

Milk River Natural Flow Comparison between Thompson and Paterson Consumptive Use Values

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1 Executive Summary

This report examines the degree to which natural flow and apportionment of the Milk River, as calculated with MilkNat2010, changes between two scenarios: the use of the Thompson (1986) consumptive use values, and the proposed consumptive use values found by Paterson (2017). To do so, data from 2009 to 2016 was back-tested with both values, and compared. The results of these runs are summarized below in Table 1-1.

Table 1-1: Summary of natural flow totals for all years

Year	Thompson Natural Flow, acre-ft	Paterson Natural Flow, acre-ft	Change, acre-ft	Change, percent
2009	64575.2	61300.5	-3274.7	-5.1%
2010	225494.8	222256.7	-3238.1	-1.4%
2011	290712.7	287474.4	-3238.3	-1.1%
2012	90533.6	87703.6	-2830.0	-3.1%
2013	79114.0	76218.2	-2895.8	-3.7%
2014	159597.0	156358.7	-3238.3	-2.0%
2015	54008.4	50863.8	-3144.6	-5.8%
2016	30121.4	26713.7	-3407.7	-11.3%

The average natural flow change was approximately -3200 acre-feet, in line with the change in consumptive use of -3228 acre-feet. The changes in the US share totals and US received flow totals were found to be approximately -2200 acre-feet and -2500 acre-feet, respectively. The change in total flow received by the US above share was also considered, but did not exhibit a pattern beyond consistently being smaller.

From these findings, it's concluded that future runs can expect the natural flow to decrease by approximately 3200 acre-feet, US share to decrease by approximately 2200 acre-feet, and US received flow to decrease by 2500 acre-feet, approximately. US received flow above share can be expected to decrease by a variable amount.

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2 Introduction

In December 2015, the International Joint Commission (IJC) commissioned a study to determine the current consumptive water use in the Milk River basin. Currently, consumptive use values are assumed to be the values found by Thompson (1986). Over the intervening years there have been significant changes in the Milk River basin: irrigation methods have become more efficient, as well as the introduction of some water-use monitoring in Alberta and Montana.

As such, a study to determine the current consumptive use was undertaken by Brent Paterson (2017). His findings, as well as Thompson's numbers, are presented below in Table 2-1. As consumptive use values are entered into MilkNat2010 in units of acre-feet on a daily basis, both Thompson's and Paterson's numbers are shown in acre-feet/day.

Table 2-1: Comparison of Paterson and Thompson consumptive use

Division Period	United States (Montana), acre-ft/d		Canada (Alberta), acre-ft/d	
	Thompson	Paterson	Thompson	Paterson
March 1-15	0	0	0	0.31
March 16-31	0	0	0	0.35
April 1-15	0	0	0	0.44
April 16-30	0	0.82	0	0.60
May 1-15	0	8.58	0	7.11
May 16-31	81.25	11.28	49.73	13.18
June 1-15	81.25	13.79	51.83	16.37
June 16-30	11.91	15.15	19.61	19.46
July 1-15	*21.71	16.73	35.72	47.56
July 16-31	*21.71	9.88	35.72	60.29
August 1-15	17.51	6.19	29.42	40.74
August 16-31	17.51	2.17	29.42	22.86
September 1-15	11.91	0.50	19.61	11.71
September 16-30	0	1.58	0	0.11
Total (acre-ft)	4092	1332	4181	3713

*These values correct an error in the original Thompson numbers

While there is a relatively minor change between the Canadian values, with the Paterson total at 89% of the Thompson total, there is a significant difference between the United States (US) values, with the Paterson total at 33% of the Thompson total. Additionally, it's seen that, despite having similar totals, the Canadian numbers follow a different distribution over time, with the Paterson numbers peaking in the last half of July and the Thompson numbers peaking in the first half of June. The United States consumptive use is significantly less in May-June with Paterson numbers as compared to Thompson numbers. This difference might be due to change in irrigation type, moving from flood irrigation to sprinkler irrigation.

In order to determine the likely future impacts of switching to Paterson's numbers, a study was undertaken to back-test Paterson's numbers with historical data. This report contains the results of this testing.

A working knowledge of the basin location and data collection is assumed of the reader; as such, this background information is omitted in the main report. For additional information, see Appendix A: Background.

3 MilkNat2010 Results and Discussion

To assess how the Paterson numbers would change the computed natural flow of the Milk River, MilkNat2010 was run for eight years of data – 2009 to 2016 – with both Thompson’s and Paterson’s numbers.

To verify that MilkNat2010 imported consumptive use data correctly, it was run twice with 2013 data – once with Thompson’s consumptive use setting selected, and once with Thompson’s consumptive use manually entered in the consumptive use columns. These were found to produce the same output, verifying the proper importing.

For every year, MilkNat2010 was run with Thompson’s consumptive use and with Paterson’s consumptive use. Additionally, for 2009 to 2012 MilkNat2010 was run with the measured Canadian and US consumptive use for that year. More details on this and data from these runs may be seen in Appendix B: Modelling Natural Flow and Water Division.

Data from the runs are summarized in Table 3-1, and may be seen in more detail in Table 3-5 to Table 3-12.

Table 3-1: Summary of natural flow totals for all years

Year	Thompson Natural Flow, acre-ft	Paterson Natural Flow, acre-ft	Change, acre-ft	Change, percent
2009	64575.2	61300.5	-3274.7	-5.1%
2010	225494.8	222256.7	-3238.1	-1.4%
2011	290712.7	287474.4	-3238.3	-1.1%
2012	90533.6	87703.6	-2830.0	-3.1%
2013	79114.0	76218.2	-2895.8	-3.7%
2014	159597.0	156358.7	-3238.3	-2.0%
2015	54008.4	50863.8	-3144.6	-5.8%
2016	30121.4	26713.7	-3407.7	-11.3%

While the proportional change is variable, the absolute change is roughly constant, at approximately -3200 acre-feet (more precisely, -3158.4 acre-feet) for the years run. This is as expected, as the difference between the total Thompson and Paterson values is -3228 acre-feet. Non-linear effects of the evapotranspiration calculations of MilkNat2010 can likely be attributed to the rest of the change observed.

As US received flow above share is a major component of the calculations, the total received by the US is summarized in Table 3-2.

Table 3-2: Summary of US received flow totals above share for all years

Year	Thompson Received Flow Above Share, acre-ft	Paterson Received Flow Above Share, acre-ft	Change, acre-ft	Change, percent
2009	14774.9	14753.8	-21.1	-0.1%
2010	69836.4	69153.0	-683.4	-1.0%
2011	102234.4	101154.7	-1079.7	-1.1%
2012	22655.2	22417.9	-237.3	-1.0%
2013	20341.3	19950.9	-390.4	-1.9%
2014	51282.9	50954.0	-328.9	-0.6%
2015	14073.0	13757.6	-315.4	-2.2%
2016	4461.8	4079.8	-382.0	-8.6%

While there is no clear trend with the US received flow changes, in every case it is a negative number, indicating that with Paterson’s numbers the US would be receiving more of their calculated share. However, as the natural flow was shown in Table 3-1to be decreased for all years, this means the total US share decreases as well – the US will receive a larger proportion of a smaller amount. To illustrate this, Table 3-3and Table 3-4 show the calculated US share and received flow totals for all years.

Table 3-3: Summary of US share totals for all years

Year	Thompson US Share, acre-ft	Paterson US Share, acre-ft	Change, acre-ft	Change, percent
2009	45295.5	42833.4	-2462.1	-5.4%
2010	151476.9	149390.6	-2086.3	-1.4%
2011	184296.4	182606.3	-1690.1	-0.9%
2012	63697.4	61572.3	-2125.1	-3.3%
2013	54590.9	52554.0	-2036.9	-3.7%
2014	104132.5	101691.4	-2441.1	-2.3%
2015	35754.2	33393.2	-2361.0	-6.6%
2016	21478.2	18920.6	-2557.6	-11.9%

Table 3-4: Summary of US received flow totals for all years

Year	Thompson Received Flow, acre-ft	Paterson Received Flow, acre-ft	Change, acre-ft	Change, percent
2009	60811.0	58718.0	-2093.0	-3.4%
2010	221313.3	218543.2	-2770.1	-1.3%
2011	286531.2	283761.3	-2769.9	-1.0%
2012	86761.5	84573.6	-2187.9	-2.5%
2013	75224.7	73040.7	-2184.0	-2.9%
2014	155415.6	152645.6	-2770.0	-1.8%
2015	50730.8	48537.4	-2193.4	-4.3%
2016	26007.2	23091.1	-2916.1	-11.2%

For the US share totals and US received flow totals, the average change is approximately -2200 acre-feet (-2220.0 acre-feet) and -2500 acre-feet (-2485.6 acre-feet), respectively.

