Absence of historical temporal trends in monthly, seasonal, and annual streamflows for the Okanagan and Similkameen Rivers in south-central British Columbia, Canada

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The rapidly growing population in the semi-arid climate of south-central British Columbia, as well as the legal implications of trans-boundary water agreements such as the International Joint Commission (IJC), have led to substantial interest in the hydrology of this region and debate over the resulting environmental management policies [1-12]. In a previous work [13], we showed that - despite substantial increases in population and agricultural activities over the past century - the net water yield from the Canadian portion of the Okanagan Valley has not changed significantly during this time. In the current study, we examine potential historical temporal trends in monthly, seasonal, and annual mean, minimum, and maximum streamflows for the Okanagan and Similkameen Rivers (Figures 1 and 2), as well as any time trends for the date to peak of the spring freshet on both river systems.

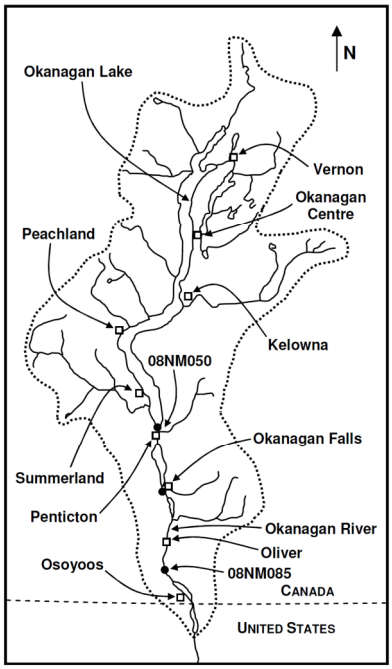

Figure 1. Schematic map of the Okanagan Valley watershed showing locations of major municipalities, lakes, rivers, and the hydrometric monitoring station under consideration (08NM085).

Historical streamflow data was obtained [14] for the following two Environment Canada hydrometric monitoring stations in the Okanagan and Similkameen Valleys which are located farthest downstream near the United States-Canada border (Table 1): Okanagan River near Oliver (08NM085; in Canada) and the Similkameen River near Nighthawk (08NL022; USGS stn. 12442500; in the United States).

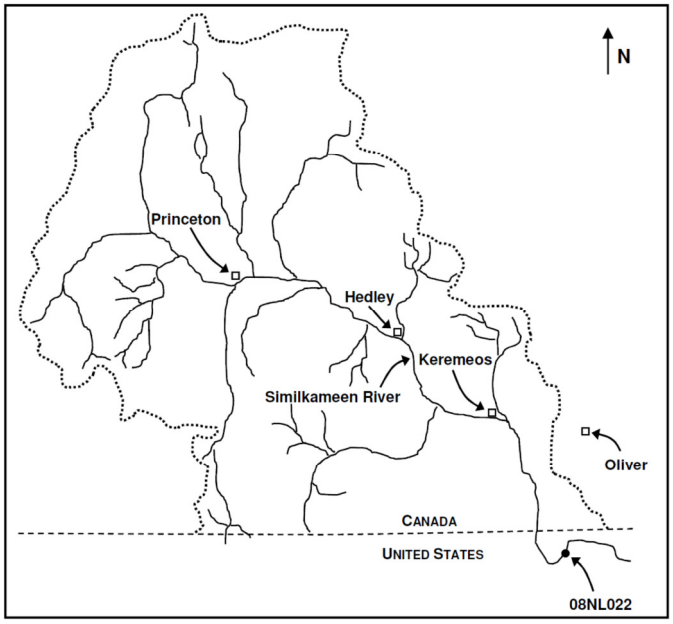

Figure 2. Schematic map of the Similkamen Valley watershed showing locations of major municipalities, lakes, rivers, and the hydrometric monitoring station under consideration (08NL022).

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 [15-20].

Table 1. Hydrometric station information for the sites under study.

	Okanagan River near Oliver	Similkameen River near Nighthawk
Station ID	08NM085	08NL022
Latitude (N)	49°6'53"	48°59'5"
Longitude (W)	119°33'50"	119°37'2"
Gross drainage area (km^2)	7540	9190
Period of record[a]	1958-2010	1929-2010
Gauge type	continuously recorded	continuously recorded

With the sole exceptions of isolated statistically significant declines in mean monthly flow during November (-0.8%/year, $p<0.05$), and in the monthly maximum daily flows during November (-0.9%/year, $p<0.01$) and December (-0.7%/year, $p<0.05$), both on the Okanagan River near Oliver (08NM085), there are no other statistically significant trends in monthly, seasonal, and annual streamflows, or in maximum and minimum daily streamflows during each month, at either of the downstream stations on the Okanagan and Similkameen Rivers (Tables 2-4).

