A Seasonal Operational Model for Water Management within Irrigation Districts

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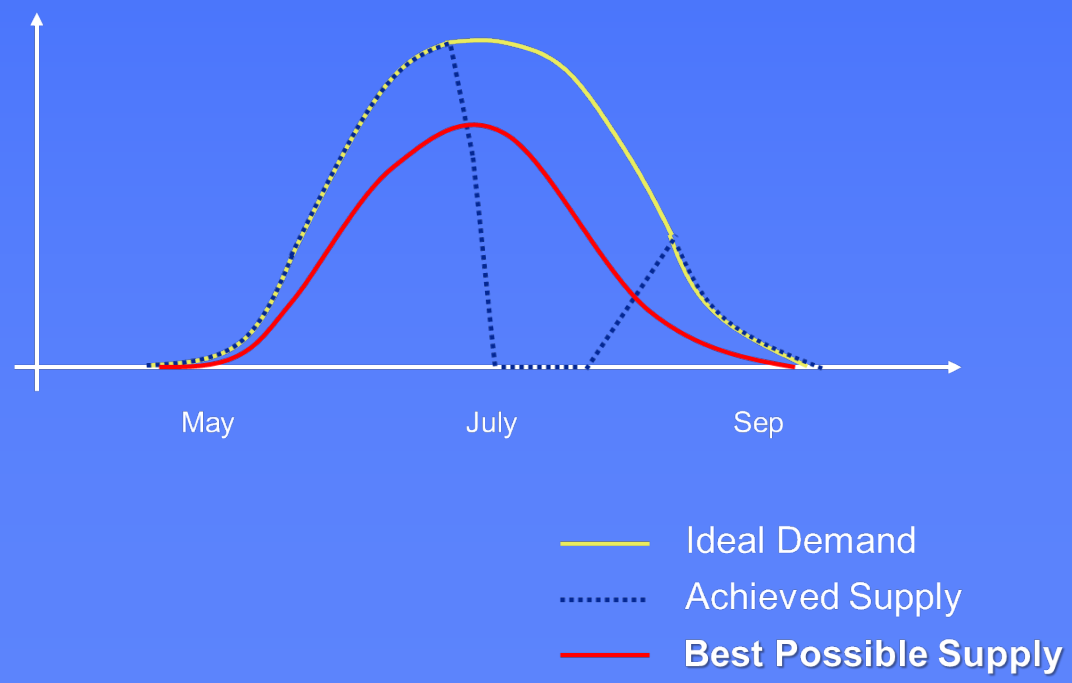
Project Objectives

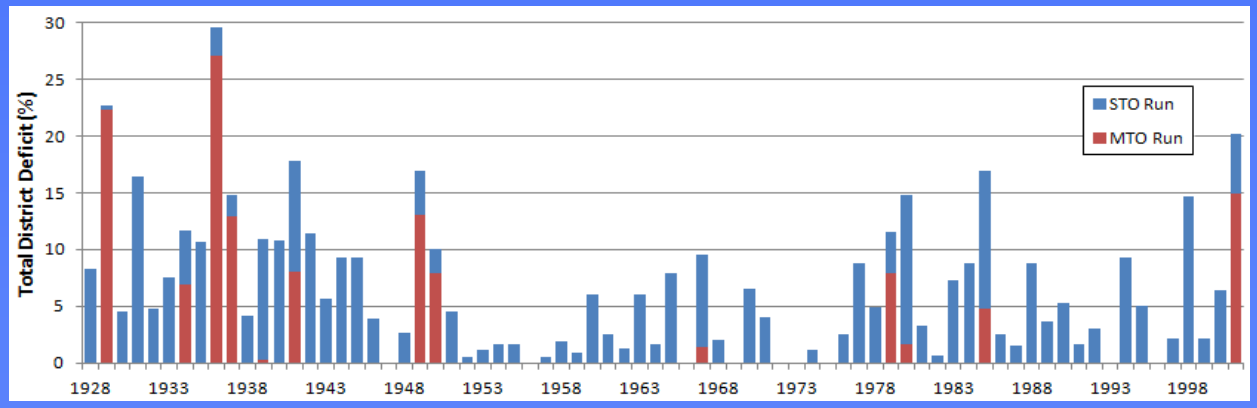
1. **Find the best way to manage irrigation district reservoirs and licensed diversions**
   - **Achieve "Best Possible Supply" to meet irrigation demands**

An example of typical seasonal irrigation demand vs. supply



Project Objectives

2. **Extend computer model results from planning studies to real time operation**
   - **Model irrigation season at weekly time scale**
   - **Move from "STO" to "MTO" (*multiple time step optimization*)**



<u>Benefit</u>: Example of reductions in annual irrigation deficits in the WID for STO *vs.* MTO simulation

Presentation Outline

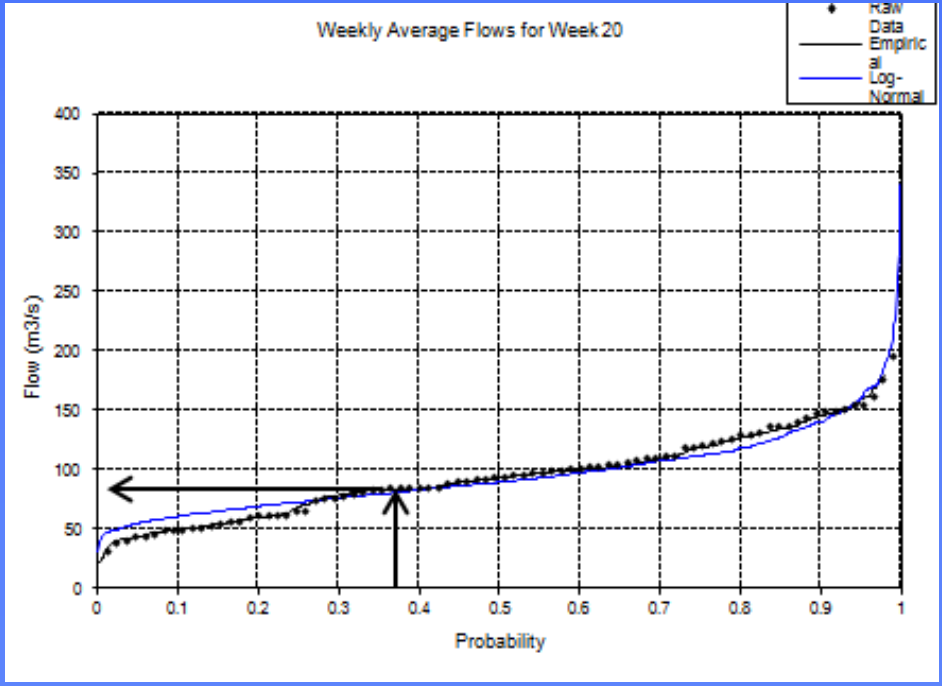
A report on our work over the last year:

1. **Seasonal runoff projections for Southern Alberta**
2. **Seasonal Operational Model development**
3. **Low flow management for City of Calgary**

1. Seasonal Runoff Forecasting

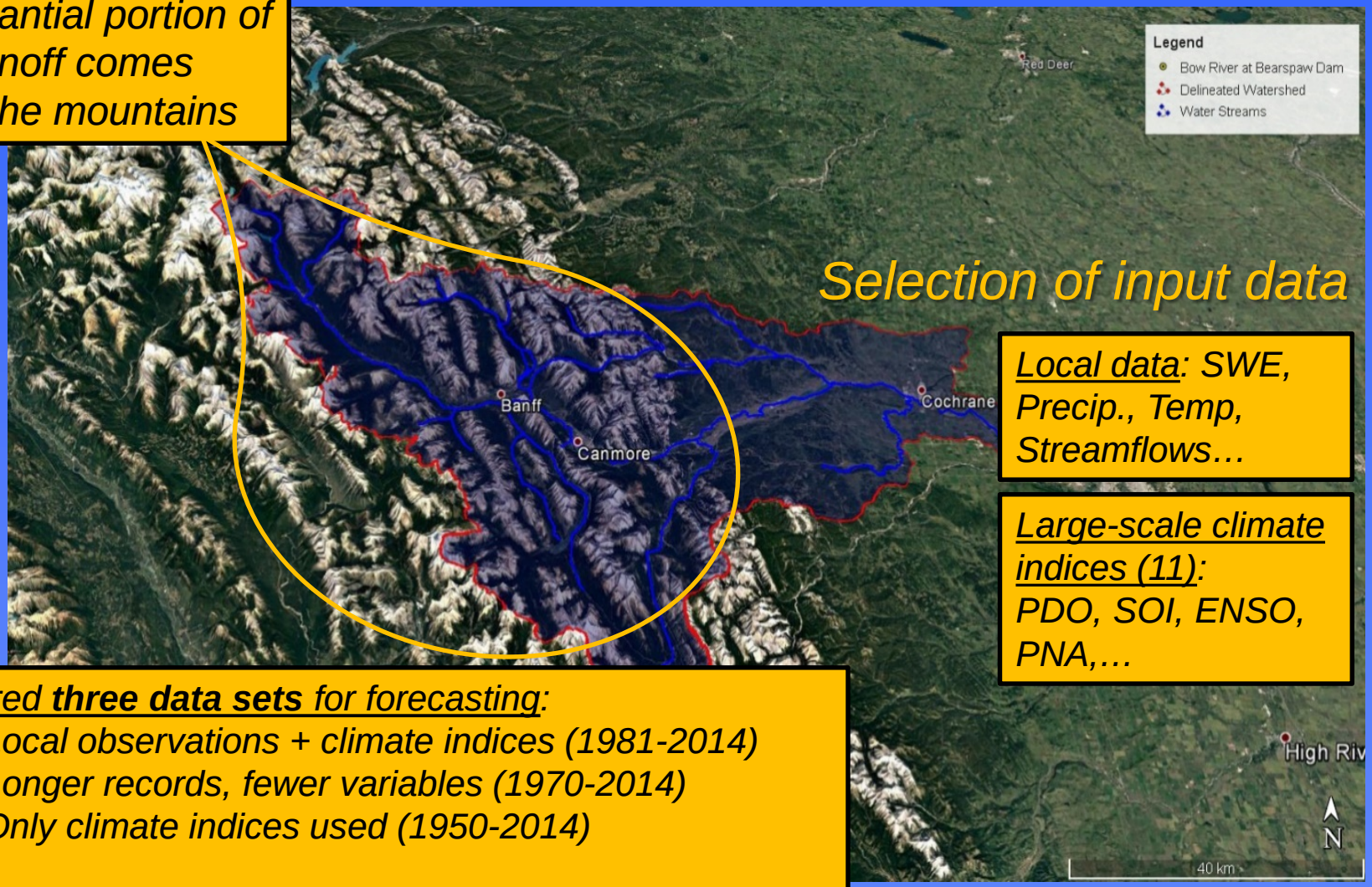
Step 1: Use **snowpack** surveys **and other indicators** to obtain seasonal runoff forecast and the return period of the current hydrological year

Step 2: Break down seasonal forecast into **weekly flows** by using probability plot of historic weekly natural flows and selecting the same return period as the seasonal forecast for all weeks after May 1st



Streamflow Forecasting Methods

Substantial portion of the runoff comes from the mountains



Selection of input data

<u>Local data</u>: SWE, Precip., Temp, Streamflows…

<u>Large-scale climate indices (11)</u>: PDO, SOI, ENSO, PNA,…

*<u>Prepared **three data sets** for forecasting</u>:*
"S1": Local observations + climate indices (1981-2014)
"S2": Longer records, fewer variables (1970-2014)
"S3": Only climate indices used (1950-2014)

Testing: 65% of record; Validation: 35% of record

Streamflow Forecasting Methods

- **Models employed**
  - Multiple Linear Regression
  - Support Vector Machines
  - Extreme Learning Machines
- **Techniques for selecting input variables**
  - High correlation (Pearson)
  - Forward stepwise selection
  - Backward stepwise elimination
  - Principle component analysis (PCA)

