A hydrometric analysis of the Moose Jaw River near Burdick (05JE006): Temporal trends and frequency analyses for mean, minimum, and maximum flows

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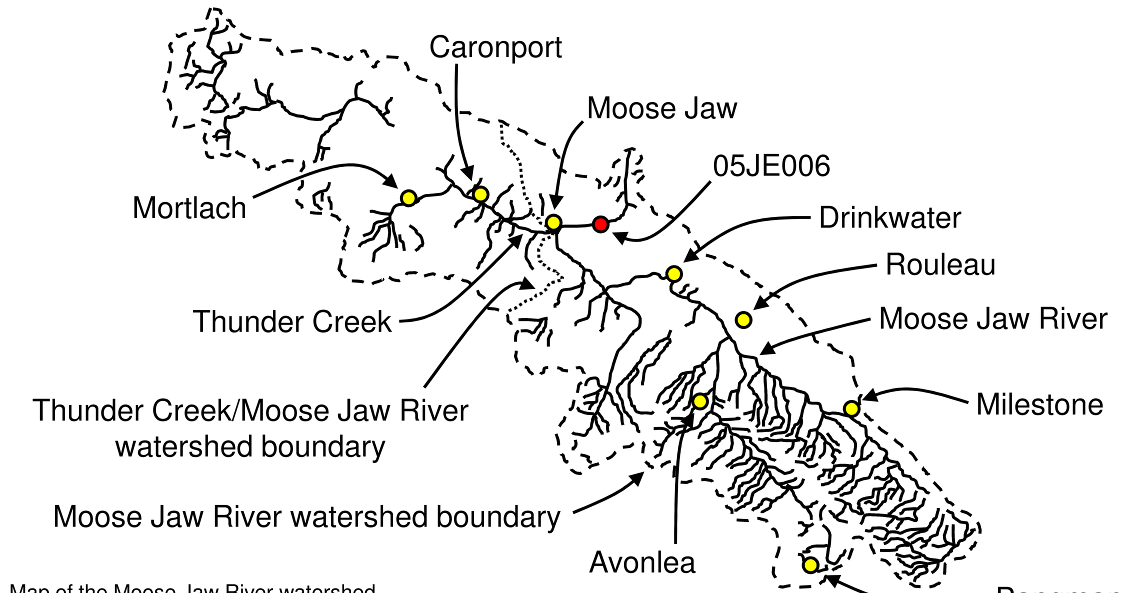
Introduction

- the Moose Jaw River watershed is located in south-central Saskatchewan, Canada
- Thunder Creek is the main tributary to the Moose Jaw River and joins the river in the city of Moose Jaw
- the river is the largest tributary of the Qu'Appelle River, and water from this hydrologic system progressively flows into the Assiniboine River, the Red River, Lake Winnipeg, and finally the Nelson River, which empties into Hudson Bay and the Arctic Ocean
- the regional climate is semi-arid, averaging ~380 mm/year precipitation (40%:60% snow:rain) with high evaporation (~980 mm/year) [1-3]



Map of the Moose Jaw River watershed (adapted from http://www.swa.ca/Stewardship/WatershedPlanning/Default.asp?type=MJWS)

Methods

- streamflow data was obtained from the online Environment Canada/Water Survey of Canada database (http://www.wateroffice.ec.gc.ca/index_e.html)
- the Moose Jaw River near Burdick (05JE006) hydrometric station has been in operation since 1944
- between 1944 and 1952, seasonal flow data was obtained via manual methods
- in 1953, a flow recorder was installed and measurements continued to be seasonal until 1972
- starting in 1973, continuous recorded flow measurements were obtained at 05JE006, allowing for a complete hydrometric record suitable for time series analysis available up to the present (2010 is the latest year for which a complete flow record exists)
- 05JE006 is the only active hydrometric station monitored by Environment Canada in the Moose Jaw River watershed: latitude, 50°24'1" N; longitude, 105°23'52" W
- the watershed upstream of 05JE006 is classified as regulated with a gross drainage area of 9230 km² and an effective drainage area of 3470 km²
- statistical analyses of streamflow data were conducted using the nonparametric Mann-Kendall test for the trend and the nonparametric Sen's method for the magnitude of the trend [4-9]
- frequency analyses were performed with DISTRIB 2.13 Statistical Distribution Analysis software [10]