Table 3-5: Summary of Milk River division for 2009

Division Period at International Boundary	Thompson Consumptive Use					Paterson Consumptive Use				
	Natural Flow	U.S.A Share	Received by U.S.A	Received by U.S.A.		Natural Flow	U.S.A Share	Received by U.S.A	Received by U.S.A.	
				Above Share	Below Share				Above Share	Below Share
[Acre-ft.]	[Acre-ft.]	[Acre-ft.]	[Acre-ft.]	[Acre-ft.]	[Acre-ft.]	[Acre-ft.]	[Acre-ft.]	[Acre-ft.]	[Acre-ft.]	[Acre-ft.]
MAR 1 - MAR 15	646.7	323.4	646.7	323.3		651.6	325.8	646.7	320.9	
MAR 16- MAR 31	11828.2	5914.2	11828.2	5914.1		11833.4	5916.7	11828.2	5911.5	
APR 1 - APR 15	7764.0	5823.2	7764.0	1940.8		7770.1	5827.6	7764.0	1936.4	
APR 16 - APR 30	10011.7	7508.7	10011.7	2502.9		10032.3	7524.3	10023.8	2499.5	
MAY 1 - MAY 15	8107.2	6063.2	8107.2	2044.1		8343.1	6236.3	8236.1	1999.8	
MAY 16 - MAY 31	8850.3	6637.8	8055.2	1417.4		7147.2	5360.4	6935.7	1575.3	
JUNE 1 - JUNE 15	7140.1	5354.8	6363.0	1008.2		5596.9	4198.0	5351.3	1153.3	
JUNE 16 - JUNE 30	2339.4	1754.6	2045.1	290.5		2382.5	1786.9	2090.7	303.8	
JULY 1 - JULY 15	372.2	279.1	0.0		-443.2	406.2	304.7	0.0		-612.3
JULY 16 - JULY 31	410.2	307.7	0.0		-469.6	497.3	372.8	0.0		-840.6
AUG 1 - AUG 15	379.5	284.7	0.0		-346.7	379.5	284.7	0.0		-516.9
AUG 16 - AUG 31	441.5	331.0	0.0		-360.4	242.6	182.0	0.0		-305.2
SEP 1 - SEP 15	1057.3	793.0	763.0		-30.0	766.6	574.9	591.5	16.6	
SEP 16 - SEP 30	1049.4	786.9	1049.4	262.5		1073.7	805.1	1072.5	267.4	
OCT 1 - OCT 15	2128.1	1596.1	2128.1	532.0		2128.1	1596.1	2128.1	532.0	
OCT 16 - OCT 31	2049.4	1537.1	2049.4	512.3		2049.4	1537.1	2049.4	512.3	
TOTAL	64575.2	45295.5	60811.0			61300.5	42833.4	58718.0		

Table 3-6: Summary of Milk River division for 2010

Division Period at International Boundary	Thompson Consumptive Use					Paterson Consumptive Use				
	Natural Flow	U.S.A Share	Received by U.S.A	Received by U.S.A.		Natural Flow	U.S.A Share	Received by U.S.A	Received by U.S.A.	
				Above Share	Below Share				Above Share	Below Share
[Acre-ft.]	[Acre-ft.]	[Acre-ft.]	[Acre-ft.]	[Acre-ft.]	[Acre-ft.]	[Acre-ft.]	[Acre-ft.]	[Acre-ft.]	[Acre-ft.]	[Acre-ft.]
MAR 1 - MAR 15	3070.3	1534.9	3070.3	1535.4		3075.2	1537.4	3070.3	1533.0	
MAR 16- MAR 31	10440.3	5220.3	10440.3	5219.9		10445.5	5222.9	10440.3	5217.3	
APR 1 - APR 15	7100.6	5325.6	7100.6	1775.1		7106.7	5330.1	7100.6	1770.5	
APR 16 - APR 30	11551.8	8663.8	11551.8	2887.9		11572.4	8679.3	11563.9	2884.7	
MAY 1 - MAY 15	19974.5	14096.0	19974.5	5878.6		20210.4	14245.4	20103.4	5858.1	
MAY 16 - MAY 31	26742.7	18106.3	25947.5	7841.2		25039.5	17068.4	24828.1	7759.7	
JUNE 1 - JUNE 15	23133.8	15884.5	22356.7	6472.2		21590.6	14881.4	21344.9	6463.6	
JUNE 16 - JUNE 30	56450.3	32896.4	56156.0	23259.6		56496.5	32921.1	56204.6	23283.5	
JULY 1 - JULY 15	19071.6	13779.9	18535.3	4755.4		19173.8	13844.5	18459.9	4615.4	
JULY 16 - JULY 31	12392.8	9294.3	11820.8	2526.4		12596.5	9447.3	11631.4	2184.1	
AUG 1 - AUG 15	6296.7	4722.5	5855.3	1132.8		6296.7	4722.5	5685.0	962.6	
AUG 16 - AUG 31	9469.2	7101.8	8998.3	1896.6		9119.0	6839.3	8753.2	1913.9	
SEP 1 - SEP 15	5915.6	4436.8	5621.3	1184.5		5625.0	4218.9	5449.9	1231.0	
SEP 16 - SEP 30	6097.4	4573.1	6097.4	1524.3		6121.7	4591.4	6120.5	1529.1	
OCT 1 - OCT 15	3925.5	2944.3	3925.5	981.2		3925.5	2944.3	3925.5	981.2	
OCT 16 - OCT 31	3861.7	2896.4	3861.7	965.3		3861.7	2896.4	3861.7	965.3	
TOTAL	225494.8	151476.9	221313.3			222256.7	149390.6	218543.2		

Table 3-7: Summary of Milk River division for 2011

Thompson Consumptive Use						Paterson Consumptive Use				
Division Period at International Boundary	Natural Flow	U.S.A Share	Received by U.S.A	Received by U.S.A.		Natural Flow	U.S.A Share	Received by U.S.A	Received by U.S.A.	
				Above Share	Below Share				Above Share	Below Share
				[Acre-ft.]	[Acre-ft.]				[Acre-ft.]	[Acre-ft.]
MAR 1 - MAR 15	1864.5	932.2	1864.5	932.2		1869.3	934.7	1864.5	929.8	
MAR 16 - MAR 31	38578.4	19289.5	38578.4	19288.9		38583.5	19292.1	38578.4	19286.3	
APR 1 - APR 15	34470.7	22022.7	34470.7	12448.0		34476.8	22026.3	34470.7	12444.4	
APR 16 - APR 30	20138.2	14716.2	20138.2	5422.0		20158.9	14729.4	20150.4	5420.9	
MAY 1 - MAY 15	23194.6	16556.1	23194.6	6638.4		23430.5	16674.1	23323.5	6649.4	
MAY 16 - MAY 31	43763.5	27171.1	42968.4	15797.2		42060.4	26319.6	41848.9	15529.3	
JUNE 1 - JUNE 15	66815.4	38366.5	66038.3	27671.8		65272.2	37595.0	65026.6	27431.6	
JUNE 16 - JUNE 30	23991.1	16819.9	23696.8	6876.9		24037.3	16846.2	23745.5	6899.3	
JULY 1 - JULY 15	10424.6	7818.3	9888.3	2070.0		10526.7	7895.0	9812.9	1917.8	
JULY 16 - JULY 31	7360.1	5520.3	6788.0	1267.7		7563.7	5672.7	6598.6	925.9	
AUG 1 - AUG 15	2676.1	2006.9	2234.6	227.7		2676.1	2006.9	2064.4	57.5	
AUG 16 - AUG 31	2108.6	1581.5	1637.7	56.2		1758.4	1318.9	1392.6	73.7	
SEP 1 - SEP 15	1895.4	1421.6	1601.2	179.6		1604.8	1203.6	1429.7	226.1	
SEP 16 - SEP 30	1830.8	1373.1	1830.8	457.6		1855.1	1391.3	1853.9	462.5	
OCT 1 - OCT 15	7171.5	5378.6	7171.5	1792.9		7171.5	5378.6	7171.5	1792.9	
OCT 16 - OCT 31	4429.2	3321.9	4429.2	1107.3		4429.2	3321.9	4429.2	1107.3	
TOTAL	290712.7	184296.4	286531.2			287474.4	182606.3	283761.3		

