ARTIFICIAL NEURAL NETWORKS AND TIME SERIES MODELLING OF FORESTED WATERSHEDS

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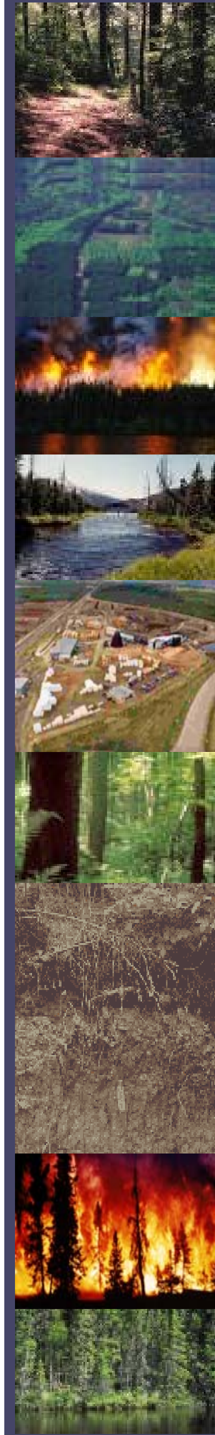
OUTLINE

- Introduction
- Objectives
- Study Area
- Modelling Approach
- Willow Creek Model Results
- 1A Creek Model Results
- Conclusions

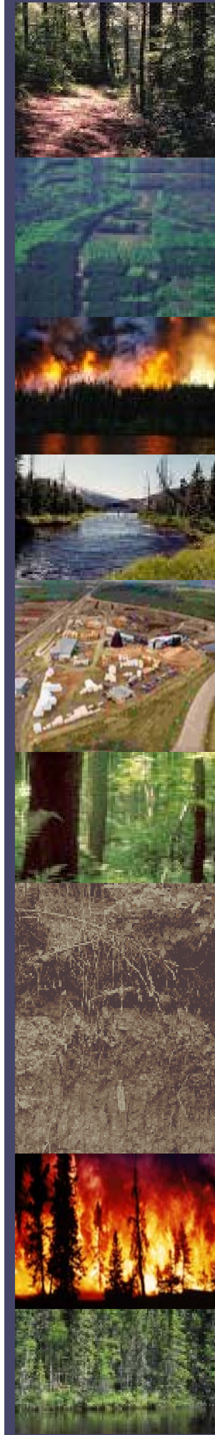


INTRODUCTION

FORWARD - **FOR**est **WA**tershed and **R**iparian **D**isturbance project

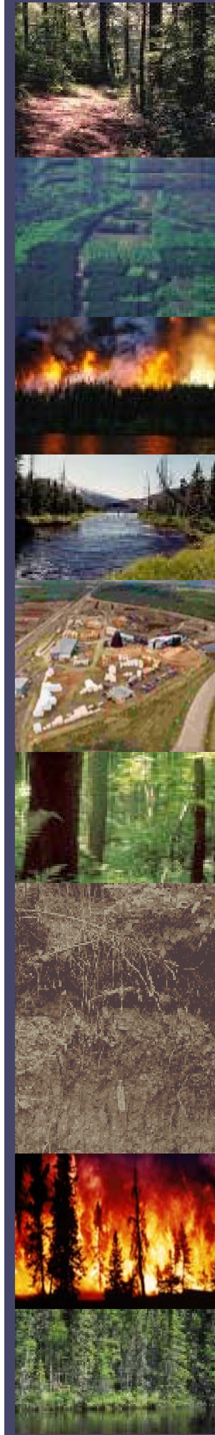
Motivation for FORWARD

- To quantify the impact of watershed disturbance on flow and water quality
- To mitigate effect of riparian buffer zones
- To Compare fire and harvesting impacts
- To Provide a management tool for the forest industry



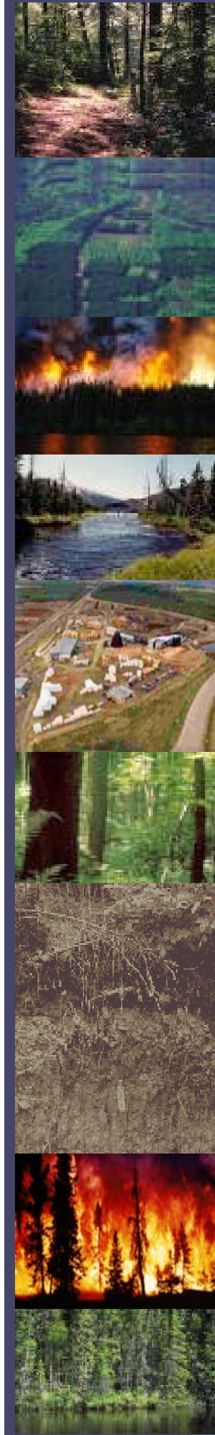
INTRODUCTION

- Boreal Plain soil is rich in nutrients
- Soil is more susceptible to erosion during snowmelt & storm events
- Forest harvesting increased dramatically
- Threaten to destabilize aquatic ecosystems (algal blooms and toxin production)
- Current forestry best practice is mostly relying on experience without scientific basis for verification