Results and Discussion

- annual hydrograph is typical of prairie rivers: spring freshet maximum during April with extended low-flow period from mid-summer through the following early spring (Figure 1)

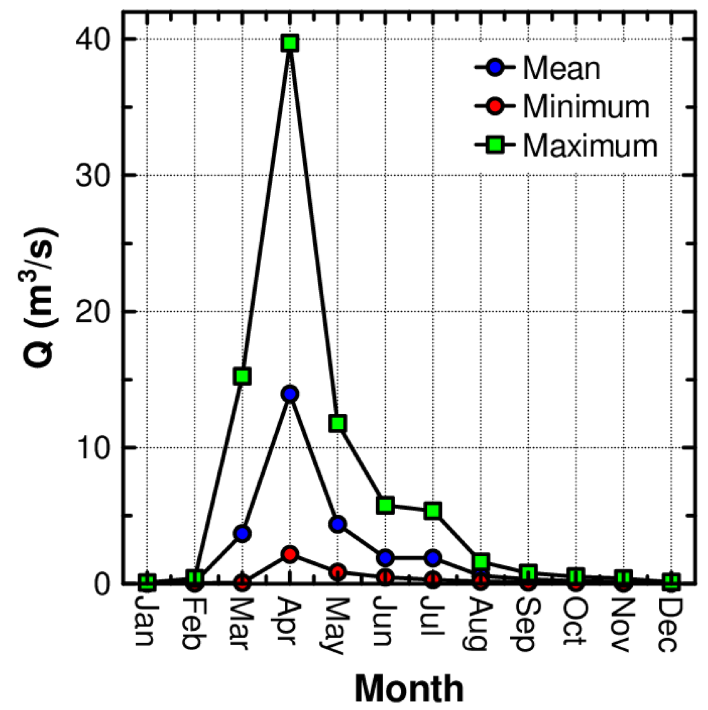


Figure 1. Annual hydrograph for the Moose Jaw River near Burdick (05JE006). Values represent mean monthly streamflows (blue), mean monthly minimum flows (red), and mean monthly maximum flows (green) over the available hydrometric record (1973-2010).

- no-flow conditions on the river routinely occur (Table 1):
  - 16/38 years (42%) have at least one occurrence of Q=0 m³/s
  - overwinter zero-flow conditions most common
  - mid-/late-summer no-flow also frequent

Table 1. Percentage of zero-flow conditions occurring at least once per month over the available hydrometric record (1973-2010) for the Moose Jaw River near Burdick (05JE006).

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
24%	32%	18%	8%	3%	8%	11%	15%	13%	11%	5%	3%

- Mann-Kendall analysis on mean monthly and annual streamflows reveals no trend (p>0.05) in annual water yields, nor in mean monthly flows between March and October
- mean monthly streamflows during January (-0.0028 [-0.0043 to -0.0010; 95% CL]; p<0.01), February (-0.0049 [-0.0070 to -0.0031]; p<0.001), November (-0.0040 [-0.0067 to -0.0014]; p<0.01), and December (-0.0036 [-0.0049 to -0.0016]; p<0.01) appear to be declining (values in m³/s/year)
  - however, during these months, there appears to have been a regime-shift in monthly flows between the 1973-1986/87 and 1987/88-2010 periods (Figure 2)
  - mean monthly streamflows during these months are systematically higher in the period 1973-1987 than between 1988-2010 for all four months (one-way ANOVA; values in m³/s): Jan., 0.126 vs. 0.016 (p<0.001); Feb., 0.192 vs. 0.053 (p<0.01); Nov., 0.222 vs. 0.099 (p<0.01); Dec., 0.130 vs. 0.037 (p<0.001)