In addition, there are no significant temporal trends in the calendar day upon which the spring freshet peak occurs: Okanagan River near

Oliver (08NM085), test Z=1.098, Q=0.230 days/year, $Q_{min,95}$=-0.136 days/year, and $Q_{max,95}$=-0.618 days/year; Similkameen River near Nighthawk (08NL022), test Z=0.065, Q=0.000 days/year, $Q_{min,95}$=-0.105 days/year, and $Q_{max,95}$=-0.123 days/year. These findings contrast with previous studies and their interpretations as summarized in a recent trans-boundary water agreement study (see ref. [21] and references therein). Based on our examinations, there appears to be no compelling evidence that streamflow patterns in the Okanagan and Similkameen Rivers have changed over the available hydrometric record, nor does there appear to be evidence that future changes in streamflow patterns are imminent or likely.

References

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Table 2. Summary of non-parametric Mann-Kendall test statistics for temporal trends in mean monthly, seasonal, and annual streamflows at the hydrometric monitoring stations on the Okanagan River near Oliver (08NM085) and the Similkameen River near Nighthawk (08NL022). Values are in m^3/s.

	Okanagan River near Oliver (08NM085)					Similkameen River near Nighthawk (08NL022)				
	Mann-Kendall trend		Sen's slope estimate			Mann-Kendall trend		Sen's slope estimate		
Time period	Test Z[a]	Significance[b]	Q[c]	$Q_{min,95}$[d]	$Q_{max,95}$[e]	Test Z	Significance	Q	$Q_{min,95}$	$Q_{max,95}$
January	-0.990	n/s	-0.040	-0.142	0.024	1.868	n/s	0.057	0.000	0.113
February	-0.176	n/s	-0.009	-0.127	0.090	1.158	n/s	0.028	-0.023	0.095
March	-0.238	n/s	-0.020	-0.185	0.155	1.836	n/s	0.058	-0.004	0.138
April	-0.399	n/s	-0.031	-0.190	0.154	0.983	n/s	0.140	-0.144	0.425
May	0.230	n/s	0.027	-0.246	0.393	-0.424	n/s	-0.167	-0.876	0.580
June	0.268	n/s	0.026	-0.309	0.348	-0.465	n/s	-0.272	-1.255	0.698
July	1.051	n/s	0.081	-0.088	0.313	-0.094	n/s	-0.012	-0.376	0.313
August	0.913	n/s	0.058	-0.059	0.187	-0.184	n/s	-0.008	-0.122	0.084
September	1.105	n/s	0.056	-0.049	0.148	-0.216	n/s	-0.005	-0.067	0.057
October	-1.351	n/s	-0.033	-0.095	0.018	-0.139	n/s	-0.006	-0.070	0.062
November	-2.516	*	-0.080	-0.154	-0.019	0.759	n/s	0.031	-0.088	0.132
December	-1.818	n/s	-0.054	-0.120	0.003	0.228	n/s	0.007	-0.073	0.087
April-July	0.560	n/s	0.269	-0.734	1.420	-1.085	n/s	-0.967	-2.878	0.906
January-March	-0.591	n/s	-0.121	-0.497	0.258	1.831	n/s	0.159	-0.011	0.352
April-June	0.276	n/s	0.095	-0.643	1.076	-1.024	n/s	-0.657	-2.336	0.773
July-September	1.266	n/s	0.219	-0.169	0.676	-0.073	n/s	-0.017	-0.546	0.425
October-December	-1.956	n/s	-0.200	-0.402	-0.001	0.453	n/s	0.064	-0.213	0.308
Annual	0.184	n/s	0.010	-0.142	0.155	-0.489	n/s	-0.048	-0.243	0.146

[a] The absolute value of the test statistic (Z) is compared to the standard normal cumulative distribution to define if there is a trend or not at the selected level α of significance. A positive (negative) value of Z indicates an upward (downward) trend. [b] The smallest significance level α with which the test shows that the null hypothesis of no trend should be rejected. n/s=not significant. *=significant at α=0.05. **=significant at α=0.01. ***=significant at α=0.001. [c] The Sen's estimate for the true slope of the linear trend. [d] The lower limit of the 95% confidence interval of Q (α= 0.05). [e] The upper limit of the 95 % confidence interval of Q (α= 0.05).

Table 3. Summary of non-parametric Mann-Kendall test statistics for temporal trends in maximum daily streamflows during each month at the hydrometric monitoring stations on the Okanagan River near Oliver (08NM085) and the Similkameen River near Nighthawk (08NL022). Values are in m^3/s.