- **Result: Extreme Learning Machines with PCA yielded the best predictions**

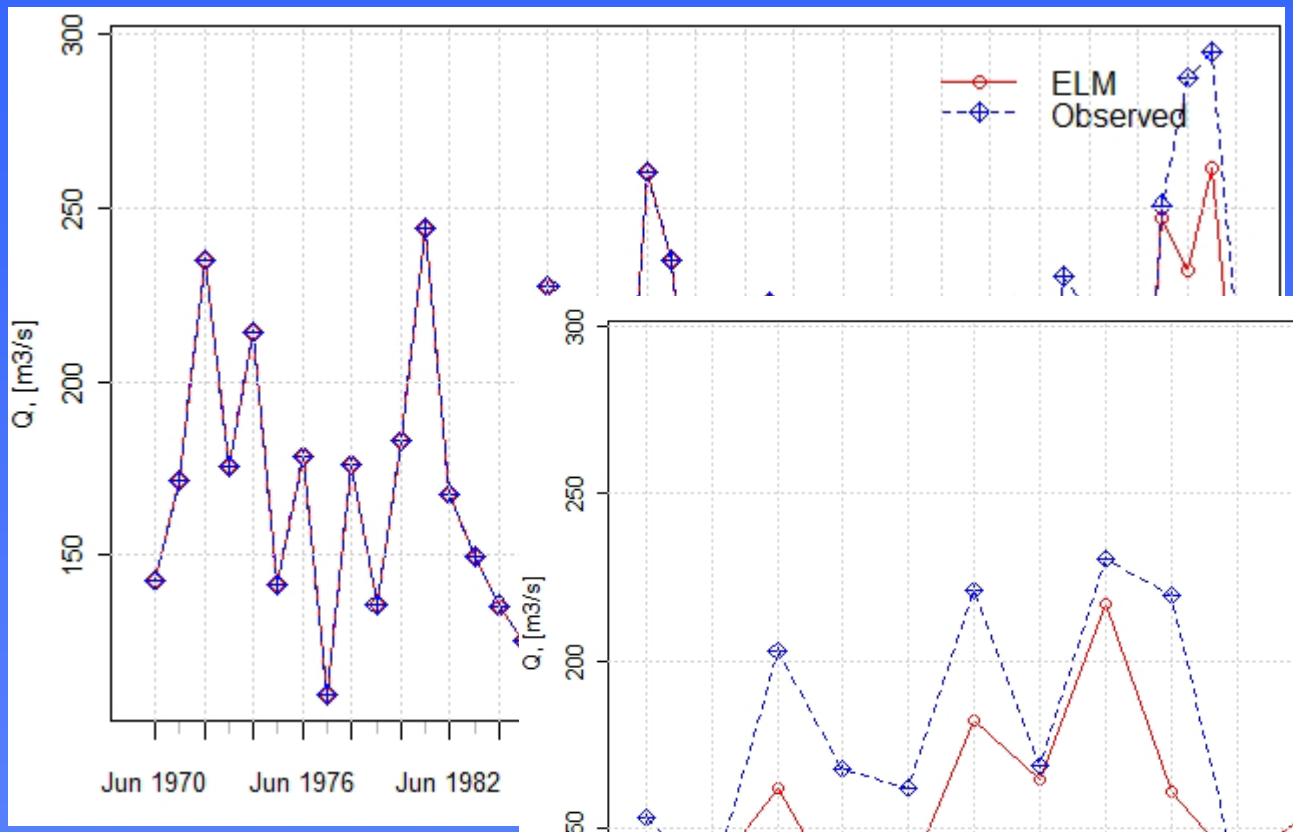
Streamflow Forecasting Results

Model	Mean absolute error (MAE; $m^3 s^{-1}$)	Root mean square error (RMSE; $m^3 s^{-1}$)	Coefficient of determination (R^2)	Nash-Sutcliffe coefficient (NSE)	Index of agreement (d)
ELM					
S1	36.3	42.2	0.81	0.31	0.80
S2	24.8	31.0	0.80	0.59	0.88
S3	34.0	42.2	0.07	0.03	0.40

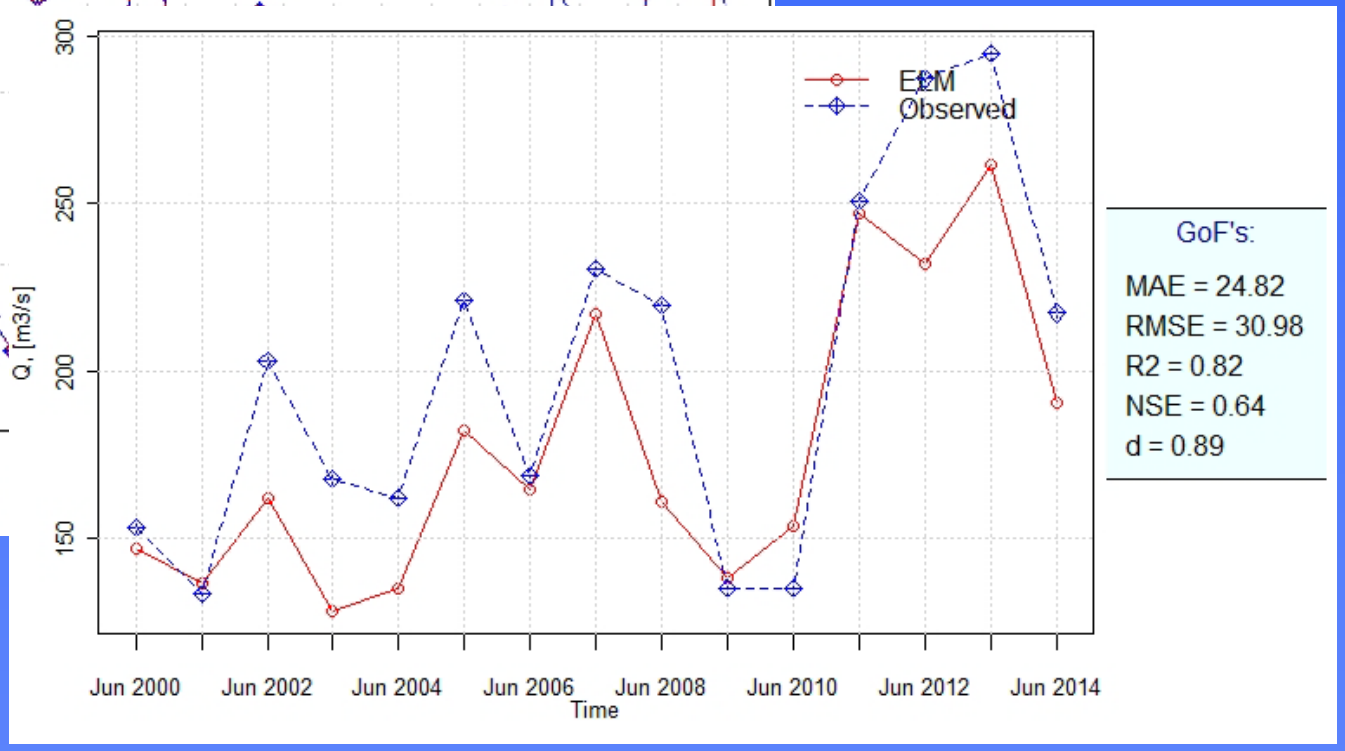
Recall: S1, S2, and S3 are the data sets used