Table 3-8: Summary of Milk River division for 2012

Thompson Consumptive Use						Paterson Consumptive Use				
Division Period at International Boundary	Natural Flow	U.S.A Share	Received by U.S.A	Received by U.S.A.		Natural Flow	U.S.A Share	Received by U.S.A	Received by U.S.A.	
				Above Share	Below Share				Above Share	Below Share
				[Acre-ft.]	[Acre-ft.]				[Acre-ft.]	[Acre-ft.]
MAR 1 - MAR 15	5728.3	2864.2	5728.3	2864.1		5733.1	2866.6	5728.3	2861.7	
MAR 16- MAR 31	11002.4	5501.2	11002.4	5501.3		11007.6	5503.8	11002.4	5498.7	
APR 1 - APR 15	10431.0	7803.2	10431.0	2627.8		10437.0	7807.7	10431.0	2623.3	
APR 16 - APR 30	9464.9	7098.8	9464.9	2366.1		9485.6	7114.2	9477.1	2362.9	
MAY 1 - MAY 15	2488.2	1866.1	2488.2	622.1		2724.2	2043.1	2617.1	574.1	
MAY 16 - MAY 31	8388.2	6291.0	7593.1	1302.1		6685.1	5013.7	6473.6	1459.9	
JUNE 1 - JUNE 15	13119.3	9839.5	12342.2	2502.8		11576.1	8682.0	11330.4	2648.4	
JUNE 16 - JUNE 30	13999.2	10499.4	13704.9	3205.6		14045.4	10534.2	13753.6	3219.3	
JULY 1 - JULY 15	6557.5	4918.2	6021.2	1103.1		6659.7	4994.7	5945.9	951.1	
JULY 16 - JULY 31	2720.6	2040.4	2148.6	108.1		2924.2	2193.1	1959.2		-234.0
AUG 1 - AUG 15	376.2	282.2	0.0		-347.5	376.2	282.2	0.0		-517.7
AUG 16 - AUG 31	134.5	100.9	0.0		-437.2	61.7	46.3	0.0		-350.4
SEP 1 - SEP 15	286.6	214.8	0.0		-222.5	131.5	98.7	0.0		-142.3
SEP 16 - SEP 30	2128.0	1596.1	2128.0	532.0		2147.5	1610.6	2146.3	535.6	
OCT 1 - OCT 15	1810.7	1357.9	1810.7	452.8		1810.7	1357.9	1810.7	452.8	
OCT 16 - OCT 31	1898.0	1423.5	1898.0	474.5		1898.0	1423.5	1898.0	474.5	
TOTAL	90533.6	63697.4	86761.5			87703.6	61572.3	84573.6		

Table 3-9: Summary of Milk River division for 2013

Thompson Consumptive Use						Paterson Consumptive Use				
Division Period at International Boundary	Natural Flow	U.S.A Share	Received by U.S.A	Received by U.S.A.		Natural Flow	U.S.A Share	Received by U.S.A	Received by U.S.A.	
				Above Share	Below Share				Above Share	Below Share
				[Acre-ft.]	[Acre-ft.]				[Acre-ft.]	[Acre-ft.]
MAR 1 - MAR 15	4740.6	2370.2	4740.6	2370.4		4745.4	2372.6	4740.6	2367.9	
MAR 16 - MAR 31	11410.7	5705.4	11410.7	5705.3		11415.9	5708.0	11410.7	5702.7	
APR 1 - APR 15	8756.2	6567.2	8756.2	2189.0		8762.3	6571.7	8756.2	2184.5	
APR 16 - APR 30	5245.5	3933.8	5245.5	1311.7		5266.1	3949.6	5257.6	1308.1	
MAY 1 - MAY 15	4592.8	3444.6	4592.8	1148.1		4828.7	3621.3	4721.7	1100.4	
MAY 16 - MAY 31	11776.4	8766.2	10981.3	2215.0		10073.3	7515.5	9861.8	2346.4	
JUNE 1 - JUNE 15	15483.2	10971.9	14706.2	3734.2		13940.1	9925.4	13694.4	3769.0	
JUNE 16 - JUNE 30	4554.8	3416.1	4260.5	844.4		4601.0	3450.7	4309.2	858.5	
JULY 1 - JULY 15	4249.7	3187.3	3713.4	526.1		4351.8	3264.0	3638.0	374.0	
JULY 16 - JULY 31	497.5	373.2	0.0		-447.8	662.9	497.0	0.0		-799.2
AUG 1 - AUG 15	1745.4	1309.1	1304.0		-5.1	1745.4	1309.1	1133.7		-175.4
AUG 16 - AUG 31	253.4	190.2	0.0		-407.6	132.1	99.1	0.0		-332.7
SEP 1 - SEP 15	1025.5	769.1	731.2		-37.9	889.8	667.4	714.7	47.3	
SEP 16 - SEP 30	652.8	489.3	652.8	163.4		673.9	505.3	672.6	167.3	
OCT 1 - OCT 15	2431.6	1823.8	2431.6	607.8		2431.6	1823.8	2431.6	607.8	
OCT 16 - OCT 31	1697.9	1273.5	1697.9	424.3		1697.9	1273.5	1697.9	424.3	
TOTAL	79114.0	54590.9	75224.7			76218.2	52554.0	73040.7		

Table 3-10: Summary of Milk River division for 2014

Division Period at International Boundary	Thompson Consumptive Use					Paterson Consumptive Use				
	Natural Flow	U.S.A Share	Received by U.S.A	Received by U.S.A.		Natural Flow	U.S.A Share	Received by U.S.A	Received by U.S.A.	
				Above Share	Below Share				Above Share	Below Share
[Acre-ft.]	[Acre-ft.]	[Acre-ft.]	[Acre-ft.]	[Acre-ft.]	[Acre-ft.]	[Acre-ft.]	[Acre-ft.]	[Acre-ft.]	[Acre-ft.]	[Acre-ft.]
MAR 1 - MAR 15	24605.0	12302.2	24605.0	12302.7		24609.8	12304.7	24605.0	12300.3	
MAR 16- MAR 31	19789.1	9894.3	19789.1	9894.8		19794.3	9896.9	19789.1	9892.2	
APR 1 - APR 15	13110.7	9833.0	13110.7	3277.7		13116.8	9837.5	13110.7	3273.2	
APR 16 - APR 30	8029.1	6021.9	8029.1	2007.2		8049.8	6037.2	8041.3	2004.1	
MAY 1 - MAY 15	9471.1	7103.4	9471.1	2367.7		9707.0	7280.3	9600.0	2319.7	
MAY 16 - MAY 31	9102.0	6826.4	8306.8	1480.4		7398.8	5549.1	7187.4	1638.3	
JUNE 1 - JUNE 15	3245.5	2434.1	2468.5	34.4		1702.3	1276.7	1456.7	180.0	
JUNE 16 - JUNE 30	35170.6	21917.8	34876.3	12958.5		35216.8	21943.9	34925.0	12981.1	
JULY 1 - JULY 15	12697.7	9517.8	12161.4	2643.7		12799.9	9592.9	12086.0	2493.1	
JULY 16 - JULY 31	3614.3	2710.7	3042.3	331.6		3818.0	2863.4	2852.9		-10.5
AUG 1 - AUG 15	2294.0	1720.5	1852.6	132.1		2294.0	1720.5	1682.3		-38.2
AUG 16 - AUG 31	5320.9	3990.6	4850.0	859.4		4970.6	3728.0	4604.9	876.9	
SEP 1 - SEP 15	4354.3	3265.6	4060.0	794.4		4063.6	3047.8	3888.5	840.7	
SEP 16 - SEP 30	3589.7	2692.2	3589.7	897.5		3614.0	2710.5	3612.8	902.3	
OCT 1 - OCT 15	2725.5	2044.1	2725.5	681.3		2725.5	2044.1	2725.5	681.3	
OCT 16 - OCT 31	2477.5	1857.9	2477.5	619.5		2477.5	1857.9	2477.5	619.5	
TOTAL	159597.0	104132.5	155415.6			156358.7	101691.4	152645.6		