	Okanagan River near Oliver (08NM085)					Similkameen River near Nighthawk (08NL022)				
	Mann-Kendall trend		Sen's slope estimate			Mann-Kendall trend		Sen's slope estimate		
Time period	Test Z[a]	Significance[b]	Q[c]	$Q_{min,95}$[d]	$Q_{max,95}$[e]	Test Z	Significance	Q	$Q_{min,95}$	$Q_{max,95}$
January	-1.350	n/s	-0.058	-0.163	0.028	1.672	n/s	0.074	-0.020	0.173
February	-0.583	n/s	-0.050	-0.206	0.117	0.877	n/s	0.036	-0.042	0.124
March	-0.552	n/s	-0.049	-0.247	0.176	1.391	n/s	0.076	-0.033	0.190
April	-0.376	n/s	-0.053	-0.259	0.196	0.400	n/s	0.146	-0.573	0.778
May	0.215	n/s	0.041	-0.371	0.517	-0.351	n/s	-0.200	-1.566	1.000
June	0.338	n/s	0.062	-0.312	0.572	-0.196	n/s	-0.183	-1.834	1.344
July	1.496	n/s	0.186	-0.043	0.622	-0.139	n/s	-0.033	-0.691	0.559
August	1.036	n/s	0.083	-0.080	0.333	-0.008	n/s	0.000	-0.149	0.165
September	1.342	n/s	0.114	-0.066	0.307	0.253	n/s	0.018	-0.084	0.120
October	-1.849	n/s	-0.071	-0.146	0.008	-0.485	n/s	-0.037	-0.200	0.108
November	-2.685	**	-0.105	-0.182	-0.032	1.627	n/s	0.162	-0.045	0.374
December	-2.025	*	-0.082	-0.160	-0.004	0.547	n/s	0.040	-0.117	0.182

[a] The absolute value of the test statistic (Z) is compared to the standard normal cumulative distribution to define if there is a trend or not at the selected level α of significance. A positive (negative) value of Z indicates an upward (downward) trend. [b] The smallest significance level α with which the test shows that the null hypothesis of no trend should be rejected. n/s=not significant. *=significant at α=0.05. **=significant at α=0.01. ***=significant at α=0.001. [c] The Sen's estimate for the true slope of the linear trend. [d] The lower limit of the 95% confidence interval of Q (α= 0.05). [e] The upper limit of the 95 % confidence interval of Q (α= 0.05).

Table 4. Summary of non-parametric Mann-Kendall test statistics for temporal trends in minimum daily streamflows during each month at the hydrometric monitoring stations on the Okanagan River near Oliver (08NM085) and the Similkameen River near Nighthawk (08NL022). Values are in m^3/s.

	Okanagan River near Oliver (08NM085)					Similkameen River near Nighthawk (08NL022)				
	Mann-Kendall trend		Sen's slope estimate			Mann-Kendall trend		Sen's slope estimate		
Time period	Test Z[a]	Significance[b]	Q[c]	$Q_{min,95}$[d]	$Q_{max,95}$[e]	Test Z	Significance	Q	$Q_{min,95}$	$Q_{max,95}$
January	-0.798	n/s	-0.022	-0.076	0.034	0.412	n/s	0.010	-0.033	0.054
February	-0.744	n/s	-0.019	-0.077	0.042	0.999	n/s	0.027	-0.025	0.079
March	-0.123	n/s	-0.006	-0.122	0.102	1.028	n/s	0.024	-0.017	0.071
April	-0.361	n/s	-0.025	-0.157	0.088	1.424	n/s	0.078	-0.025	0.199
May	-1.043	n/s	-0.078	-0.206	0.078	-0.069	n/s	-0.014	-0.531	0.451
June	0.130	n/s	0.006	-0.131	0.171	-0.498	n/s	-0.130	-0.726	0.438
July	0.606	n/s	0.028	-0.075	0.141	-0.347	n/s	-0.019	-0.172	0.123
August	0.568	n/s	0.028	-0.064	0.120	-0.473	n/s	-0.015	-0.080	0.046
September	0.284	n/s	0.008	-0.054	0.072	-0.979	n/s	-0.022	-0.065	0.025
October	-1.826	n/s	-0.036	-0.094	0.003	-1.073	n/s	-0.020	-0.065	0.019
November	-1.573	n/s	-0.053	-0.127	0.007	-1.611	n/s	-0.052	-0.123	0.013
December	-1.734	n/s	-0.036	-0.089	0.004	-1.362	n/s	-0.036	-0.088	0.016

[a] The absolute value of the test statistic (Z) is compared to the standard normal cumulative distribution to define if there is a trend or not at the selected level α of significance. A positive (negative) value of Z indicates an upward (downward) trend. [b] The smallest significance level α with which the test shows that the null hypothesis of no trend should be rejected. n/s=not significant. *=significant at α=0.05. **=significant at α=0.01. ***=significant at α=0.001. [c] The Sen's estimate for the true slope of the linear trend. [d] The lower limit of the 95% confidence interval of Q (α= 0.05). [e] The upper limit of the 95 % confidence interval of Q (α= 0.05).