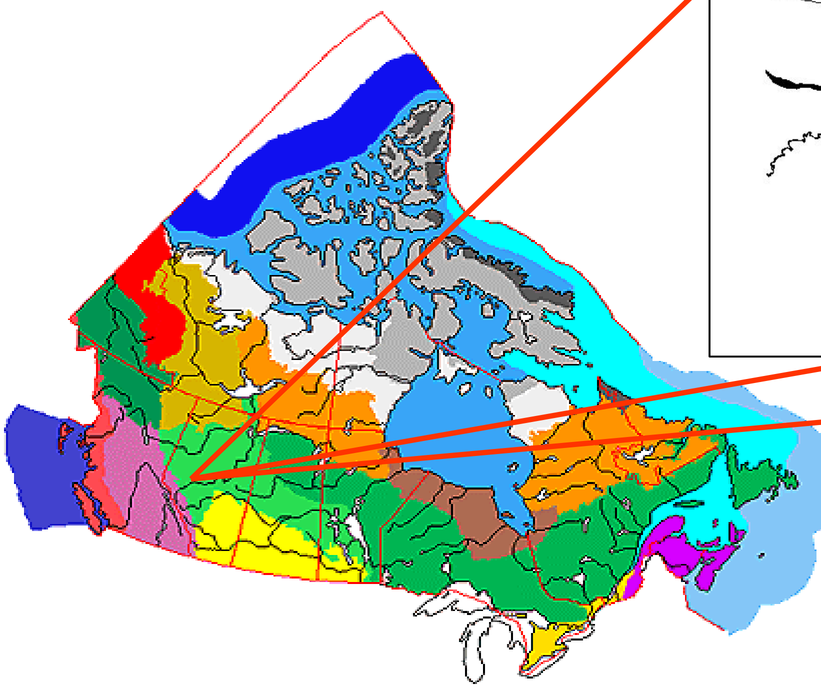


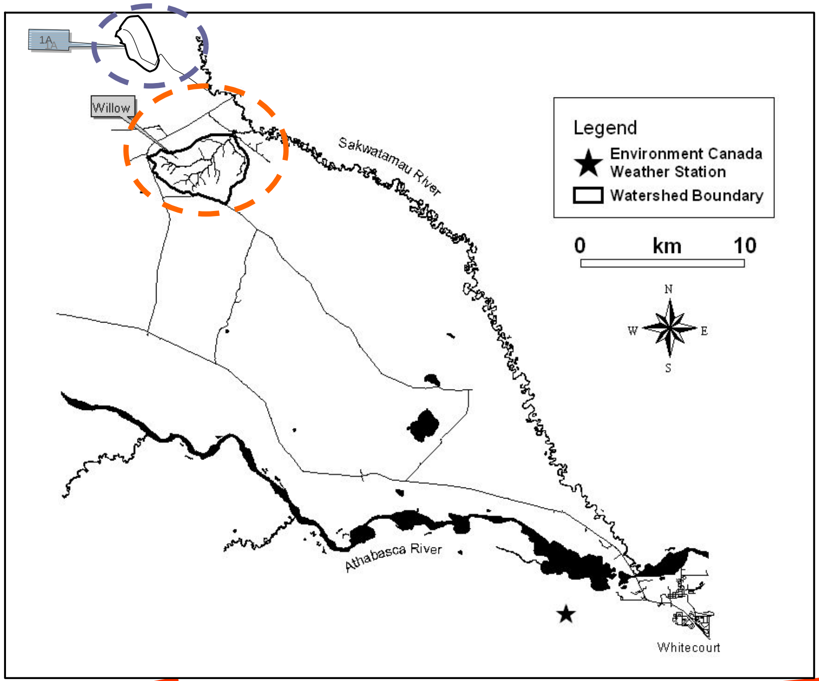
OBJECTIVES

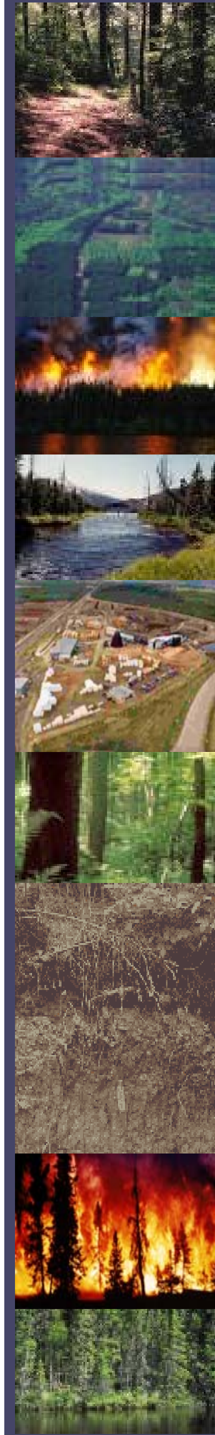
- To model Q attempting to understand downstream hydrologic impacts
- To model TP as an influencing parameter for aquatic systems on the Boreal Plain (algal blooms and toxins production)
- To develop a useful modelling tool for similar unguaged watersheds
- To provide a systematic approach to modelling time correlated variables using ANN



STUDY AREA







FORWARD

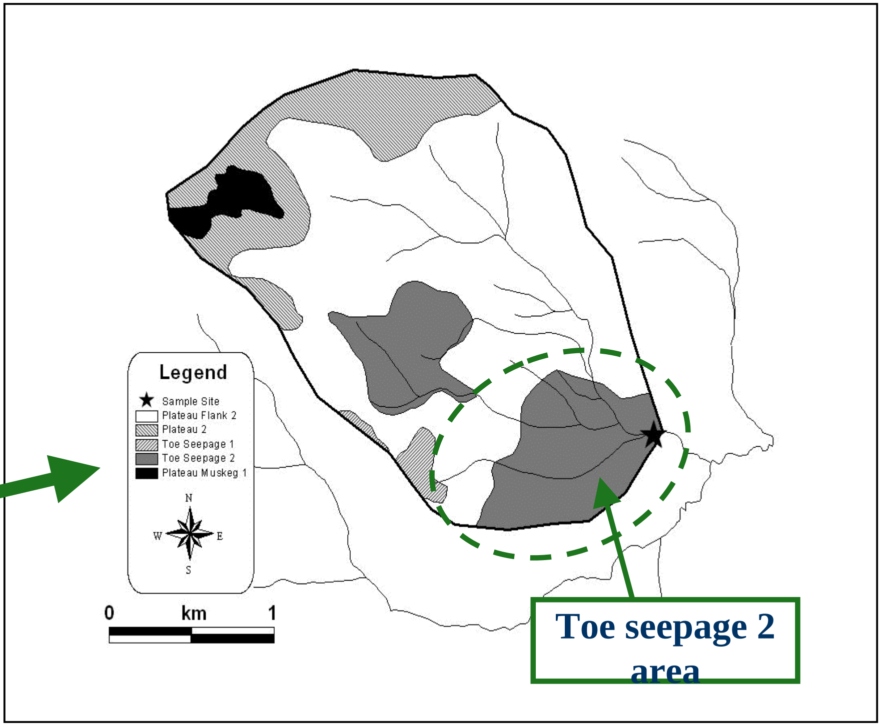
VARIATION IN SOIL TYPE

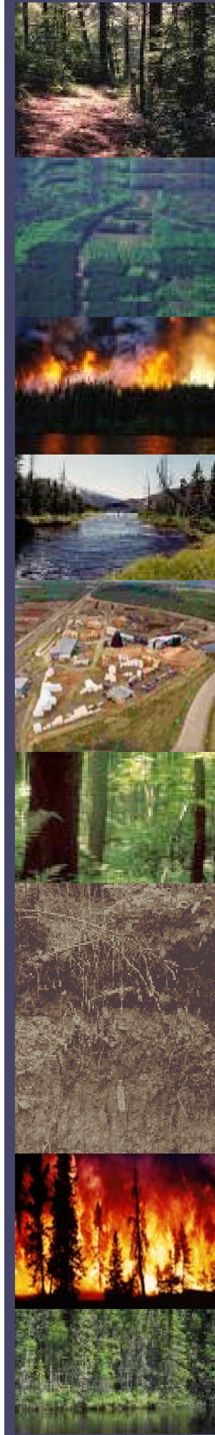
Willow Creek

(10% peatland)