Table 3-11: Summary of Milk River division for 2015

Division Period at International Boundary	Thompson Consumptive Use					Paterson Consumptive Use				
	Natural Flow	U.S.A Share	Received by U.S.A	Received by U.S.A.		Natural Flow	U.S.A Share	Received by U.S.A	Received by U.S.A.	
				Above Share	Below Share				Above Share	Below Share
[Acre-ft.]	[Acre-ft.]	[Acre-ft.]	[Acre-ft.]	[Acre-ft.]	[Acre-ft.]	[Acre-ft.]	[Acre-ft.]	[Acre-ft.]	[Acre-ft.]	[Acre-ft.]
MAR 1 - MAR 15	9593.8	4796.9	9593.8	4796.9		9598.7	4799.3	9593.8	4794.5	
MAR 16 - MAR 31	9413.7	4706.9	9413.7	4706.8		9418.9	4709.5	9413.7	4704.2	
APR 1 - APR 15	4756.1	3567.1	4756.1	1189.0		4762.2	3571.7	4756.1	1184.5	
APR 16 - APR 30	2851.5	2138.6	2851.5	712.9		2872.2	2154.2	2863.7	709.5	
MAY 1 - MAY 15	2436.4	1827.3	2436.4	609.2		2672.4	2004.2	2565.3	561.2	
MAY 16 - MAY 31	8612.1	6459.1	7817.0	1357.9		6909.0	5181.7	6697.5	1515.9	
JUNE 1 - JUNE 15	7898.2	5923.6	7121.1	1197.5		6391.7	4793.9	6146.1	1352.2	
JUNE 16 - JUNE 30	57.2	43.0	0.0		-280.0	63.7	47.8	0.0		-275.9
JULY 1 - JULY 15	1060.6	795.4	524.3		-271.1	1108.2	831.1	394.4		-436.7
JULY 16 - JULY 31	585.0	438.8	13.0		-425.8	687.0	515.2	0.0		-793.3
AUG 1 - AUG 15	0.0	0.0	0.0		-441.4	0.0	0.0	0.0		-611.7
AUG 16 - AUG 31	245.6	184.2	0.0		-409.4	96.7	72.6	0.0		-341.6
SEP 1 - SEP 15	2139.1	1604.2	1844.8	240.5		1899.7	1424.8	1724.6	299.8	
SEP 16 - SEP 30	1775.2	1331.6	1775.2	443.6		1799.5	1349.7	1798.3	448.6	
OCT 1 - OCT 15	1548.8	1161.5	1548.8	387.3		1548.8	1161.5	1548.8	387.3	
OCT 16 - OCT 31	1035.1	776.0	1035.1	259.1		1035.1	776.0	1035.1	259.1	
TOTAL	54008.4	35754.2	50730.8			50863.8	33393.2	48537.4		

Table 3-12: Summary of Milk River division for 2016

Division Period at International Boundary	Thompson Consumptive Use					Paterson Consumptive Use				
	Natural Flow	U.S.A Share	Received by U.S.A	Received by U.S.A.		Natural Flow	U.S.A Share	Received by U.S.A	Received by U.S.A.	
				Above Share	Below Share				Above Share	Below Share
[Acre-ft.]	[Acre-ft.]	[Acre-ft.]	[Acre-ft.]	[Acre-ft.]	[Acre-ft.]	[Acre-ft.]	[Acre-ft.]	[Acre-ft.]	[Acre-ft.]	[Acre-ft.]
MAR 1 - MAR 15	2588.5	1294.3	2588.5	1294.2		2593.4	1296.7	2588.5	1291.8	
MAR 16- MAR 31	1861.9	931.1	1861.9	930.8		1866.7	933.5	1861.6	928.0	
APR 1 - APR 15	1007.4	755.6	1007.4	251.8		1011.0	758.3	1005.0	246.6	
APR 16 - APR 30	1056.2	792.1	1056.2	264.1		1068.6	801.5	1060.1	258.6	
MAY 1 - MAY 15	798.7	599.0	798.7	199.7		977.6	733.3	870.6	137.3	
MAY 16 - MAY 31	7020.7	5265.5	6225.5	960.0		5317.5	3988.1	5106.1	1118.0	
JUNE 1 - JUNE 15	4022.3	3016.7	3245.2	228.5		2479.1	1859.4	2233.4	374.1	
JUNE 16 - JUNE 30	227.1	170.3	0.0		-237.5	242.5	181.9	0.0		-231.3
JULY 1 - JULY 15	635.8	476.9	99.6		-377.3	672.5	504.3	0.0		-545.6
JULY 16 - JULY 31	1276.4	957.2	704.3		-252.9	1416.4	1062.4	451.3		-611.1
AUG 1 - AUG 15	2279.9	1709.8	1838.5	128.7		2279.9	1709.8	1668.2		-41.6
AUG 16 - AUG 31	1344.3	1008.2	873.5		-134.7	997.1	748.0	631.3		-116.7
SEP 1 - SEP 15	714.6	536.0	420.3		-115.7	479.5	359.6	304.3		-55.2
SEP 16 - SEP 30	2145.7	1609.2	2145.7	536.5		2170.0	1627.5	2168.8	541.3	
OCT 1 - OCT 15	1541.2	1155.8	1541.2	385.4		1541.2	1155.8	1541.2	385.4	
OCT 16 - OCT 31	1600.7	1200.5	1600.7	400.2		1600.7	1200.5	1600.7	400.2	
TOTAL	30121.4	21478.2	26007.2			26713.7	18920.6	23091.1		

4 Conclusion

The consumptive use values found by Paterson are substantially different than the Thompson numbers, with a different distribution of peak use and lower totals. For Canadian consumptive use the Paterson total is 89% of the Thompson total, and for US consumptive use the Paterson total is 33% of the Thompson total. Between the two, this represents a total change in consumptive use of -3228 acre-feet.

When calculating natural flow for the years 2009-2016, an average change of about -3200 acre-feet was found between the Paterson and Thompson runs, with a maximum change of -3408 acre-feet in 2016 and a minimum change of -2830 acre-feet in 2012. This makes sense, considering the change in consumptive use.

From these results, a change in the calculated natural flow with Paterson's numbers for future runs can be expected to be about -3200 acre-feet. While the changes in the US share totals and US received flow totals were less consistent, an average change of approximately -2200 acre-feet (maximum: -2557.6 acre-feet in 2016; minimum: -1690.1 acre-feet in 2011) and -2500 acre-feet (maximum: -2916.1 acre-feet in 2016; minimum: -2093.0 acre-feet in 2009), respectively, was found. This change is what can likely be expected in future runs.

4.1 Suggestions for Future Work

In order to refine the results of the Milk River natural flow calculations, three further avenues of work may be considered.

In order to increase the accuracy of the calculations, two additional consumptive use data sets might be developed: one for years with high precipitation and one for years of low precipitation.

The upper Milk River basin extends over a large area, and is heterogeneous. Currently, only one evaporation station is used, and further stations may increase the reliability of the data.

Climate change and population growth may put further strain on the water supply. Improving infrastructure, increasing the efficiency of the irrigation channels, and increasing the level of the St. Mary dam may be ways to mitigate against this.

5 References

Thompson, R. E. Jr. 1986. Natural Flow and Water Consumption in the Milk River Basin, Montana, and Alberta, Canada. U. S. Geological Survey Water Resources Investigations Report 86-4006.

Paterson, B. 2017. Milk River Consumptive Use Study.