Results and Discussion

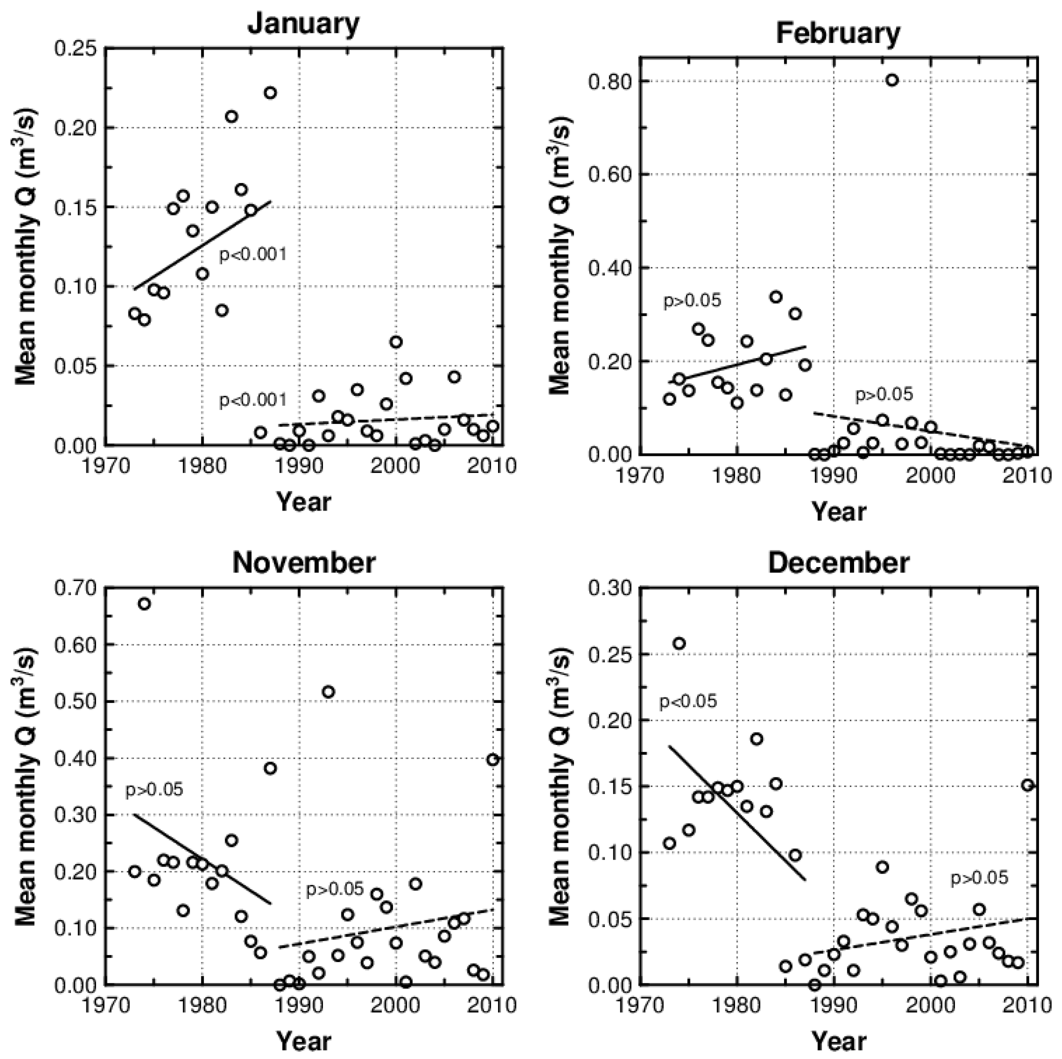


Figure 2. Temporal trends in mean monthly streamflows during January, February, November, and December for the Moose Jaw River near Burdick (05JE006) hydrometric station between 1973 and 2010. Best-fit parametric linear regressions (and associated statistical significance) are shown for the periods 1973-1987 (solid lines) and 1988-2010 (dashed lines).

- pattern and magnitude of the mean monthly streamflow differences between the two time periods suggests non-natural cause, potentially a change in flow measurement technique/calibration under ice conditions
- find similar results for the time series of monthly maximum and minimum streamflows
  - also observe different monthly minimum/maximum flow patterns and magnitudes between 1973-1987 and 1988-2010 during winter
- no significant temporal trends in monthly maximum flows between March and November or in annual maximum flow (values in m³/s/year):
  - flows decreasing during January (-0.0040 [-0.0065 to -0.0014]; p<0.01), February (-0.0068 [-0.0115 to -0.0030]; p<0.001), and December (-0.0053 [-0.0075 to -0.0028]; p<0.001)
- no significant temporal trends in monthly minimum flows between April and November (values in m³/s/year):
  - annual minimum flow decreasing (-0.0001 [-0.0002 to 0.0000]; p<0.001)
  - flows decreasing during January (-0.0014 [-0.0025 to -0.0005]; p<0.001), February (-0.0028 [-0.0042 to -0.0005]; p<0.001), March (-0.0036 [-0.0054 to -0.0021]; p<0.001), and December (-0.0020 [-0.0030 to -0.0005]; p<0.01)