MAE and RMSE are compared against seasonal (MJJ) average streamflows

Streamflow Forecasting Results

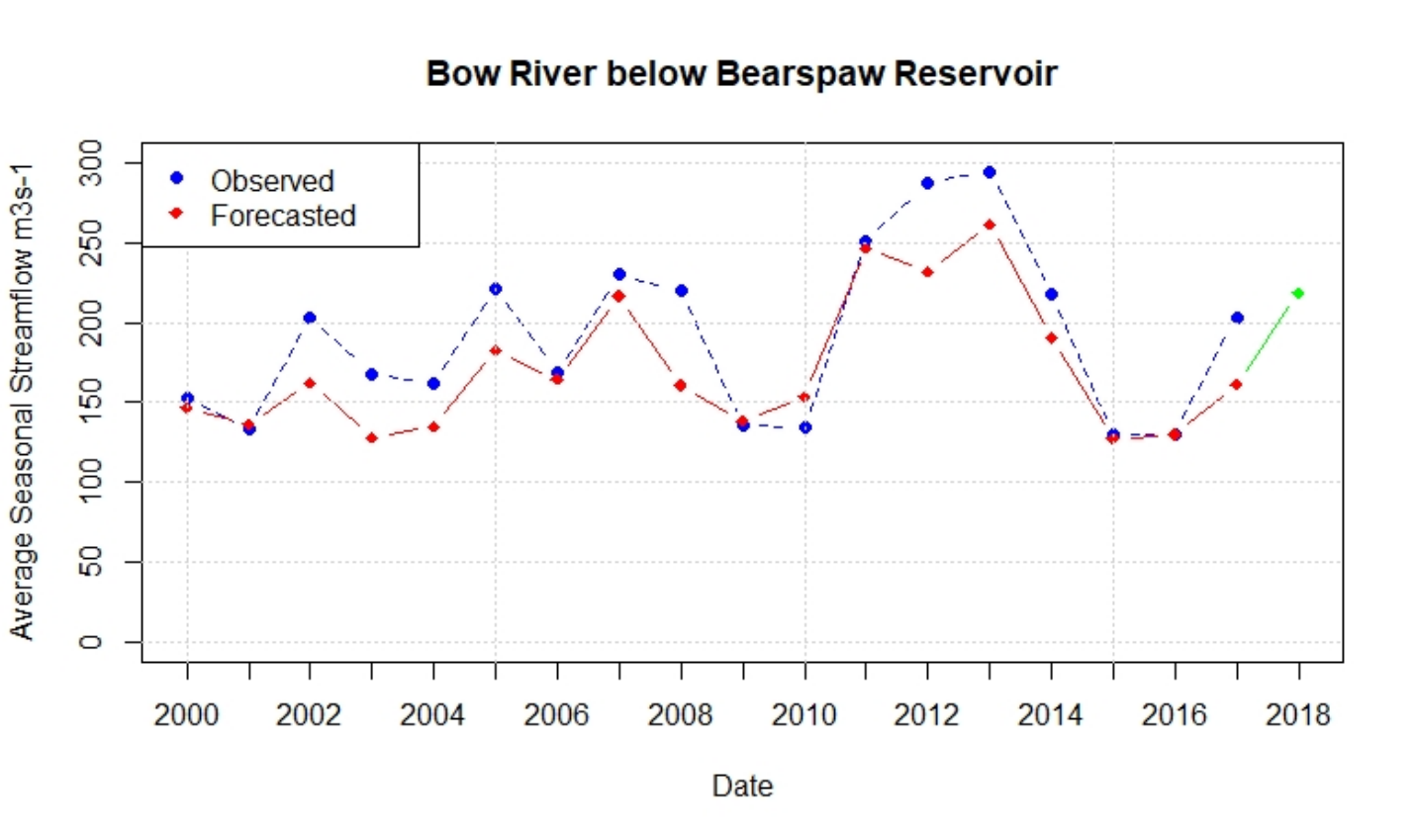


Shown: Average seasonal streamflows (MJJ average)



ELM S2 model and observed streamflow for the training and testing period (1970-2014)

Updated Results (May 23)



GoF's:

MAE = 23.2

RMSE = 29.97

R2 = 0.83

NSE = 0.66

d = 0.9

ELM S2 model and observed streamflow for the testing period (2000-2017)

➔ ***Current prediction for summer 2018 is*** ***218 m^3s^{-1}***

Next Steps in Stream. Forecasting

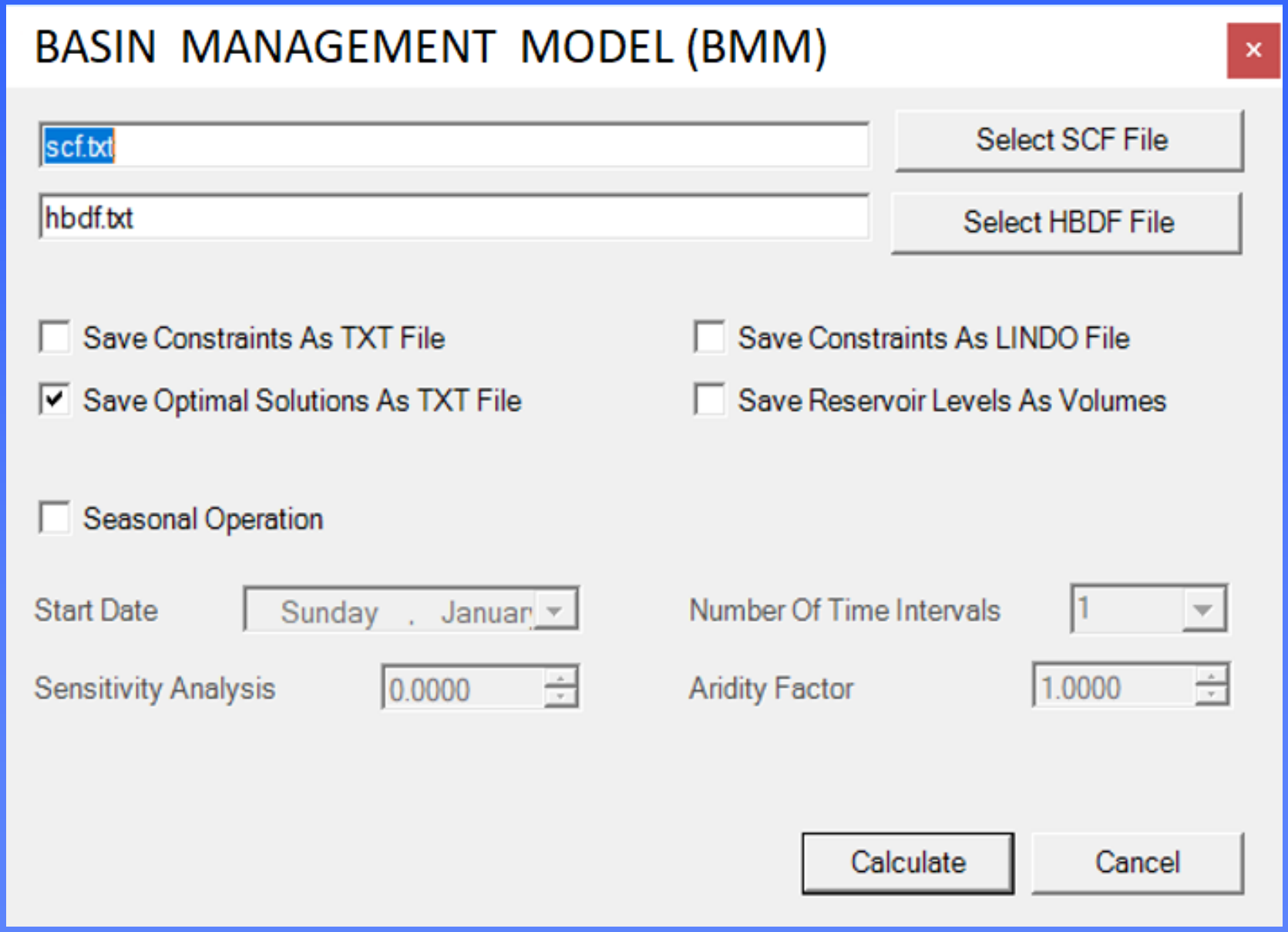
- Current ELM S2 model is ready for use
- Testing alternative forecasting methods that rely on sea surface temperatures (SST)
  - Offer possibility of improved results
  - Wavelet Analysis has been used successfully in many other regions