1A Creek

(30%peatland)





MODELLING APPROACH

Weather Station Data

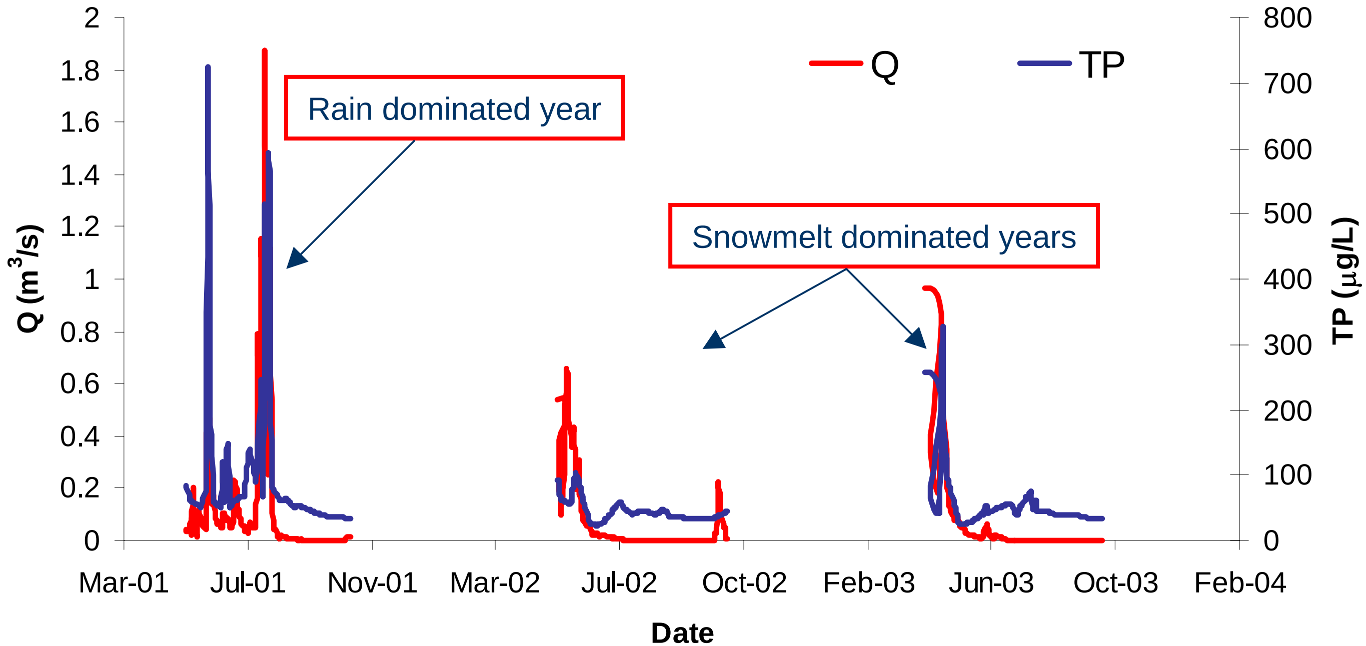
Flow Model → **Predict *Q*** → **TP Model** → **Predict *TP***

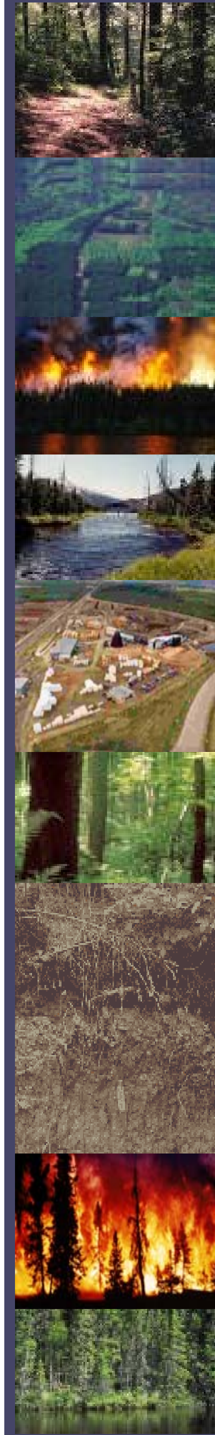
ANN Models' Development

- Data Pre-processing Phase
- Model Building Phase
- Model Evaluation Phase

DATA PRE-PROCESSING PHASE

- Annual cyclic nature of Q and TP series for 1A and Willow
- Seasonal variation within the year
- High time correlation





DATA PRE-PROCESSING PHASE

Hystereses effect

Early Spring

Mid Summer

DATA PRE-PROCESSING PHASE

- Annual cyclic nature of Q and TP series
- Seasonal variation within the year
- Hystereses effect

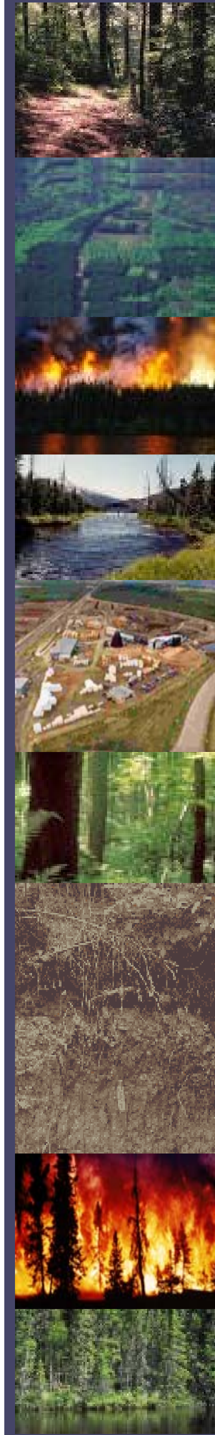
Spectral Analysis

Adding $sin(2\Pi\nu t)$ and $cos(2\Pi\nu t)$ as inputs to reflect inter and intra annual periodicities