6 Appendix A: Background

6.1 Location and brief accounts of St. Mary-Milk Basins

The St. Mary-Milk River basins encompass the state of Montana in the US and the provinces of Alberta and Saskatchewan in Canada as shown in Figure 6-1. The St. Mary River basin and Milk River basin are physically two river basins. The St. Mary River originates from the foothills of the Rocky Mountains in US and flows northeast before it joins with Oldman River. After joining the Oldman River, it meanders through the Alberta Prairies before emptying into the South Saskatchewan River. The Milk River originates from the foothills of the Rocky Mountains, flows north to Canada, and then east parallel to the international border before it meanders back south to Montana. It finally feeds the Missouri River.

The two basins are connected through a basin transfer scheme. Water from the St. Mary basin is transferred to the Milk basin via the St. Mary Canal. The two basins are treated as a single basin for the purpose of water sharing between the US and Canada.

6.2 Data Sources and Availability

6.2.1 Streamflow Data

There are a total of 107 hydrological stations in the St. Mary-Milk basin. Thirty five stations are jointly operated by the US and Canada, forty stations are operated by US and thirty two stations are operated by Canada. For computation of natural flow of the Milk River five stations are used, shown in Table 6-1.

Table 6-1: Stations used to calculate Milk River natural flow

ECCC ID	USGS ID	Station Name	Units	Data Provider
11AA025	06133000	Milk River at Western Crossing of International Boundary	m ³ /s	WSD
11AA032	06133500	North F Milk River above St. Mary Canal near Browning, MT	ft ³ /s	USGS
11AA001	06134000	North Milk River near International Boundary	m ³ /s	WSD
11AA005	06134500	Milk River at Milk River, Alberta	m ³ /s	WSD
11AA031	06135000	Milk River at Eastern Crossing of International Boundary	ft ³ /s	USGS

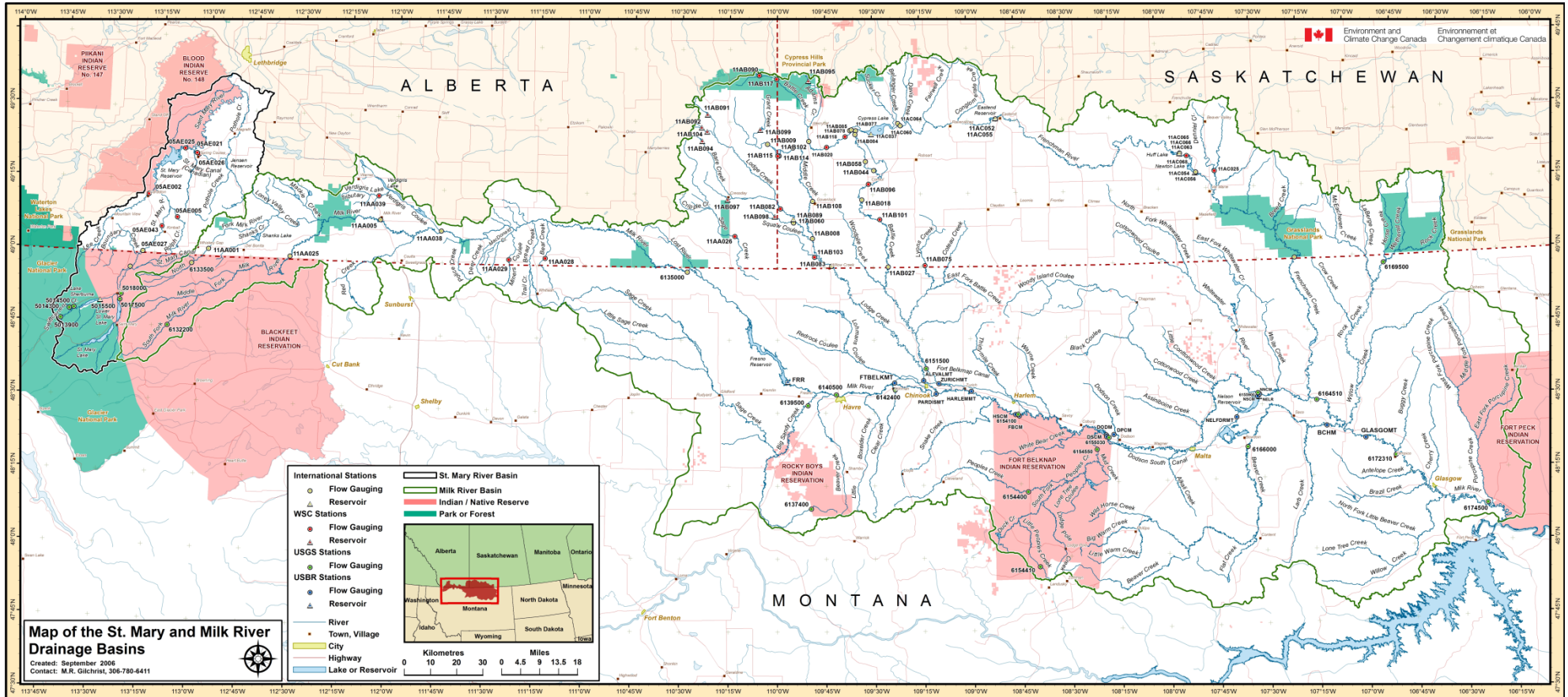


Figure 6-1: Location map. The Milk River basin is edged in green, and the St. Mary River basin is edged in black.

Streamflow data for Canada could be acquired from Water Office Canada (<https://wateroffice.ec.gc.ca/>), and data for the US portion could be accessed from USGS water data (https://waterdata.usgs.gov/nwis/dv/?referred_module=sw).

The locations of the streamflow gauging stations used in MilkNat2010 are shown in Figure 6-2.

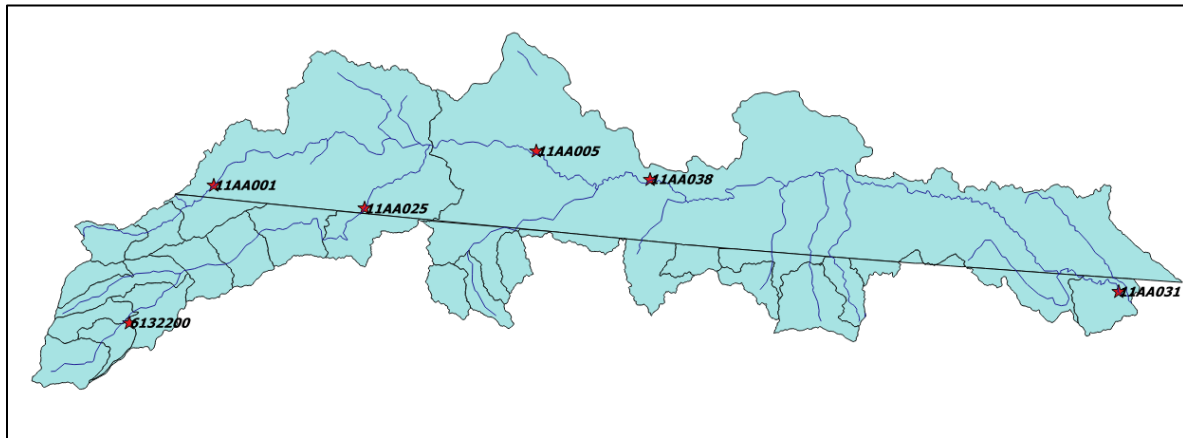


Figure 6-2: Locations of streamflow gauging stations in the upper Milk River basin. 11AA038 is not used.

6.2.2 Precipitation

Evaporation data recorded at the Onefour, Alberta meteorological station is used for the model input. The data is stored in Alberta Engineering services server \\int.ec.gc.ca/shares/W\WSC_AB_ADMIN\Engineering_Services_Alberta\IJC. Evaporation in the basin ranges from 1025mm to 1160 mm with mean annual evaporation of 1100mm.

Since 2013, a modified Penman equation has been used to estimate evaporative losses for Milk River natural flow computations. Data for use in the Penman equation are collected from a weather station located near Milk River at the Eastern Crossing of the International Boundary.

6.2.3 Paterson Consumptive Use Numbers

US consumptive use values are from Table 5.5 and Table 5.6 and Canadian consumptive use values are from Table 6.5 of Paterson (2017). These data, with the calculated daily means, are shown below in Table 6-2 and Table 6-3.