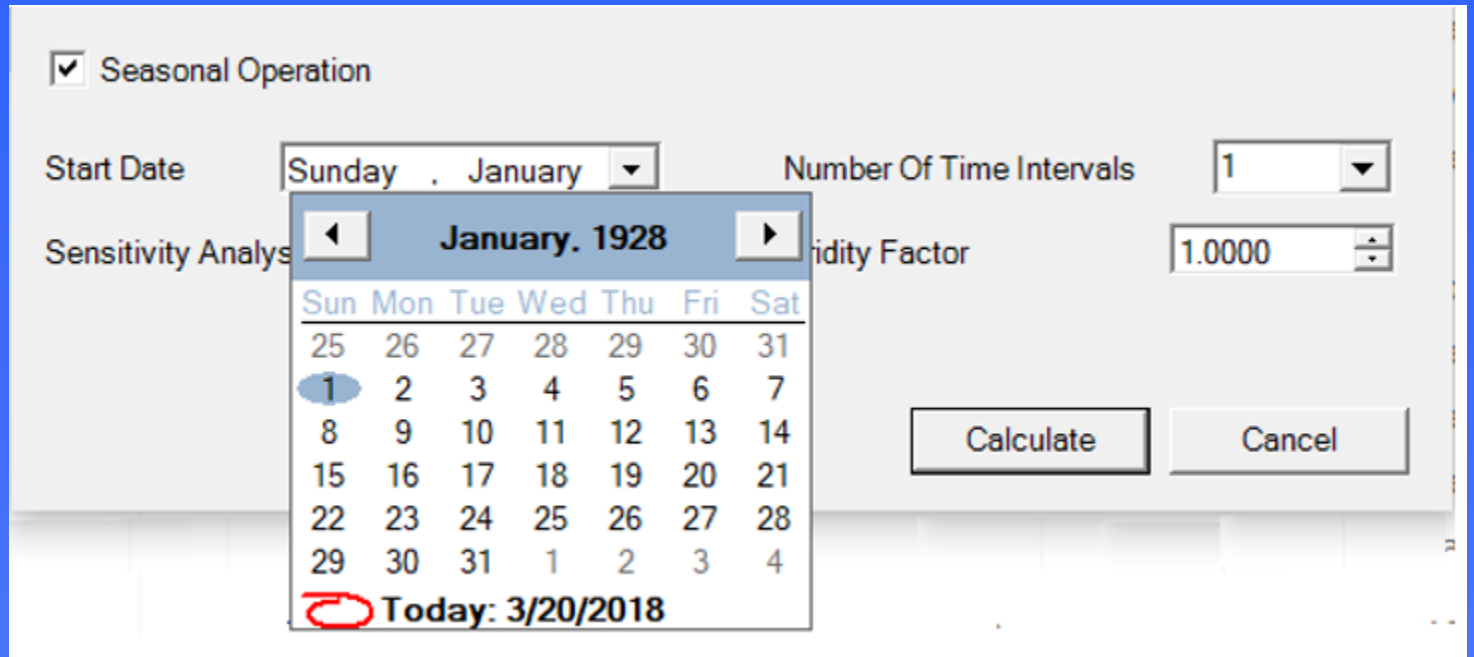
2. Seasonal Operational Model

Characteristics of Seasonal Operational Model

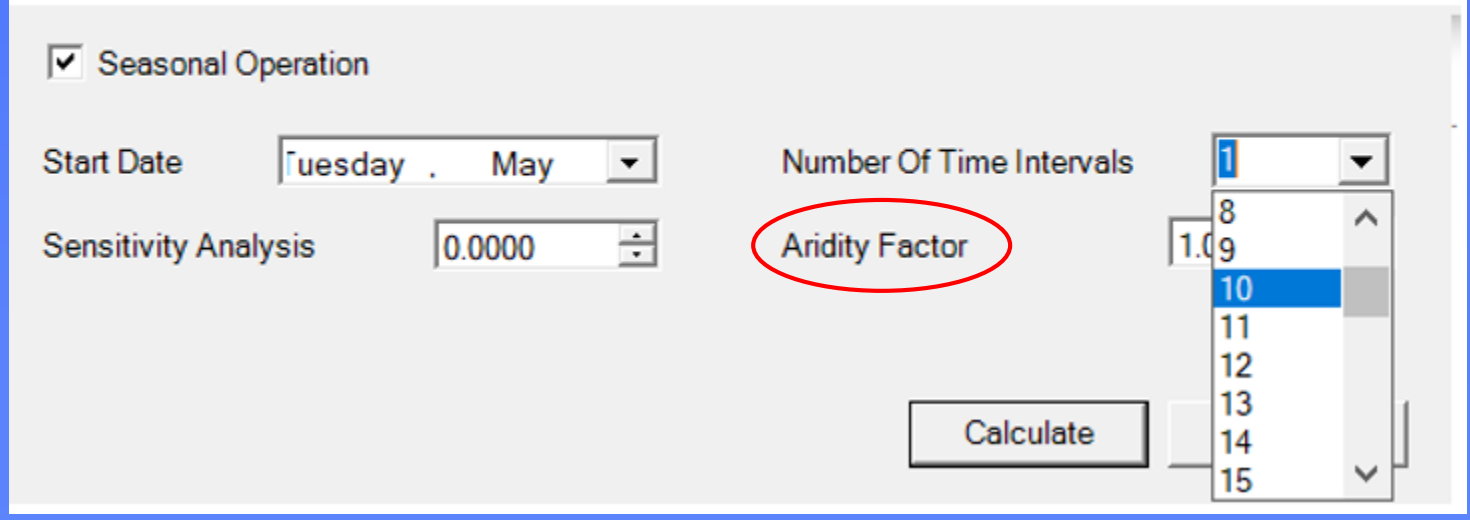
- Optimization model at weekly time step
- Includes all relevant physical constraints
  - Canal and storage capacities, outflow capacities, return flows, etc.
- Includes operational constraints
  - Water license limits (vol. + max. flow), minimum flows, apportionment, deficit sharing agreements
- Runs Single or Multiple Time Step Optimization
- Can simultaneously find ideal supply releases and demand reductions in dry years