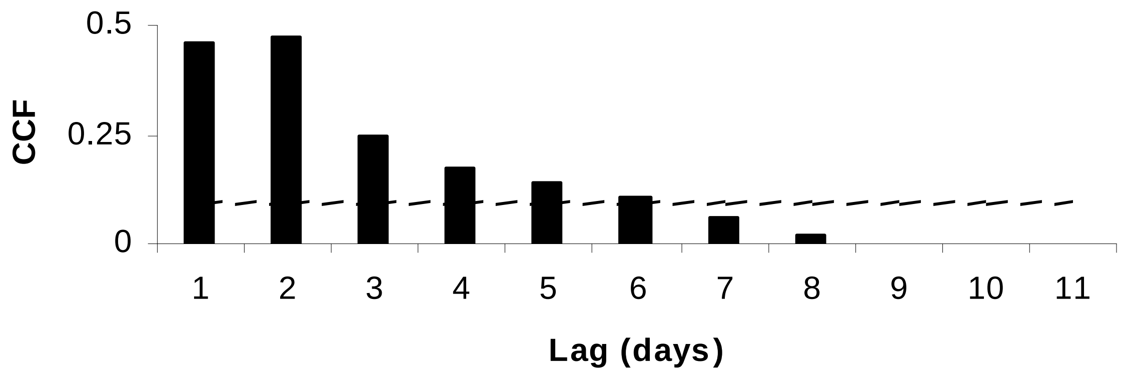
- High time correlation

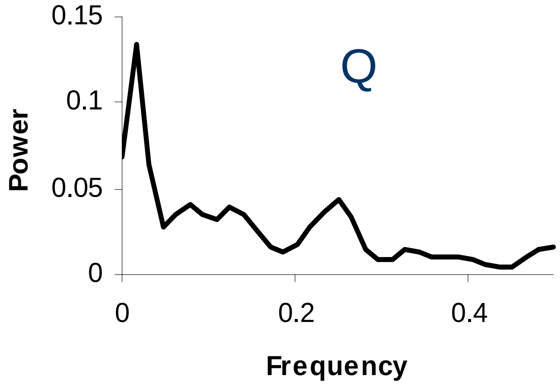
Identify lagged inputs using time series analysis

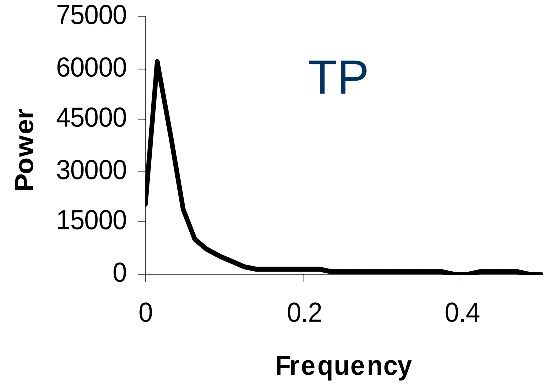
e.g. (R_t, R_{t-1},R_{t-2}, S_t, S_{t-1}, ……. etc…)



