Design manual for floods and droughts under climate change scenarios in New Brunswick, Canada

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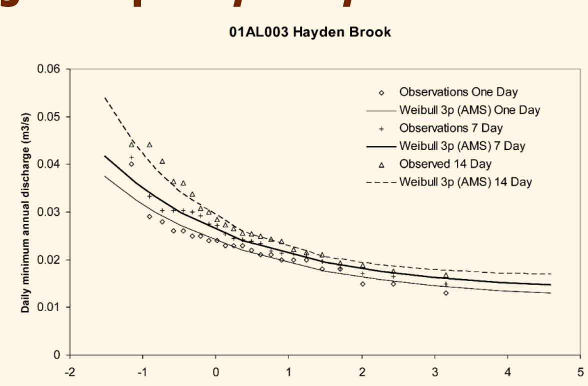
ABSTRACT

There is currently a broad scientific consensus that the global climate is changing in ways that are likely to have a profound impact on our society and on the natural environment over the coming decades. This study covers flood and drought analysis in New Brunswick. First, a flood and drought frequency analysis was carried out to determine the characteristics of high and low flow events. Then, the impacts of climate change on the discharge regimes were analysed, using artificial neural network models. Future climate data were extracted from the Canadian Coupled General Climate Model (CGCM3.1) under the greenhouse gas emission scenarios B1 and A2 defined by the Intergovernmental Panel on Climate Change (IPCC). The climate change fields (temperatures and precipitation) were downscaled using the delta change approach. A frequency analysis was carried out using the generalized extreme value (GEV) distribution function. An index, called the Regional Climate Index (RCI) was also introduced to help the design process.

Drought frequency analysis

Analysed hydrometric stations : 38
6 km^2 < Drainage Area < 14700 km^2

Distribution Function
3 parameter Weibull



Low flow regression equations for the New Brunswick region.

T	Duration / Durée	q	s	k	R^2	RMSE(m^3/s)
2-year 2-ans	1-day / 1-jour	0.05369	0.07562	-2.735	0.943	1.438
	7-day / 7-jours	0.05499	0.07570	-2.715	0.948	1.606
	14-day / 14-jours	0.05691	0.07698	-2.750	0.952	1.961
10-year 10-ans	1-day / 1-jour	0.04337	0.07191	-2.623	0.915	1.118
	7-day / 7-jours	0.04435	0.07096	-2.572	0.916	1.216
	14-day / 14-jours	0.04552	0.07311	-2.636	0.918	1.370
20-year 20-ans	1-day / 1-jour	0.04126	0.07057	-2.582	0.909	1.022
	7-day / 7-jours	0.04221	0.07029	-2.555	0.907	1.110
	14-day / 14-jours	0.04314	0.07341	-2.646	0.908	1.224
50-year 50-ans	1-day / 1-jour	0.03945	0.06875	-2.527	0.909	0.925
	7-day / 7-jours	0.04039	0.06977	-2.543	0.904	1.105
	14-day / 14-jours	0.04107	0.07420	-2.673	0.903	1.185
2-year 2-ans	1-day / 1-jour	0.05234	-	-0.17761	0.936	1.517
	7-day / 7-jours	0.05364	-	-0.15524	0.941	1.673
	14-day / 14-jours	0.05553	-	-0.14700	0.945	2.012
10-year 10-ans	1-day / 1-jour	0.04208	-	-0.19093	0.905	1.179
	7-day / 7-jours	0.04308	-	-0.17284	0.907	1.270
	14-day / 14-jours	0.04422	-	-0.16320	0.909	1.417
20-year 20-ans	1-day / 1-jour	0.04000	-	-0.19561	0.899	1.078
	7-day / 7-jours	0.04095	-	-0.17768	0.898	1.160
	14-day / 14-jours	0.04183	-	-0.16374	0.898	1.270
50-year 50-ans	1-day / 1-jour	0.03822	-	-0.20204	0.896	0.977
	7-day / 7-jours	0.03914	-	-0.18369	0.891	1.158
	14-day / 14-jours	0.03975	-	-0.16370	0.890	1.244

$$Q_D = (q\sqrt{DA} + s\sqrt{MAP} + k)^2 \text{ or}$$
$$Q_D = (q\sqrt{DA} + k)^2$$