New Model Interface





The second selection is the number of time intervals:



Dynamic Model Input

Please, Enter Seasonal Parameters And Close Window Form To Continue With ...

	A	B
1		
2	Reservoirs Initial Storage Levels	
3		
4	Reservoir Name / Num	Starting Storage Level
5	Reservoir 1	1104.9000
6	Reservoir 2	1185.2000
7	Reservoir 3	1103.0000

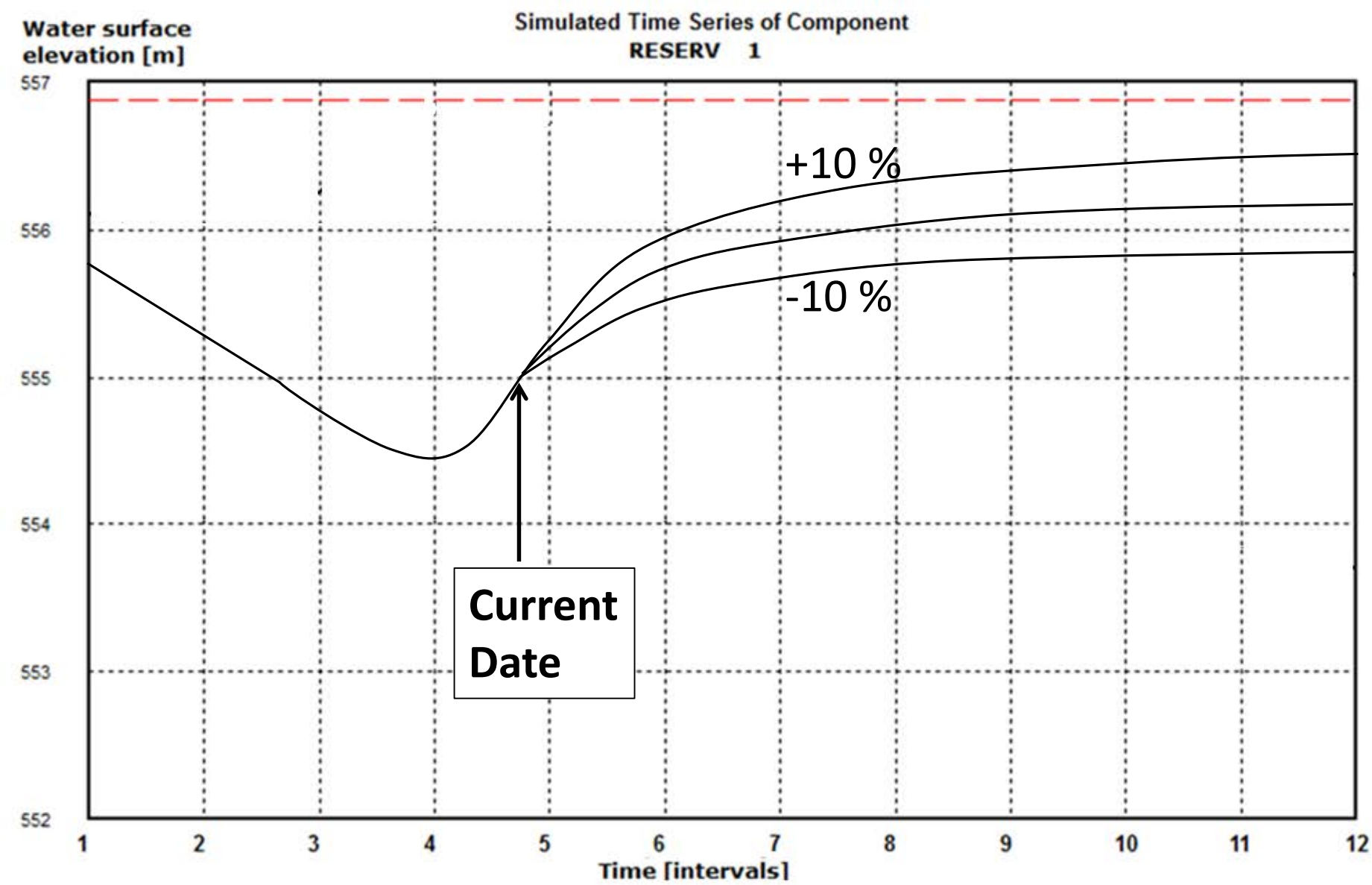
Reservoir Levels | Water Demands | Diversion Licenses | Apportionment Targets

Please, Enter Seasonal Parameters And Close Window Form To Continue With ...

