce the impact of wetland drainage on streamflow volume but <u>did not</u> reduce the impact on peak flows.**
- **Relative impact of wetland drainage is greatest for low to medium flow years but still important for high flow years**

Conclusions

- In flood conditions;
  - Wetland drainage has a very strong impact on streamflow. Modelled drainage of existing wetlands increases the 2011 peak flow by 78% and the 2011 flow volume by 32%.
  - Wetland restoration has a strong impact on streamflow. Modelled restoration of current drainage to 1958 wetland conditions reduces the 2011 peak flow by 32% and the 2011 flow volume by 29%.
- In normal to dry years, wetland drainage has an exceptionally strong impact on streamflow. Modelled drainage of existing wetlands increases peak flows by 150% - 350%, and streamflow volumes by 200% - 300%.
- Over six years of simulation, complete wetland drainage increased total streamflow volumes by 55% and restoration to 1958 conditions decreased total volumes by 26%.
- The combination of climate change and wetland drainage has created hydrological regime change in Smith Creek with a dramatic increase in streamflow volume and runoff generation efficiency and the development of unprecedented rainfall induced and summer flooding in the last 20 years

Thanks

- Prairie Habitat Joint Venture Committee
- Saskatchewan Water Security Agency
- Manitoba Water Stewardship
- Agriculture and Agrifood Canada
- Environment Canada
- Ducks Unlimited Canada
- Smith Creek Watershed Association
- Canadian Foundation for Climate and Atmospheric Sciences
- Natural Science and Engineering Research Council of Canada
- Canada Research Chair Programme

Contact
John Pomeroy john.pomeroy@usask.ca

www.usask.ca/hydrology

Centre for Hydrology Report No. 14
http://www.usask.ca/hydrology/papers/Pomeroy_et_al_2014.pdf