Results and Discussion

- ambiguity in whether statistically significant negative time trends in overwinter mean monthly flows and monthly minimum/maximum flows for the Moose Jaw River near Burdick (05JE006) hydrometric station between 1973 and 2010 are "real" or whether they represent a change in measurement technique/calibration during the mid-/late-1980s
- frequency analyses on mean monthly, average annual, monthly minimum/maximum, and annual minimum flows generally yielded poor fits, and problems with negative flow predictions for mid- to long-term return periods regardless of distribution type
- annual maximum streamflow time series is reasonably well-described by Pearson Type III and log Pearson Type III distributions (Figure 3)

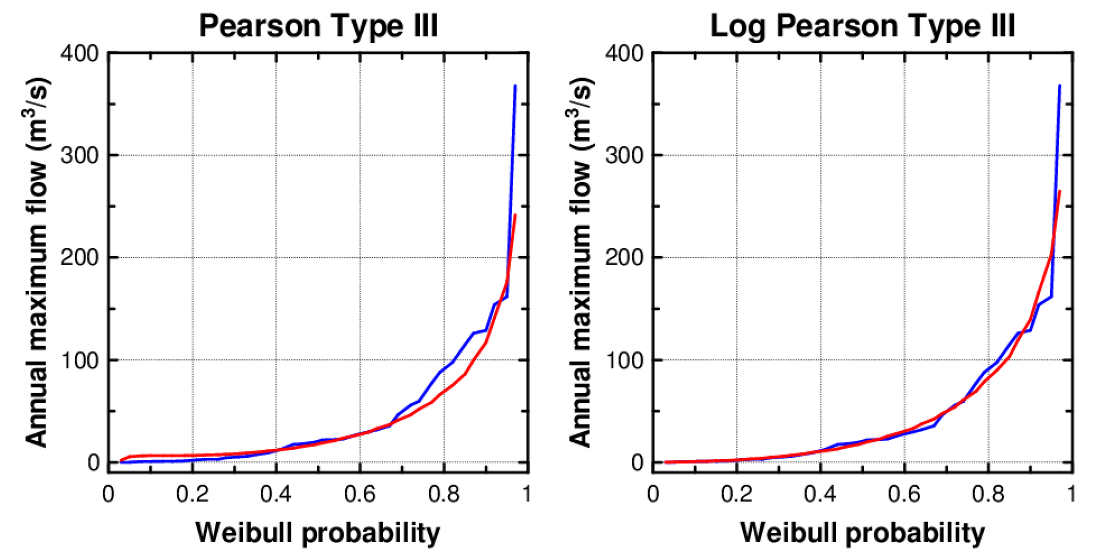


Figure 3. Pearson Type III and log Pearson Type III frequency distribution fits (red lines) for the available 1973-2010 annual maximum streamflow time series (blue lines) at the Moose Jaw River near Burdick (05JE006) hydrometric station.

- both distribution types underestimate extreme maximum flows, and are thus not conservative (other distribution types examined also underestimate extreme maximum flows)

Table 2. Estimated return periods (±std. dev.) for the annual maximum streamflow at the Moose Jaw River near Burdick (05JE006) hydrometric station using the Pearson Type III and log Pearson Type III distributions.

Return period (years)	Pearson Type III		Log Pearson Type III	
	wet year	dry year	wet year	dry year
2	17.9±12.7		18.5±8.4	
3	36.9±33.9	9.1±12.6	42.2±15.4	6.9±3.6
5	67.9±48.0	6.6±27.4	80.8±23.0	2.3±1.4
10	119.1±52.5	6.4±29.7	142.0±48.1	0.6±0.5
25	198.9±60.0	4.4±8.7	225.9±135.4	0.1±0.2
50	266.5±88.9	0.0	285.6±240.8	0.0
100	339.4±138.2	0.0	339.0±376.2	0.0
200	417.0±202.3	0.0	385.1±537.4	0.0

- using these fits, the 2009 maximum flow (17.3 m³/s) was a 1-in-2 year event, the 2010 maximum flow (46.4 m³/s) was a 1-in-3/4 year event, and the drought year of 1988 maximum flow (0.02 m³/s) was a 1-in-50 year event

References

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