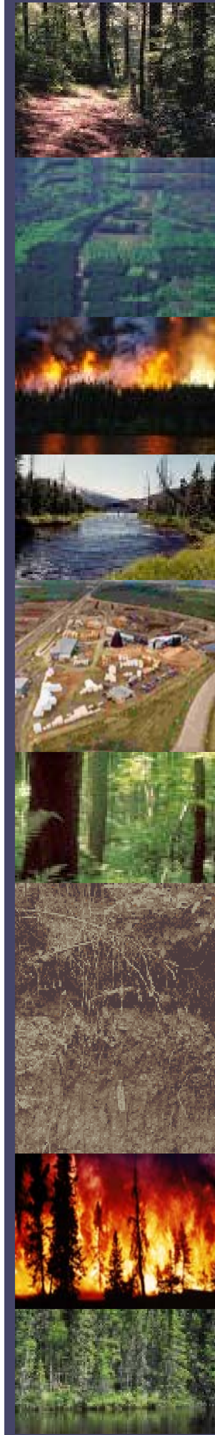
TIME SERIES ANALYSIS





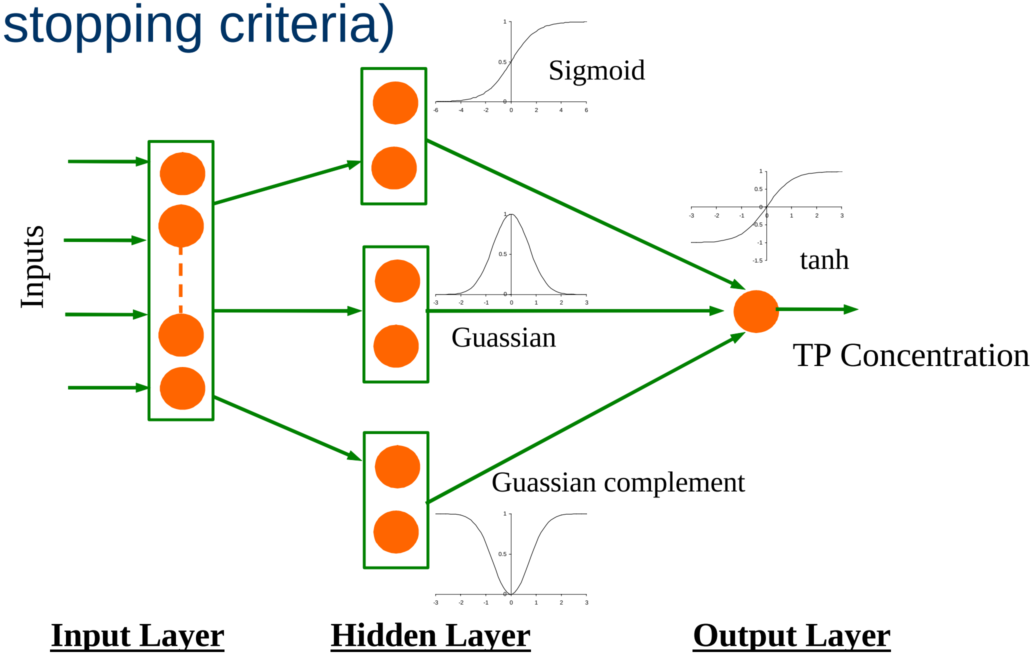


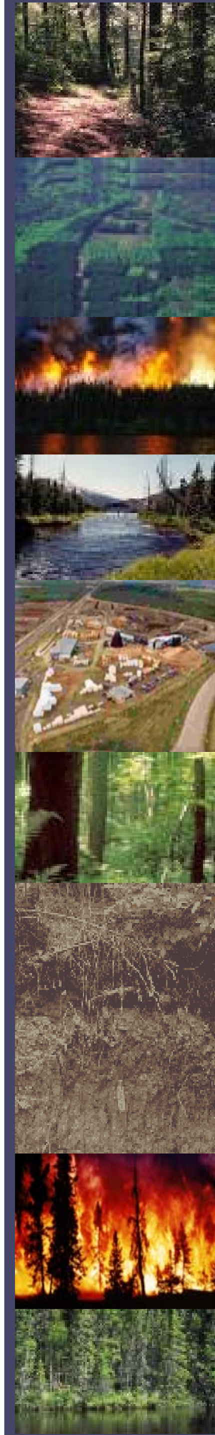
Results are for 1A Creek Watershed



MODEL BUILDING PHASE

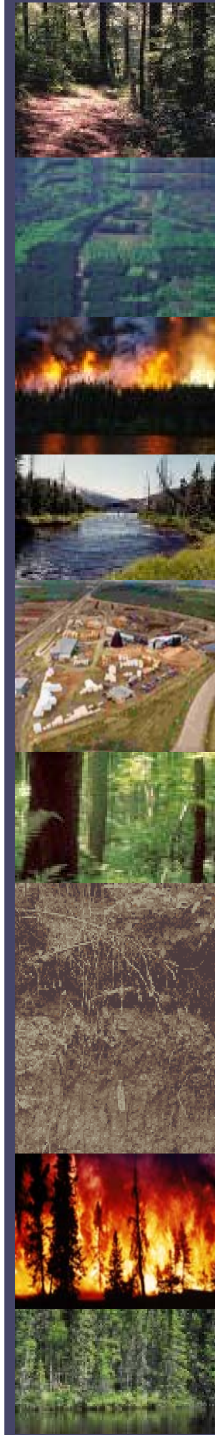
Optimizing network variables (Data division, choice of training algorithm, no. of hidden layers, no. of hidden neurons, type of transfer function, learning and momentum rates, and stopping criteria)





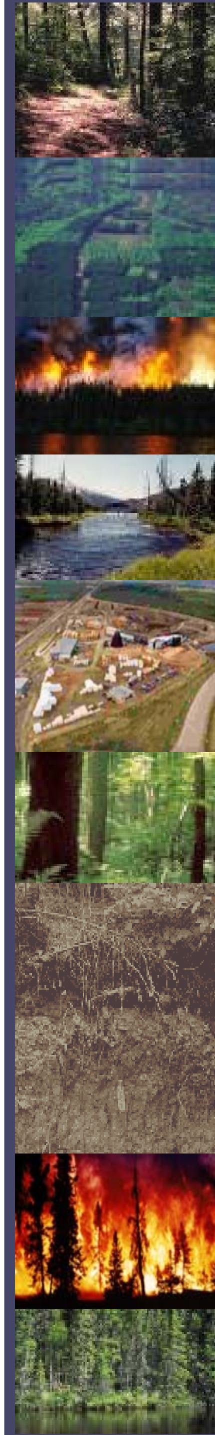
MODEL BUILDING PHASE

	Model 1 (Q for Willow)	**Model 2 (TP for Willow)**	**Model 3 (Q for 1A)**	**Model 4 (TP for 1A)**
Scaling function	Linear, <<-1,1>>	Linear, <<-1,1>>	Linear, <<-1,1>>	Linear, <<-1,1>>
Optimum network (I-HG-HL-HGC-O)	15-4-4-4-1	8-5-5-5-1	11-5-2-5-1	7-7-5-7-1
Output activation function	tanh	Logistic	tanh	tanh
Training algorithm	BP	BP-TurboProp	BP	BP-TurboProp
Learning rate	0.2	Insensitive	0.15	Insensitive
Momentum coefficient	0.2	Insensitive	0.15	Insensitive