Table 6-2: Paterson consumptive use values for the US

Year	User	April		May		June		July		August		September	
		1-15	16-30	1-15	16-31	1-15	16-30	1-15	16-31	1-15	16-31	1-15	16-30
		Number of days	15	15	15	16	15	15	15	16	15	16	15
2008	Head waters	0	31	160	160	38	39	71	72	39	0	0	0
2007	Southern tributaries	0	8	82	115	132	145	160	101	59	25	5	15
Total	acre-ft.	0	39	242	275	170	184	231	173	98	25	5	15
	Daily (acre-ft.)	0.0	2.6	16.1	17.2	11.3	12.3	15.4	10.8	6.5	1.6	0.3	1.0
2009	Head waters	0	8	36	37	113	114	151	151	50	50	0	0
2007	Southern tributaries	0	8	82	115	132	145	160	101	59	25	5	15
Total	acre-ft.	0	16	118	152	245	259	311	252	109	75	5	15
	Daily (acre-ft.)	0.00	1.07	7.87	9.50	16.33	17.27	20.73	15.75	7.27	4.69	0.33	1.00
2010	Head waters	0	0	0	31	0	0	68	0	0	0	0	0
2007	Southern tributaries	0	8	82	115	132	145	160	101	59	25	5	15
Total	acre-ft.	0	8	82	146	132	145	228	101	59	25	5	15
	Daily (acre-ft.)	0.00	0.53	5.47	9.13	8.80	9.67	15.20	6.31	3.93	1.56	0.33	1.00
2011	Head waters	0.0	0.0	0.0	31.0	40.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2007	Southern tributaries	0	8	82	115	132	145	160	101	59	25	5	15
Total	acre-ft.	0	8	82	146	172	145	160	101	59	25	5	15
	Daily (acre-ft.)	0.00	0.53	5.47	9.13	11.47	9.67	10.67	6.31	3.93	1.56	0.33	1.00
2012	Head waters	0.0	0.0	169.0	166.0	132.0	76.0	71.0	2.0	2.0	2.0	3.0	4.0
2007	Southern tributaries	0	8	82	115	132	145	160	101	59	25	5	15
Total	acre-ft.	0	8	251	281	264	221	231	103	61	27	8	19
	Daily (acre-ft.)	0.00	0.53	16.73	17.56	17.60	14.73	15.40	6.44	4.07	1.69	0.53	1.27
2013	Total	0.0	8.0	106.0	149.0	143.0	192.0	313.0	253.0	128.0	37.0	15.0	23.0
2014	Total	0.0	8.0	113.0	119.0	195.0	395.0	220.0	165.0	139.0	39.0	15.0	23.0
2015	Total	0.0	8.0	82.0	178.0	347.0	313.0	389.0	143.0	92.0	35.0	5.0	53.0
2016	Total	0.0	8.0	82.0	179.0	193.0	191.0	175.0	132.0	90.0	25.0	5.0	35.0
Mean		0.00	12.33	128.67	180.56	206.78	227.22	250.89	158.11	92.78	34.78	7.56	23.67
Daily mean (acre-ft.)		0.00	0.82	8.58	11.28	13.79	15.15	16.73	9.88	6.19	2.17	0.50	1.58

Table 6-3: Paterson consumptive use values for Canada

Month period	March		April		May		June		July		August		September		
	1--15	15--31	1--15	16-30	1--15	16--31	1--15	16--30	1--15	16--31	1--15	16--31	1--15	16-30	
Number of days	15	16	15	15	15	16	15	15	15	16	15	16	15	15	
2007	Total acre-ft.	0	0	12	20	68	374	545	427	1484	1450	883	564	0	
	Daily acre-ft.	0.00	0.00	0.80	1.33	4.53	23.38	36.33	28.47	98.93	90.63	58.87	35.25	0	0
2008	Total acre-ft.	8	10	7	8	11	302	87	316	682	1062	690	364	94	
	Daily acre-ft.	0.5	0.6	0.5	0.5	0.7	18.9	5.8	21.1	45.5	66.4	46.0	22.8	6.3	
2009	Total acre-ft.	0	0	2	3	260	297	419	740	913	1257	429	364	298	
	Daily acre-ft.	0.00	0.00	0.13	0.20	17.33	18.56	27.93	49.33	60.87	78.56	28.60	22.75	19.87	
2010	Total acre-ft.	5	5	5	7	49	71	113	36	134	497	351	148	49	10
	Daily acre-ft.	0.33	0.31	0.33	0.47	3.27	4.44	7.53	2.40	8.93	31.06	23.40	9.25	3.27	0.67
2011	Total acre-ft.	8	10	7	8	11	89	21	102	247	650	572	351	286	
	Daily acre-ft.	0.53	0.63	0.47	0.53	0.73	5.56	1.40	6.80	16.47	40.63	38.13	21.94	19.07	0.00
2012	Total acre-ft.	7	9	7	8	241	132	288	130	820	872	742	404	327	
	Daily acre-ft.	0.47	0.56	0.47	0.53	16.07	8.25	19.20	8.67	54.67	54.50	49.47	25.25	21.80	0.0
Mean		5	6	7	9	107	211	246	292	713	965	611	366	176	2
Daily mean (acre-ft)		0.31	0.35	0.44	0.60	7.11	13.18	16.37	19.46	47.56	60.29	40.74	22.86	11.71	0.11

7 Appendix B: Modelling Natural Flow and Water Division

7.1 Procedures for the Division of the Waters

Division of water between the US and Canada is based on irrigation and non-irrigation seasons and the amount of streamflow. In the irrigation season, April 1 – October 31, Canada is entitled to three-fourths of the St. Mary River's natural flow when the flow is 666 ft³/s or less, while the US is entitled to three-fourths of the Milk River's natural flow when the discharge is 666 ft³/s or less. The portion of the discharge that is in excess of 666 ft³/s is shared equally. Outside the irrigation season, St. Mary and Milk Rivers streamflows are equally shared between the US and Canada.

7.2 Natural flow computation of Milk River

Natural flow computation of Milk River at Eastern International boundary is balance of total inflow minus total consumptive use and evaporation loss. The computation could be represented as follows:

$$NQ_{\left(\frac{6135000}{11AA031}\right)} = RQ_{(6135000/11AA031)} - Q_{QUSdiv} - Q_{CANdiv} + Q_{USuse} + Q_{CANuse} + IET$$

Where: NQ is natural flow at Milk River at Eastern Crossing,

RQ is recorded flow at Milk River at Eastern Crossing,

Q_{QUSdiv} is diversion to Milk by US = $Q_{11AA001} - Q_{06133500}$

Q_{CANdiv} is diversion to Milk by Canada ~ 0

Q_{USuse} is consumptive use by US = Consumptive use by US at Upper Milk

Q_{CANuse} is consumptive use by Canada Consumptive use by Canada

IET is the increase in evapotranspiration of Milk River water resulting from increases in flow from diversions to the Milk River. This is calculated in part from pan evaporation.

7.3 MilkNat2010 Settings

To run MilkNat2010 the following settings, shown in Table 7-1, were applied. For all years, Thompson consumptive use was ran as a normal year, and all Paterson data was run with a zero day lag applied.

Table 7-1: Opening and closing dates, lag times, and Penman/pan coefficients

Year	Diversion by St. Mary Canal		Lag time		Penman/ Pan Coefficient
	Opening date	Closing date	Opening	Closing	
2009	March 19	September 27	4	4	0.85
2010	March 22	September 5	4	4	0.85
2011	July 26	October 12	7	8	0.85
2012	April 9	September 17	7	7	0.85
2013	March 11	September 30	8	7	1.05
2014	May 13	September 15	7	6	1.05
2015	March 31	September 9	7	6	1.0
2016	March 22	September 10	8	8	1.0

7.4 Deviation from Published Results for 2009–2011

A careful reader will note that, although they are close, the calculated Thompson values from MilkNat2010 are different than the published values in the IJC annual reports for 2009, 2010, and 2011. This can likely be attributed to two factors. First, while every effort has been made to ensure the same historical data used in the original runs was used, there is the possibility the model was set up slightly differently than when it was originally run. Second, MilkNat2010 wasn't implemented until 2012. Prior to this, a similar model, MilkNat, was used, which may have calculated the natural flow slightly differently.