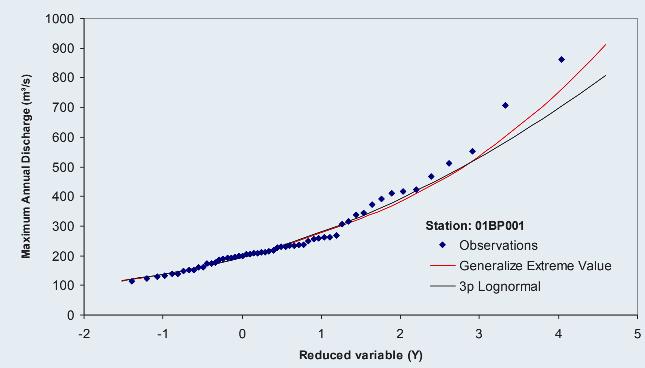
DA = Drainage area km^2
MAP = Mean annual precipitation

Flood frequency analysis

- Analysed hydrometric stations : 58
- 3.89 km^2 < Drainage Area < 39900 km^2

Distribution Functions

- 3 parameter lognormal
- Generalized Extreme Value (GEV)



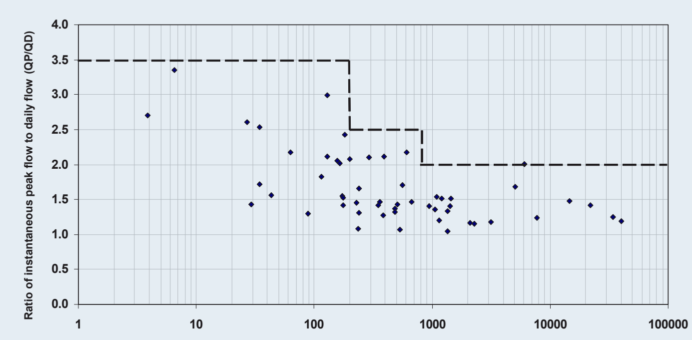
Regional regression coefficient estimates and R² (GEV distribution)

	a	*b1*	*b2*	R²
MAFL	0.463476	0.884	*	0.984
	4.2645E-06	0.926	1.617	0.990
QD2 (m^3/s)	0.394690	0.897	*	0.985
	1.1131E-05	0.935	1.460	0.990
QD10 (m^3/s)	0.753188	0.871	*	0.981
	1.3152E-06	0.919	1.848	0.988
QD20 (m^3/s)	0.950031	0.857	*	0.977
	5.5022E-07	0.910	2.002	0.987
QD50 (m^3/s)	1.273837	0.839	*	0.971
	1.7180E-07	0.896	2.205	0.983
QD100 (m^3/s)	1.580312	0.824	*	0.964
	7.0216E-08	0.886	2.360	0.978

$$Q_D = a\,(DA)^{b1} \quad \text{or}$$
$$Q_D = a\,(DA)^{b1}(MAP)^{b2}$$

DA = Drainage area km^2
MAP = Mean annual precipitation

Peak flows
Max of Q_{peak}/Q_{daily}

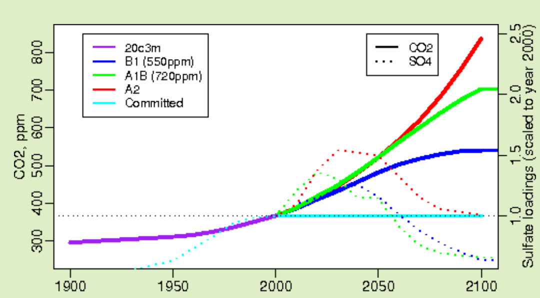


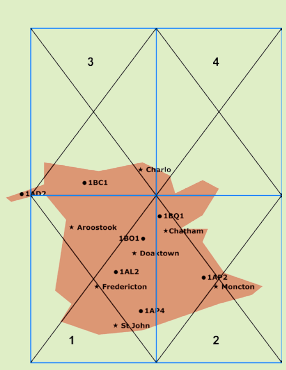
Climate change scenarios in New Brunswick, Canada

Hydrometric & meteorological stations : 7
668 km^2 < Drainage Area < 14700 km^2

Climate data

Climate data were extracted from the Canadian Coupled Global Climate Model (CGCM3.1 / T63) under the green house gas emission scenarios 20C3M, B1 and A2 defined by the Intergovernmental Panel on Climate Change (IPCC).





New Brunswick grid

- 4 grid boxes (box size - 200 x 300 km)
- Scenarios : 20C3M, B1 & A2
- Time periods : 1970-99 & 2010-99
- Data sets available from Canadian Center for Climate modelling and analysis (CCCma)
- Data from each box contributes to station data (spatial interpolation, IDW method)
- Characterization of floods & droughts

Climate data downscaling

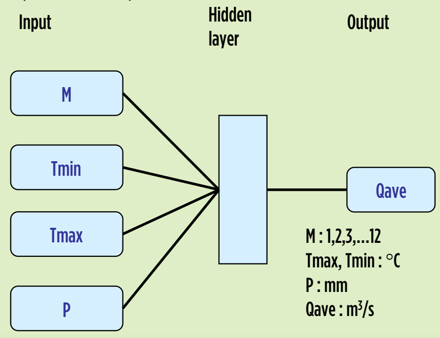
The climate change fields (temperatures and precipitation) were downscaled using delta change approach.

$$T_{new} = T_{hist} + T_{delta}$$
$$P_{new} = P_{hist} * P_{fact}$$

$T_{delta} \longrightarrow$ difference in the CGM simulated mean temperature from the future time period relative to the historic period (1970-99).