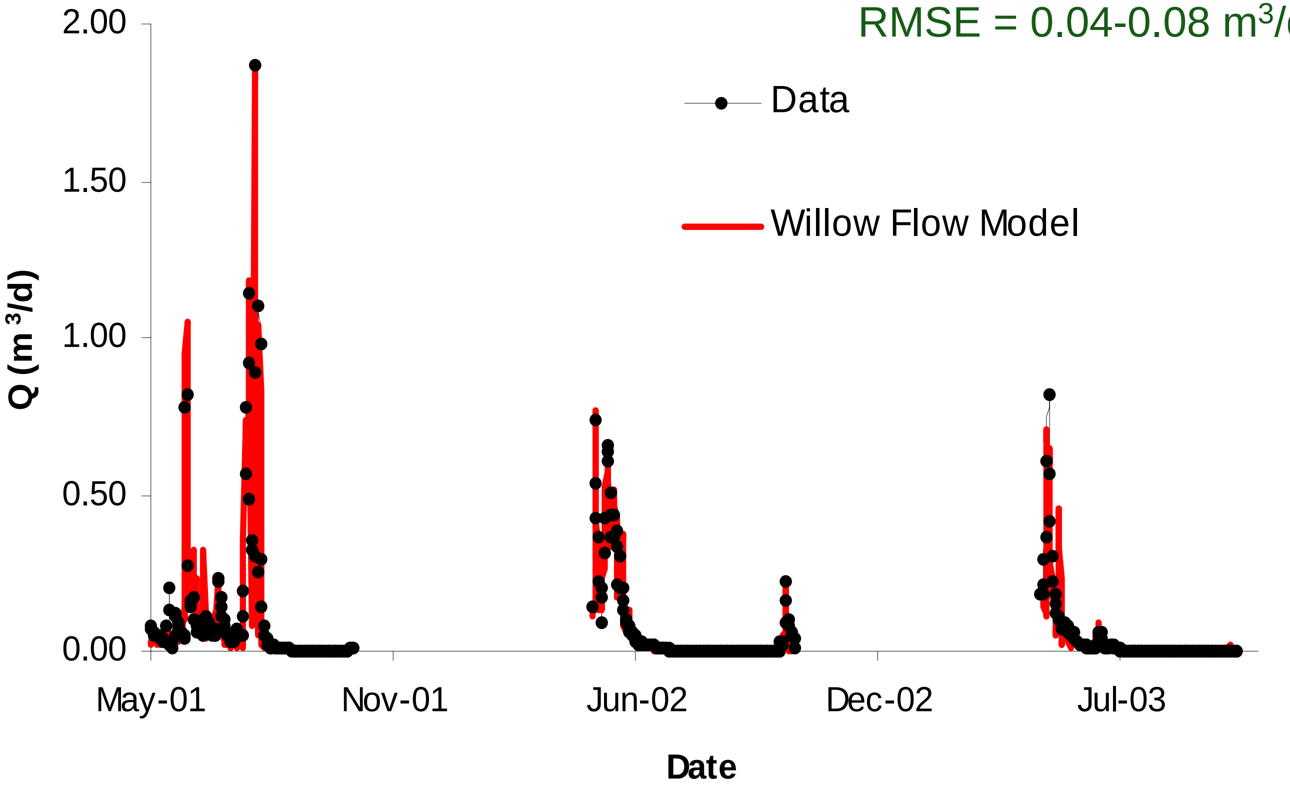
MODEL EVALUATION PHASE

- Model evaluation was based on 4 criteria
  - Coefficient of multiple determination (R^2)
  - Graphical examination of measured Vs. predicted series
  - Examining model residuals for independency and possible trends
  - Swapping testing data sets, retraining, testing for model stability and robustness