8 Appendix C: Further Results and Discussion

8.1 MilkNat2010 Runs with Measured Yearly Data

As Paterson data was available for both Canada and the US for the years 2009 – 2012, additional runs of MilkNat2010 were undertaken for these years using the measured values. These are summarized in Table 8-1, with the values calculated from the average Paterson data presented for comparison, and presented in detail in Table 8-2 to Table 8-5.

Table 8-1: Total natural flow for 2009 – 2012 for Paterson yearly data, Paterson average data, and Thompson data

Year	Thompson Natural Flow, acre-ft (1)	Paterson Average Data Natural Flow, acre-ft (2)	Paterson Yearly Data Natural Flow, acre-ft (3)	Change, acre-ft (1 to 3)	Change, percent
2009	64575.2	61300.5	62554.3	-2020.9	-3.1%
2010	225494.8	222256.7	219646.2	-5848.6	-2.6%
2011	290712.7	287474.4	285719.2	-4993.5	-1.7%
2012	90533.6	87703.6	88190.4	-2343.2	-2.6%

While the magnitude of the change varies from about -2000 to -6000 acre-feet, the same overall results are observed from these runs: a drop in the calculated natural flow. While the analysis isn't presented, the total received by the US and the total US share exhibit the same pattern as shown in MilkNat2010 Results and Discussion, with a drop in all years for both of these totals.

Table 8-2: Summary of Milk River division for 2009 with yearly Paterson data

Thompson Consumptive Use						Paterson Consumptive Use for 2009				
Division Period at International Boundary	Natural Flow [Acre-ft.]	U.S.A Share [Acre-ft.]	Received by U.S.A [Acre-ft.]	Received by U.S.A.		Natural Flow [Acre-ft.]	U.S.A Share [Acre-ft.]	Received by U.S.A [Acre-ft.]	Received by U.S.A.	
				Above Share	Below Share				Above Share	Below Share
				[Acre-ft.]	[Acre-ft.]				[Acre-ft.]	[Acre-ft.]
MAR 1 - MAR 15	646.7	323.4	646.7	323.3		646.7	323.4	646.7	323.3	
MAR 16 - MAR 31	11828.2	5914.2	11828.2	5914.1		11828.2	5914.2	11828.2	5914.1	
APR 1 - APR 15	7764.0	5823.2	7764.0	1940.8		7766.5	5824.8	7764.0	1939.2	
APR 16 - APR 30	10011.7	7508.7	10011.7	2502.9		10029.9	7522.4	10027.5	2505.0	
MAY 1 - MAY 15	8107.2	6063.2	8107.2	2044.1		8485.4	6340.6	8225.2	1884.6	
MAY 16 - MAY 31	8850.3	6637.8	8055.2	1417.4		7204.2	5403.2	6907.2	1504.0	
JUNE 1 - JUNE 15	7140.1	5354.8	6363.0	1008.2		5808.5	4356.3	5389.0	1032.7	
JUNE 16 - JUNE 30	2339.4	1754.6	2045.1	290.5		2861.5	2146.0	2122.1		-23.9
JULY 1 - JULY 15	372.2	279.1	0.0		-443.2	512.5	384.3	0.0		-785.1
JULY 16 - JULY 31	410.2	307.7	0.0		-469.6	713.4	535.0	0.0		-1078.5
AUG 1 - AUG 15	379.5	284.7	0.0		-346.7	304.5	228.5	0.0		-353.2
AUG 16 - AUG 31	441.5	331.0	0.0		-360.4	264.5	198.5	0.0		-298.4
SEP 1 - SEP 15	1057.3	793.0	763.0		-30.0	887.0	665.0	589.1		-76.0
SEP 16 - SEP 30	1049.4	786.9	1049.4	262.5		1064.0	798.0	1064.0	266.0	
OCT 1 - OCT 15	2128.1	1596.1	2128.1	532.0		2128.1	1596.1	2128.1	532.0	
OCT 16 - OCT 31	2049.4	1537.1	2049.4	512.3		2049.4	1537.1	2049.4	512.3	
TOTAL	64575.2	45295.5	60811.0			62554.3	43773.4	58740.5		

Table 8-3: Summary of Milk River division for 2010 with yearly Paterson data

Thompson Consumptive Use						Paterson Consumptive Use for 2010				
Division Period at International Boundary	Natural Flow	U.S.A Share	Received by U.S.A	Received by U.S.A.		Natural Flow	U.S.A Share	Received by U.S.A	Received by U.S.A.	
				Above Share	Below Share				Above Share	Below Share
				[Acre-ft.]	[Acre-ft.]				[Acre-ft.]	[Acre-ft.]
MAR 1 - MAR 15	3070.3	1534.9	3070.3	1535.4		3075.2	1537.4	3070.3	1533.0	
MAR 16- MAR 31	10440.3	5220.3	10440.3	5219.9		10445.5	5222.9	10440.3	5217.3	
APR 1 - APR 15	7100.6	5325.6	7100.6	1775.1		7105.5	5329.2	7100.6	1771.4	
APR 16 - APR 30	11551.8	8663.8	11551.8	2887.9		11567.6	8675.8	11560.3	2884.5	
MAY 1 - MAY 15	19974.5	14096.0	19974.5	5878.6		20104.6	14178.2	20056.0	5877.8	
MAY 16 - MAY 31	26742.7	18106.3	25947.5	7841.2		24865.7	16962.4	24794.4	7832.0	
JUNE 1 - JUNE 15	23133.8	15884.5	22356.7	6472.2		21383.9	14747.0	21270.8	6523.7	
JUNE 16 - JUNE 30	56450.3	32896.4	56156.0	23259.6		56158.4	32740.7	56121.9	23381.2	
JULY 1 - JULY 15	19071.6	13779.9	18535.3	4755.4		18570.6	13462.5	18436.8	4974.3	
JULY 16 - JULY 31	12392.8	9294.3	11820.8	2526.4		12071.1	9053.1	11574.3	2521.2	
AUG 1 - AUG 15	6296.7	4722.5	5855.3	1132.8		6002.4	4501.9	5651.0	1149.1	
AUG 16 - AUG 31	9469.2	7101.8	8998.3	1896.6		8890.7	6668.0	8742.8	2074.8	
SEP 1 - SEP 15	5915.6	4436.8	5621.3	1184.5		5496.1	4122.1	5447.4	1325.4	
SEP 16 - SEP 30	6097.4	4573.1	6097.4	1524.3		6121.7	4591.4	6112.0	1520.6	
OCT 1 - OCT 15	3925.5	2944.3	3925.5	981.2		3925.5	2944.3	3925.5	981.2	
OCT 16 - OCT 31	3861.7	2896.4	3861.7	965.3		3861.7	2896.4	3861.7	965.3	
TOTAL	225494.8	151476.9	221313.3			219646.2	147633.3	218166.1		