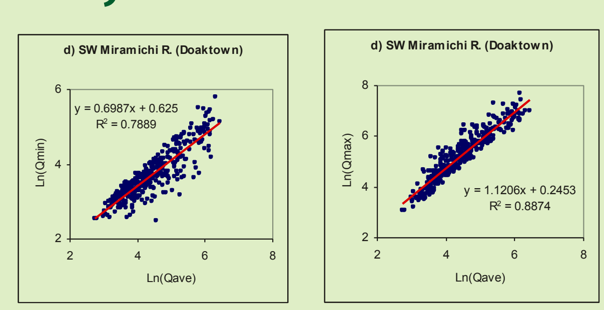
$P_{fact} \longrightarrow$ ratio of the CGM simulated mean precipitation from the future time period relative to the historic period (1970-99).

Neural Network (NN) model for modeling mean discharge (Qave)
(0.69 < R^2 < 0.79)

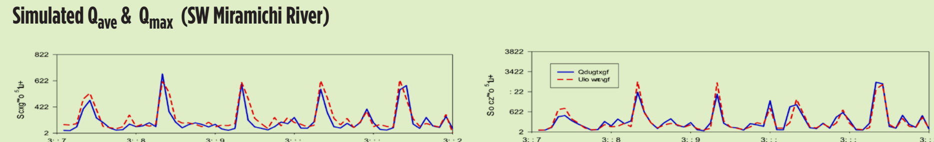


M : 1,2,3,...12
Tmax, Tmin : °C
P : mm
Qave : m^3/s

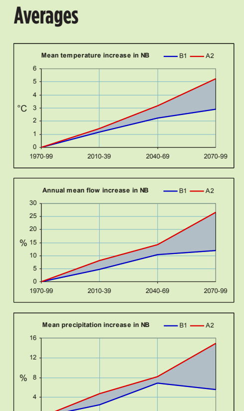
Regression models for modeling highflow (Q_{max}) & lowflow (Q_{min})
(0.66 < R2 < 0.92)



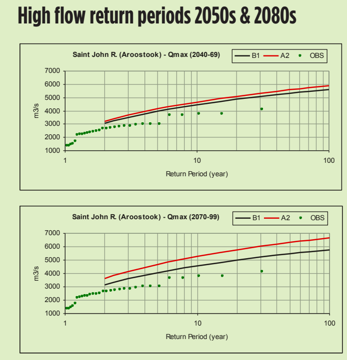
Simulated Q_{ave} & Q_{max} (SW Miramichi River)



Averages



High flow return periods 2050s & 2080s



Low flow return periods 2050s & 2080s

Regional Climate Index (RCI) for flood & drought

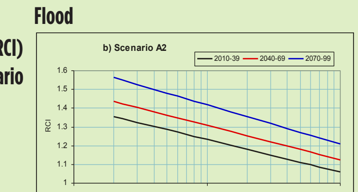
$$RCI_F = Q_{F,T}^{x,ts,sc} \;/\; Q_{F,T}^{x,2010}$$
$$RCI_D = Q_{D,T}^{x,ts,sc} \;/\; Q_{D,T}^{x,2010}$$

x = any site
ts = time slice
sc = scenario

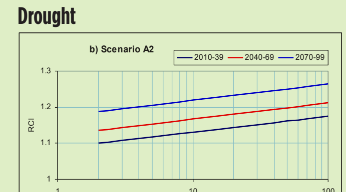
$$Q_{F,T}^{x,ts,sc} = Q_{F,T}^{x,2010} \quad RCI_F(T)$$
$$Q_{D,T}^{x,ts,sc} = Q_{D,T}^{x,2010} \quad RCI_D(T)$$

Regional climate index (RCI) curves for A2 scenario

Flood



Drought



CONCLUSIONS

- Climate models used suggest an increase in precipitation and temperature in the future
- Downscaled models in connection with hydrological models are capable of predicting future flows
- Flow return periods predict a significant evolution under climate change
- Current high flow events could potentially become a more dominant high flow events in the future (and thus representing a flow with a much lower recurrence interval).
- Future climate may bring more water during periods of low flow
- Regional Climate Index for floods (RCI) may be used for design purposes