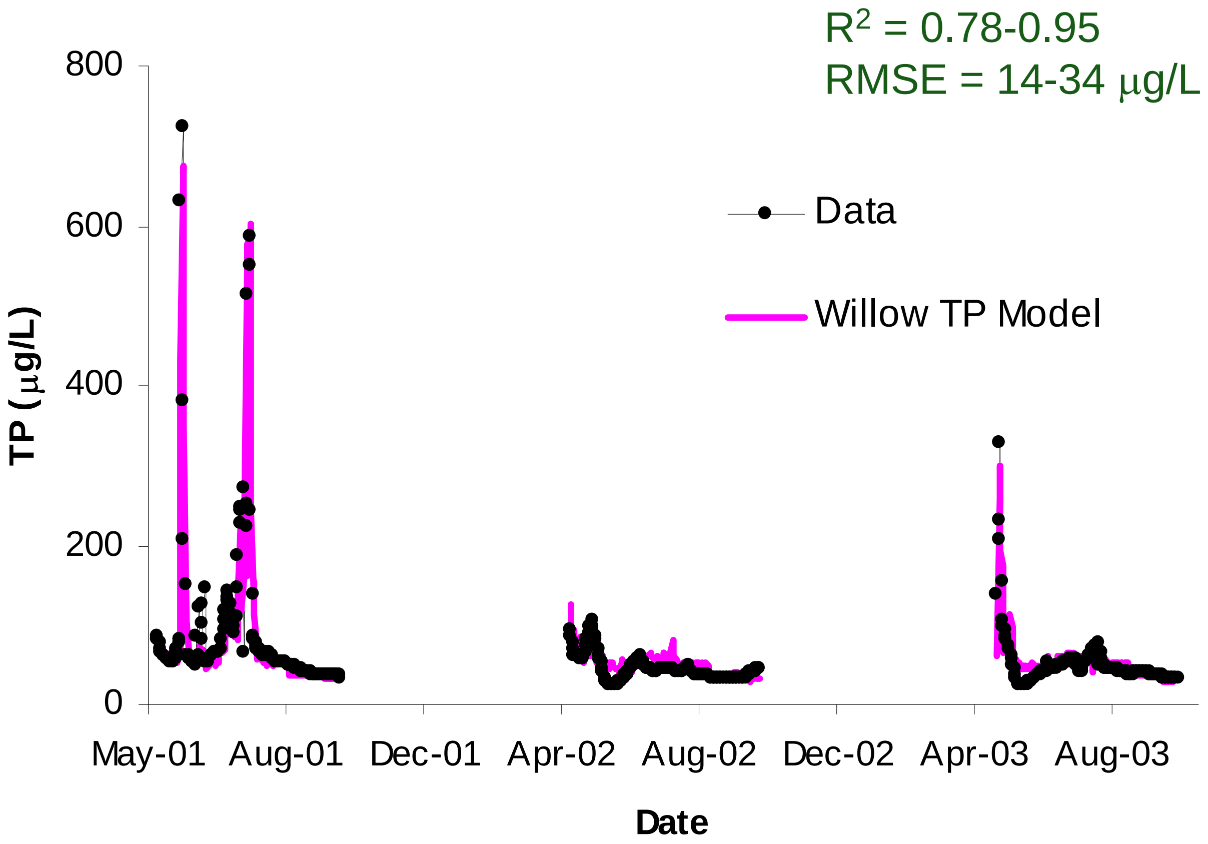


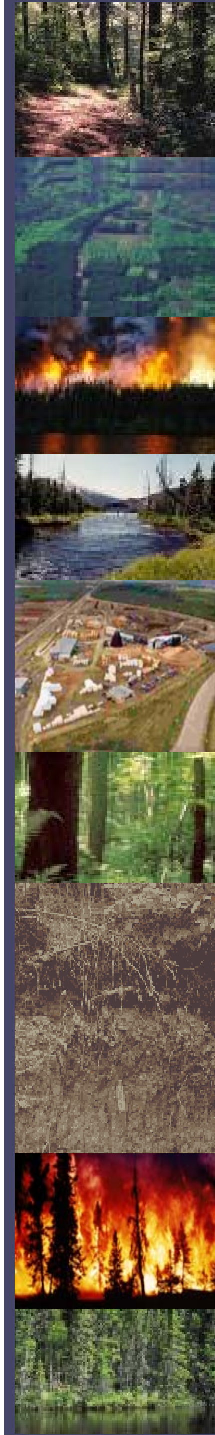
CASE STUDY 1: WILLOW

R^2 = 0.8-0.96
RMSE = 0.04-0.08 m^3/d



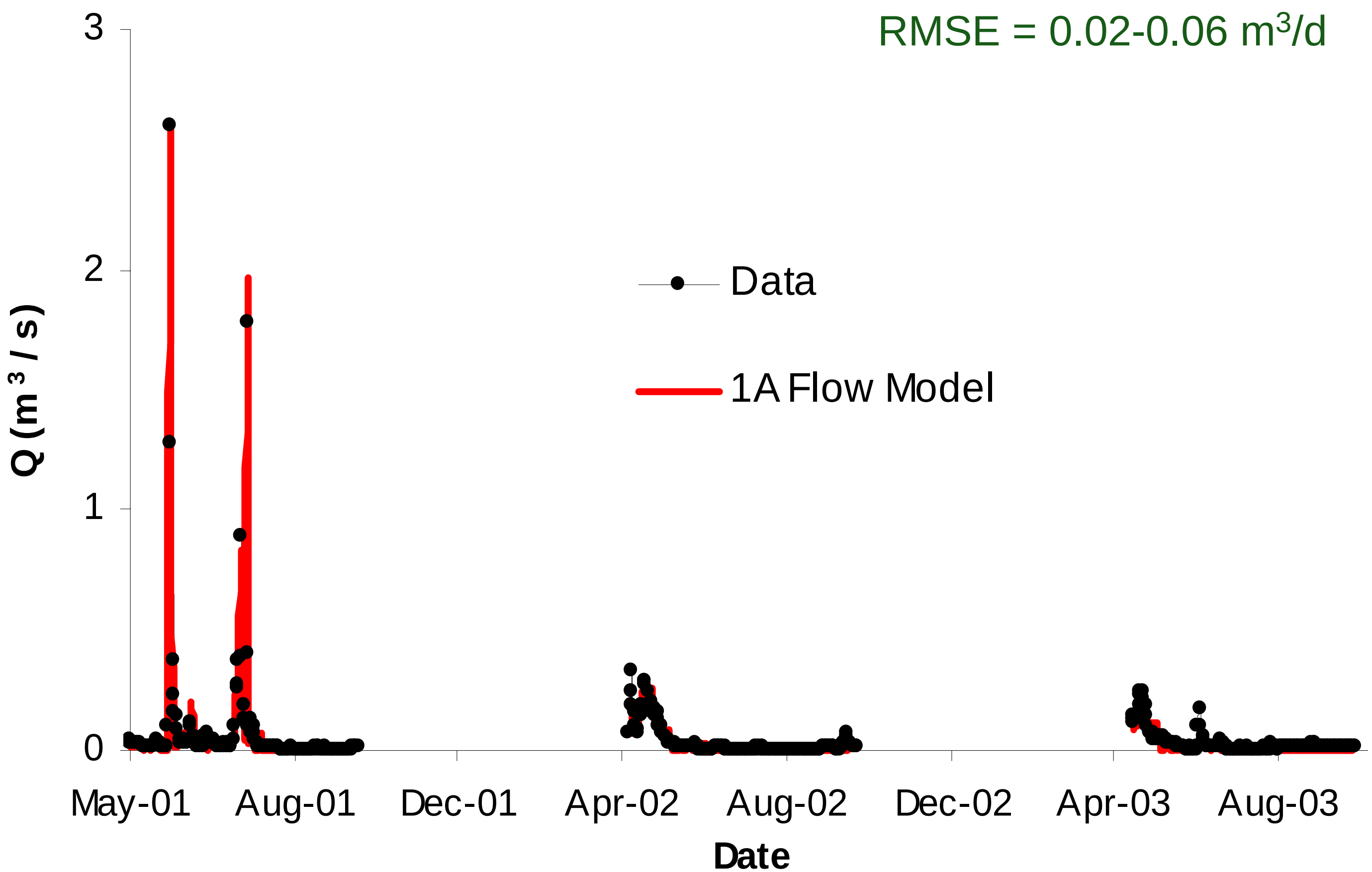
CASE STUDY 1: WILLOW





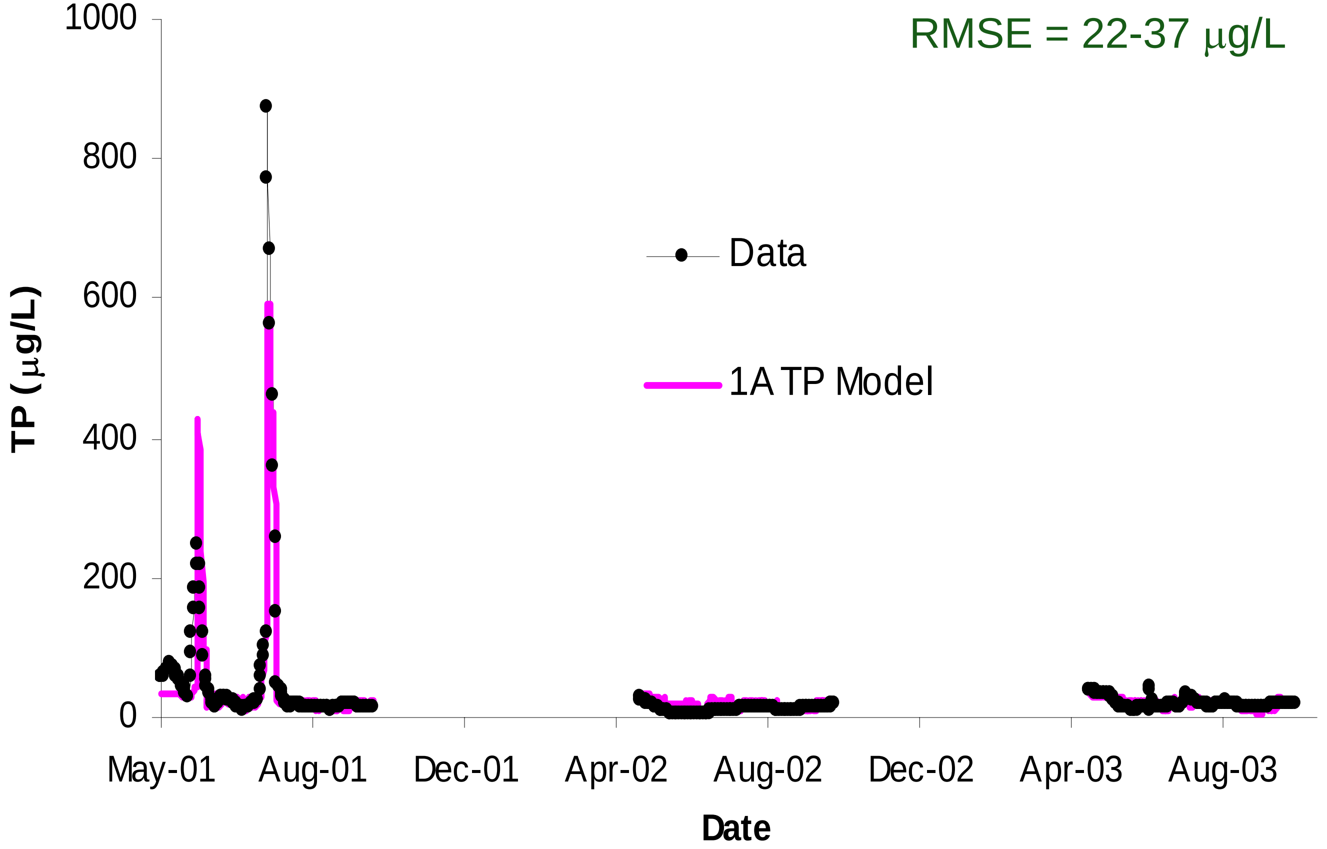
CASE STUDY 2: 1A CREEK

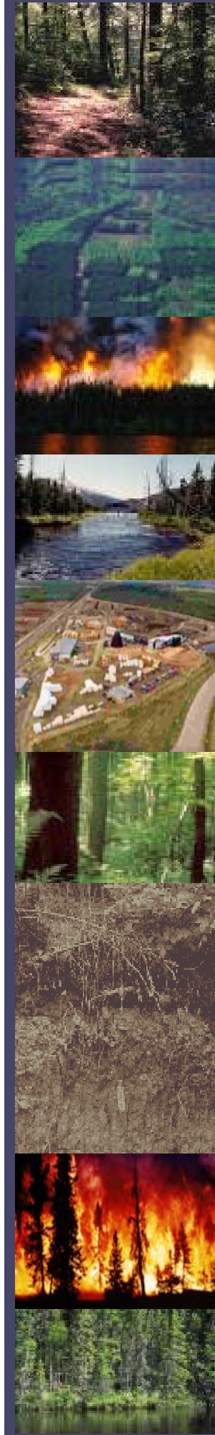
R^2 = 0.81-0.99
RMSE = 0.02-0.06 m^3/d



CASE STUDY 2: 1A CREEK

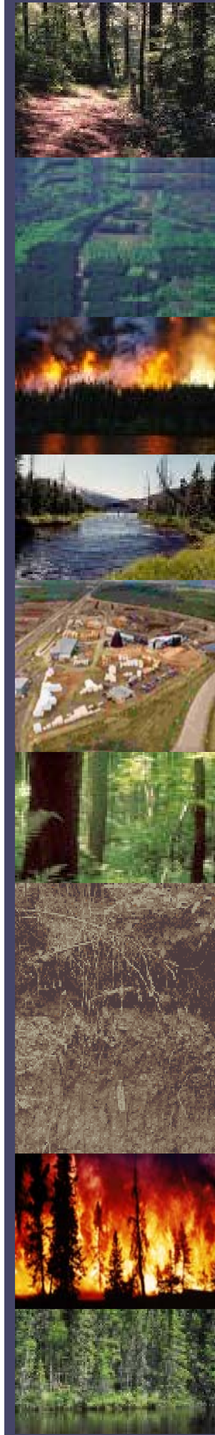
R^2 = 0.78-0.86
RMSE = 22-37 μg/L





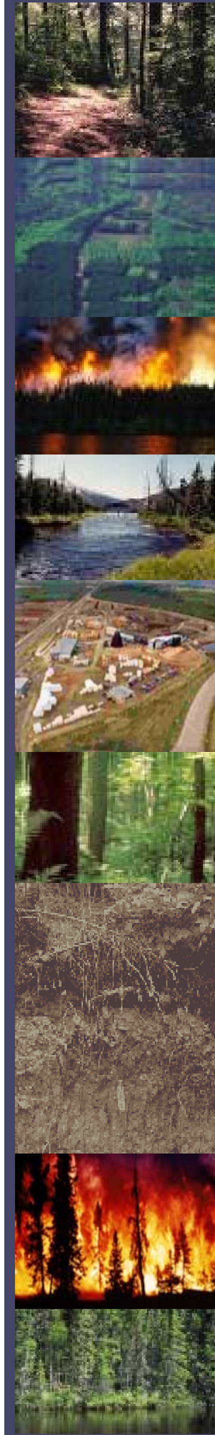
CONCLUSIONS

- The developed ANN Q and TP models were successful in simulating measured values, R^2 exceeded 0.8 for all modelled data sets
- A three-slab hidden layer with different activation functions managed to reflect the distinct behavior of base flow, snow melt, and rain events
- Hystereses and seasonal effects were reasonably accounted for by combining spectral analysis and ANN



CONCLUSIONS

- It is likely that the large toe seepage area in the watershed can be hydrologicaly disconnected when the ground is frozen delaying water export from the peatland to the stream. Q models was able to capture this phenomenon
- 1A TP model was not very accurate in simulating peaks response. More research towards the dynamics of phosphorus export from peatlands is required for better modelling representation.
- This study not only highlights the applicability of ANN in modelling flow and TP but also provides a general framework towards modelling highly correlated parameters that suffer data hystereses



ACKNOWLEDGMENT

- Natural Sciences and Engineering Research Council of Canada (NSERC)
- Universities
  - University of Alberta
  - University of Saskatchewan
  - Lakehead University
- Industrial Partners
  - Millar Western Forest Products Ltd
  - Alberta Health and Wellness
  - West Fraser Mills
  - Vanderwell Contractors
  - Louisiana-Pacific Canada Ltd