	A	B
1		
2	Diversion Channels Demands Forecast	
3		
4	Diversion Channel Name / Nur	Remaining Water To Be Diverte
5	DiversionChannel 10	431047.0000
6	DiversionChannel 19	1227312.6000
7	DiversionChannel 15	35771.0000
8	DiversionChannel 14	60934.0000
9	DiversionChannel 12	20969.0000
10	DiversionChannel 17	49672.0000

Reservoir Levels | Water Demands | Diversion Licenses | Apportionment Targets

Model Result: Projected storage levels and crop application based on seasonal forecasts



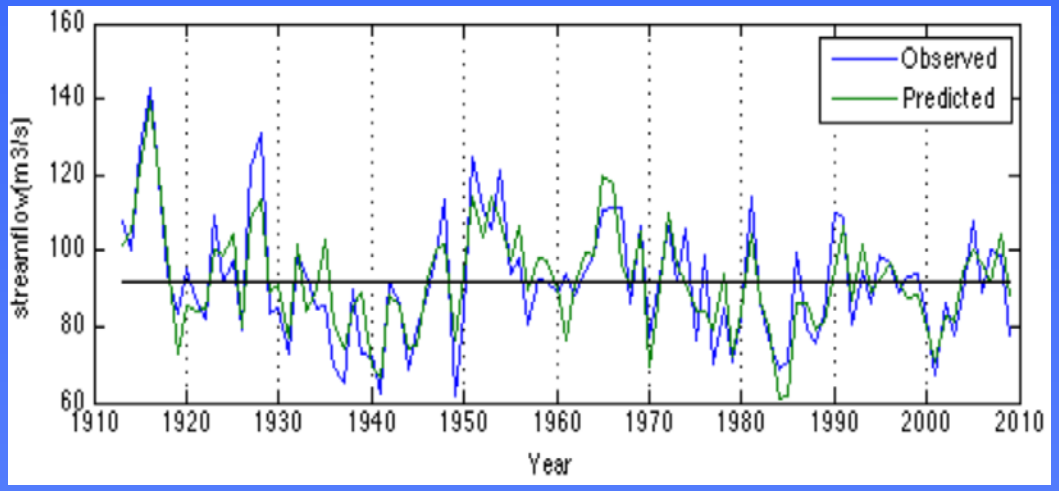
Next Steps in Model Dev't

- Testing and validation
  - Includes development of publishable MTO model benchmark test
- Setting up the model for Irrigation Districts
- Porting the model to the web

3. Low Flow Mgt. for Calgary

➔ **Completed hydrometric data "gap-filling" algorithm**

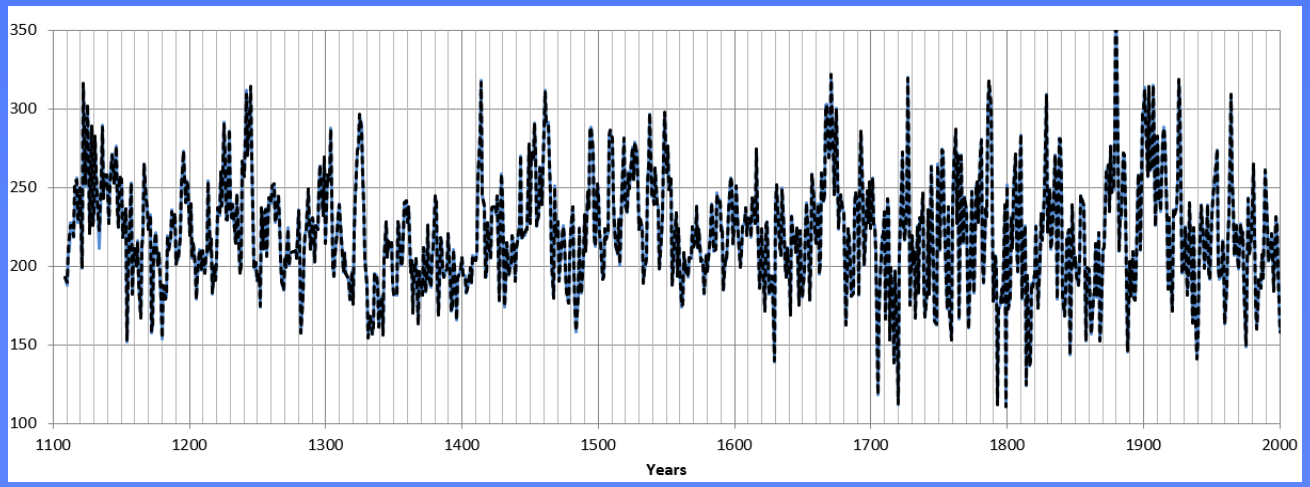
- **Produced weekly flow series at 15 stations for 904 years of data**
- **Publication of algorithm subject to minor revisions in HSJ**



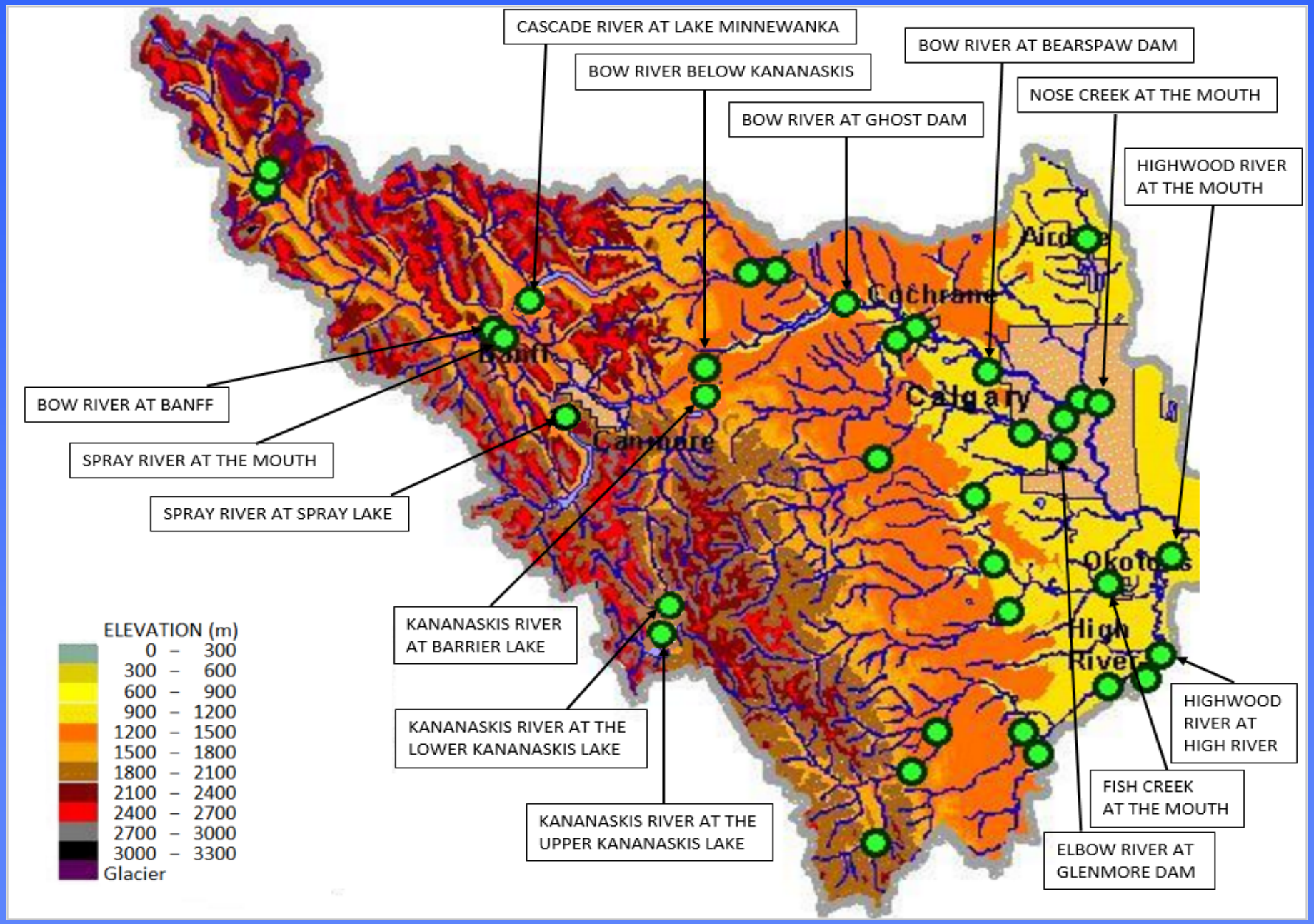
Work based on study with Prof. Sauchyn:

Reconstruction of 904 years of annual flows using tree ring data

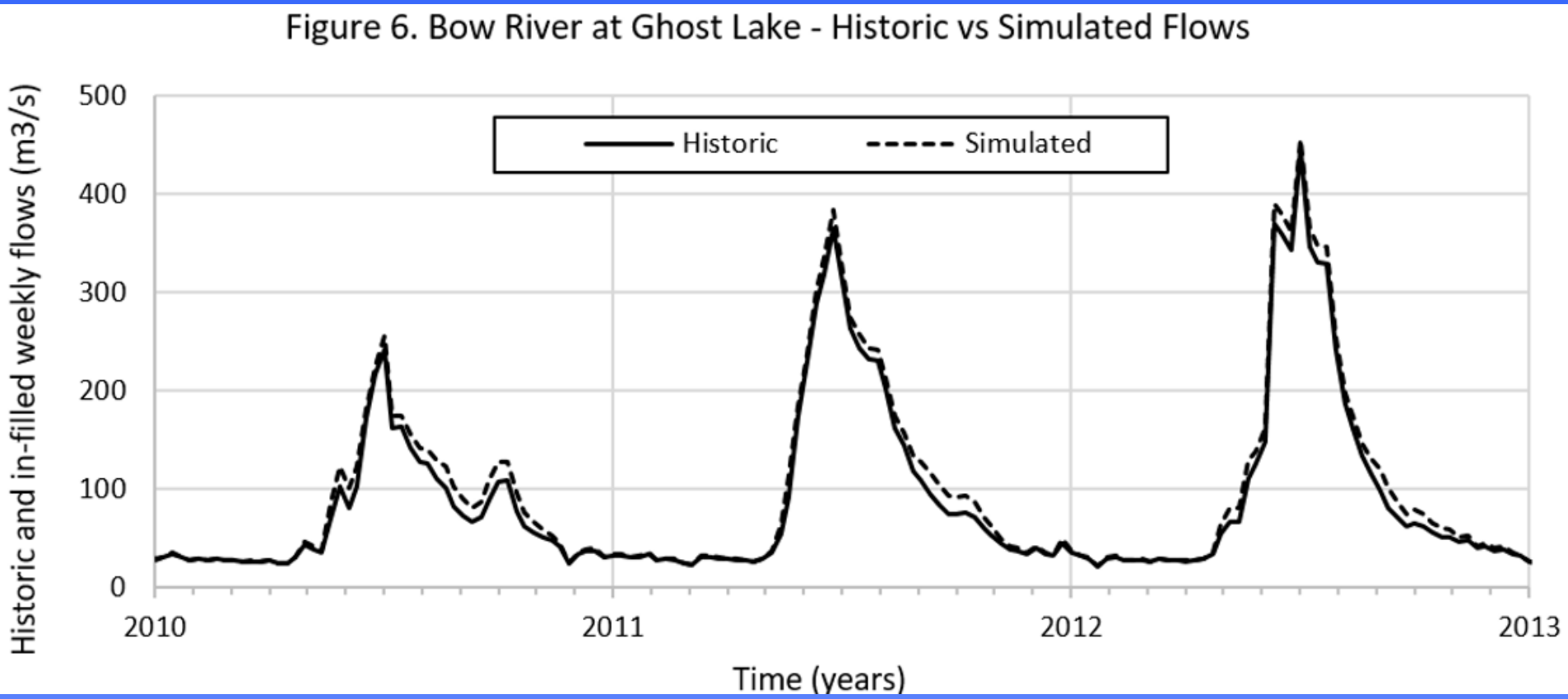
Example of 904 years of flows for a single site at weekly scale



The Fifteen Stations in the Study



Validation of the Gap-Filling Algorithm



Ilich, Gharib and Davies (*HSJ*, under revision)

Results for City of Calgary

- **Completed Bow River Basin modelling study for City of Calgary**
  - **Relied on 904 years of weekly natural flows matched with the existing licenses and infrastructure**
  - **Utilized new operating rules for Glenmore Dam to offset potential deficit at Bearspaw Dam, and also used recently established operating rules for Ghost Dam**
  - **Utilized higher storage available at Glenmore Dam based on design specs for new spillway gates and revised operating rule curve**
- **Results showed deficits for the Calgary water supply in only 7 of 904 years**
- **Study was reviewed and accepted by the City of Calgary**

- ***904 years of weekly flows (1111 – 2014) are available to other researchers***

Conclusion

- **Our aims are to develop a method that,**
  - **Allocates water more efficiently than the current computer-based tools → *more efficient water use***
  - **Improves reservoir operations**
  - **Provides optimal diversion and reservoir releases from week-to-week or month-to-month within a single season, based on actions to date and current hydrological data**

- **Practical Result: Optimization of operations over ~10 week horizon, with *updated guidance* based on current storage levels and crop demands**