Table 8-4: Summary of Milk River division for 2011 with yearly Paterson data

Thompson Consumptive Use						Paterson Consumptive Use for 2011				
Division Period at International Boundary	Natural Flow [Acre-ft.]	U.S.A Share [Acre-ft.]	Received by U.S.A [Acre-ft.]	Received by U.S.A.		Natural Flow [Acre-ft.]	U.S.A Share [Acre-ft.]	Received by U.S.A [Acre-ft.]	Received by U.S.A.	
				Above Share	Below Share				Above Share	Below Share
				[Acre-ft.]	[Acre-ft.]				[Acre-ft.]	[Acre-ft.]
MAR 1 - MAR 15	1864.5	932.2	1864.5	932.2		1873.0	936.6	1864.5	927.9	
MAR 16- MAR 31	38578.4	19289.5	38578.4	19288.9		38588.7	19294.6	38578.4	19283.7	
APR 1 - APR 15	34470.7	22022.7	34470.7	12448.0		34478.0	22026.8	34470.7	12443.9	
APR 16 - APR 30	20138.2	14716.2	20138.2	5422.0		20155.2	14727.0	20146.7	5419.7	
MAY 1 - MAY 15	23194.6	16556.1	23194.6	6638.4		23287.0	16602.4	23276.1	6673.7	
MAY 16 - MAY 31	43763.5	27171.1	42968.4	15797.2		41904.7	26241.8	41815.2	15573.4	
JUNE 1 - JUNE 15	66815.4	38366.5	66038.3	27671.8		65012.0	37464.8	64991.3	27526.5	
JUNE 16 - JUNE 30	23991.1	16819.9	23696.8	6876.9		23764.9	16690.2	23662.8	6972.6	
JULY 1 - JULY 15	10424.6	7818.3	9888.3	2070.0		9969.7	7477.4	9722.9	2245.5	
JULY 16 - JULY 31	7360.1	5520.3	6788.0	1267.7		7191.4	5393.5	6541.6	1148.1	
AUG 1 - AUG 15	2676.1	2006.9	2234.6	227.7		2601.9	1951.6	2030.4	78.7	
AUG 16 - AUG 31	2108.6	1581.5	1637.7	56.2		1733.7	1300.2	1382.2	82.0	
SEP 1 - SEP 15	1895.4	1421.6	1601.2	179.6		1713.0	1284.7	1427.3	142.6	
SEP 16 - SEP 30	1830.8	1373.1	1830.8	457.6		1845.3	1384.0	1845.3	461.4	
OCT 1 - OCT 15	7171.5	5378.6	7171.5	1792.9		7171.5	5378.6	7171.5	1792.9	
OCT 16 - OCT 31	4429.2	3321.9	4429.2	1107.3		4429.2	3321.9	4429.2	1107.3	
TOTAL	290712.7	184296.4	286531.2			285719.2	181476.1	283356.1		

Table 8-5: Summary of Milk River division for 2012 with yearly Paterson data

Thompson Consumptive Use						Paterson Consumptive Use for 2012				
Division Period at International Boundary	Natural Flow	U.S.A Share	Received by U.S.A	Received by U.S.A.		Natural Flow	U.S.A Share	Received by U.S.A	Received by U.S.A.	
				Above Share	Below Share				Above Share	Below Share
				[Acre-ft.]	[Acre-ft.]				[Acre-ft.]	[Acre-ft.]
MAR 1 - MAR 15	5728.3	2864.2	5728.3	2864.1		5735.6	2867.7	5728.3	2860.5	
MAR 16- MAR 31	11002.4	5501.2	11002.4	5501.3		11011.5	5505.8	11002.4	5496.6	
APR 1 - APR 15	10431.0	7803.2	10431.0	2627.8		10438.3	7808.6	10431.0	2622.3	
APR 16 - APR 30	9464.9	7098.8	9464.9	2366.1		9668.9	7251.7	9660.4	2408.7	
MAY 1 - MAY 15	2488.2	1866.1	2488.2	622.1		2986.3	2239.8	2745.5	505.7	
MAY 16 - MAY 31	8388.2	6291.0	7593.1	1302.1		6707.0	5030.2	6574.7	1544.6	
JUNE 1 - JUNE 15	13119.3	9839.5	12342.2	2502.8		11682.7	8762.1	11394.5	2632.4	
JUNE 16 - JUNE 30	13999.2	10499.4	13704.9	3205.6		13877.4	10407.9	13747.3	3339.3	
JULY 1 - JULY 15	6557.5	4918.2	6021.2	1103.1		6746.1	5059.4	5926.5	867.1	
JULY 16 - JULY 31	2720.6	2040.4	2148.6	108.1		2775.1	2081.3	1903.4		-178.0
AUG 1 - AUG 15	376.2	282.2	0.0		-347.5	454.0	340.6	0.0		-628.4
AUG 16 - AUG 31	134.5	100.9	0.0		-437.2	65.4	49.0	0.0		-387.0
SEP 1 - SEP 15	286.6	214.8	0.0		-222.5	204.1	153.1	0.0		-276.0
SEP 16 - SEP 30	2128.0	1596.1	2128.0	532.0		2129.3	1597.0	2129.3	532.3	
OCT 1 - OCT 15	1810.7	1357.9	1810.7	452.8		1810.7	1357.9	1810.7	452.8	
OCT 16 - OCT 31	1898.0	1423.5	1898.0	474.5		1898.0	1423.5	1898.0	474.5	
TOTAL	90533.6	63697.4	86761.5			88190.4	61935.6	84952.0		

8.2 Comparison of Thompson and Paterson Consumptive Water Use

As yearly Paterson data is available for both Canada and the US for 2008 to 2012, comparisons between Paterson's data and Thompson's data can be done. A summary may be seen in Table 8-6, with detailed results in Table 8-7 and Table 8-8.

Table 8-6: Yearly data comparison between Thompson and Paterson numbers

	Canada				US			
	Thompson, acre-ft	Paterson, acre-ft	Change, acre-ft	Change, %	Thompson, acre-ft	Paterson, acre-ft	Change, acre-ft	Change, %
2008	4190	3623	-567	-13.5%	4057	1457	-2600	-64.1%
2009	4190	4982	792	18.9%	4057	1557	-2500	-61.6%
2010	4190	1470	-2720	-64.9%	4057	946	-3111	-76.7%
2011	4190	2344	-1846	-44.1%	4057	918	-3139	-77.4%
2012	4190	3971	-219	-5.2%	4057	1474	-2583	-63.7%

Table 8-7: Thompson and Paterson Canada consumptive water use in acre-feet

Year	Month Period	April		May		June		July		August		September		Total
		1--15	15--30	1--15	16--31	1--15	16--30	1--15	16--31	1--15	16--31	1--15	16-30	
2008	Thompson use				790	790	290	568	568	447	447	290		4190
	Paterson use	7	8	11	302	87	316	682	1062	690	364	94		3623
	Difference	7	8	11	-488	-703	26	114	494	243	-83	-196		-567
2009	Thompson use				790	790	290	568	568	447	447	290		4190
	Paterson use	2	3	260	297	419	740	913	1257	429	364	298		4982
	Difference	2	3	260	-493	-371	450	345	689	-18	-83	8		792
2010	Thompson use				790	790	290	568	568	447	447	290		4190
	Paterson use	5	7	49	71	113	36	134	497	351	148	49	10	1470
	Difference	5	7	49	-719	-677	-254	-434	-71	-96	-299	-241	10	-2720
2011	Thompson use				790	790	290	568	568	447	447	290		4190
	Paterson use	7	8	11	89	21	102	247	650	572	351	286		2344
	Difference	7	8	11	-701	-769	-188	-321	82	125	-96	-4		-1846
2012	Thompson use				790	790	290	568	568	447	447	290		4190
	Paterson use	7	8	241	132	288	130	820	872	742	404	327	0	3971
	Difference	7	8	241	-658	-502	-160	252	304	295	-43	37	0	-219

Table 8-8: Thompson and Paterson US consumptive water use in acre-feet

Year	Month Period	April		May		June		July		August		September		Total
		1--15	16-30	1--15	16-31	1--15	16-30	1--15	16-31	1--15	16-31	1--15	16-30	
2008	Thompson use				1241	1241	175	343	343	270	270	175		4057
	Paterson use	0	39	242	275	170	184	231	173	98	25	5	15	1457
	Difference	0	39	242	-966	-1071	9	-112	-170	-172	-245	-170	15	-2600
2009	Thompson use				1241	1241	175	343	343	270	270	175		4057
	Paterson use	0	16	118	152	245	259	311	252	109	75	5	15	1557
	Difference	0	16	118	-1089	-996	84	-32	-91	-161	-195	-170	15	-2500
2010	Thompson use				1241	1241	175	343	343	270	270	175		4057
	Paterson use	0	8	82	146	132	145	228	101	59	25	5	15	946
	Difference	0	8	82	-1095	-1109	-30	-115	-242	-211	-245	-170	15	-3111
2011	Thompson use				1241	1241	175	343	343	270	270	175		4057
	Paterson use	0	8	82	146	172	145	160	101	59	25	5	15	918
	Difference	0	8	82	-1095	-1069	-30	-183	-242	-211	-245	-170	15	-3139
2012	Thompson use				1241	1241	175	343	343	270	270	175		4057
	Paterson use	0	8	251	281	264	221	231	103	61	27	8	19	1474
	Difference	0	8	251	-960	-977	46	-112	-240	-209	-243	-167	19	-2583