SOUTH SASKATCHEWAN RIVER BASIN IN ALBERTA

WATER SUPPLY STUDY

VOLUME 2: TECHNICAL MEMORANDA

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1.0 INTRODUCTION

This Volume 2 of the report, ***South Saskatchewan River Basin (Alberta) Water Supply Study – Final Report*** is a compilation of technical memorandums that were prepared during the course of studies conducted in 2008 and 2009. The documents were written in stand-alone format to summarize information about various study databases or methodologies, or to address various issues that arose during the course of the study. They reflect conditions and thinking of the individual study team members at the time they were prepared. They may not always reflect conditions and thinking of the study team that evolved by the time the final report was prepared. Where a conflict in data or methodology exists between this document and the main report, the reader should be aware that the main report represents more recent thoughts on the issue.

Documents are written primarily using metric units. Exceptions are where it is deemed the imperial units are much more familiar and meaningful to the intended readership. A *Table of Unit Conversion Factors* is included on the last page of this document.

References are provided at the end of each Technical Memorandum or in footnotes.

Technical Memorandum No. 1 – WATER SUPPLY

April 2008

South Saskatchewan River Basin
Water Supply Study

Technical Memorandum No. 1

April 2008

Water Supply

Prepared for: South Saskatchewan Water Supply Steering Committee

Prepared by: Klohn Crippen Berger Ltd.

Date: 29 April 2008

Issues

- What are the current hydrologic characteristics in the SSRB? How have they changed from the past?
- Is there evidence of climate change in the streamflow records? In the precipitation records?
- What has been Alberta's performance in meeting its PPWB apportionment commitments?

1.0 INTRODUCTION

The water management plan for the South Saskatchewan River Basin (SSRB) was approved by the Alberta Government in August 2006. This plan led to establishment of the basin's Water Conservation Objectives (WCOs) in January 2007, and restricted the use of all unallocated water in the Bow, Oldman and South Saskatchewan Sub-basins in August 2007 (Regulation 171/2007). The plan and subsequent decisions have heightened competition for water in the SSRB. Water users throughout the basin are concerned about the security of supply and economic growth now and in the future.

The SSRB Water Supply Steering Committee commissioned a science-based study with objectives as follows:

- assess current and future water supply and demand in the SSRB;
- identify constraints to water supply and economic growth; and,
- identify, analyze and evaluate structural and non-structural water management alternatives to address constraints and issues.

This Technical Memorandum deals with the water supply available in the basin, both for current conditions and for future conditions.

2.0 PREVIOUS STUDIES

There has been significant interest in the water supply in the South Saskatchewan River basin for many years. In addition to the SSRB planning studies completed in 2005, a few other significant studies are summarized briefly below.

Alberta Environment (1984) characterized the water resource of the South Saskatchewan River Basin and assessed a number of potential economic development scenarios.

The Irrigation Water Management Study Committee (2002) reviewed the findings of a 4-year research program on irrigation in southern Alberta to provide a comprehensive, scientifically sound analysis of the current state of water management within the irrigation districts of southern Alberta, make projections related to water management and efficiency improvements in the future, and assess the risks and impacts of expansion of the irrigated areas within the districts.

Seneka (2004) assessed the total annual flow at several locations in Alberta, including four locations in the South Saskatchewan River Basin. The flow analysis utilized naturalized flows extending through 2001. Using the Mann-Kendall test, Seneka found that there was no detectable trend for annual streamflow volumes in the Bow River at Calgary and the Oldman River near Lethbridge. The Red Deer River at Red Deer and the South Saskatchewan River at Medicine Hat showed decreasing trends, but the trends were not significant at the 95% level. In contrast, annual precipitation showed a slight increasing trend combined with decreasing year-to-year variability. Seneka suggested that changes in the seasonality of precipitation could explain the differences between precipitation and runoff trends.

Rood *et al* (2005) analyzed annual flow volumes for 31 locations in Alberta, B.C. and north-western U.S., of which 10 locations are within the western portion of the SSRB. The study used recorded flows rather than the naturalized flows examined by Seneka (2004), although most of the stations used in the analysis monitored unregulated streams. Half of the locations examined in the SSRB monitor regulated flow. The analyses included "(1) Spearman r ('rho') and (2) Kendall t ('tau') b non-parametric rank correlations and (3) parametric bivariate analyses consisting of linear regressions followed by Analyses of Variance (ANOVA)". The examined period of record typically ended in 2002. The study concluded that for most of the South Saskatchewan River Basin stations, annual flow volumes show decreasing trends, although the trends were not always statistically significant. Possible reasons for the differing conclusions between Seneka (2004) and Rood (2005) are discussed in the relevant sections below.

3.0 DATA SOURCES

3.1 Precipitation and Evapotranspiration Data

Precipitation and evapotranspiration data are analyzed to provide a context for the streamflow data. A few long-term Environment Canada stations were selected for precipitation information across the basin, as listed in **Table 3.1** and shown in **Figure 3.1** (Appendix of Figures). The evapotranspiration values presented in this memorandum are areal evapotranspiration depths calculated by Alberta Environment (undated) for the stations listed in **Table 3.1**. The depths were calculated using the complementary relationship areal evapotranspiration model, for which areal evapotranspiration is defined as “the actual evapotranspiration from an area so large that the effects of evapotranspiration on the temperature and humidity of the over-passing air are fully developed” (Morton *et al*, 1985). Areal evapotranspiration is limited by the water available in the soil, and therefore is less than the potential evapotranspiration that could occur from a surface that is kept moist.

Precipitation and evapotranspiration statistics presented below include annual (calendar-year) precipitation depth, summer (May–October) precipitation depth, and (calendar-year) annual net precipitation (precipitation minus areal evapotranspiration).

TABLE 3.1
Climate Station Records Selected for Analysis

Station Name	Environment Canada Station No.	Period of Record	Years of Record	Mean Annual Precipitation (mm)	Mean Annual Evapo-transpiration[1] (mm)	Analyzed by Seneka (2004)
Red Deer A	Composite[2]	1914–2006	93	475		√
Lacombe		1939–2001	63		401	
Banff	Composite[3]	1890–2006	117	476		√
Calgary A	3031093	1885–2006	122	421		√
		1922–2001	80		410	
Lethbridge A	Composite[4]	1908–2006	99	403		√
		1912–2001	90		416	
Medicine Hat A	3034480	1884–2006	123	335		√
		1912–2001	90		359	

Notes:

1. Evapotranspiration = areal evapotranspiration as published by Alberta Environment (undated).
2. Red Deer stations: 3025440 (1914–1937); 3025480 (1938–2006).
3. Banff stations: 3030520 (1890–1995); 3030519 (1995–2006).
4. Lethbridge stations: 3033890 (1908–1937); 3033880 (1938–2006).

3.2 Streamflow Data

Hydrometric data presented in this report include the following:

Natural flow *(or discharge)* is flow that is not noticeably affected by direct human activities such as reservoir operation, water withdrawals, diversions or releases. The flow may, however, be indirectly affected by human activities such as land-use change.

Flow regulation: Changes in flow caused by direct human activities including reservoir operation, water withdrawal, water diversion or water release.

Regulated flow is flow that is noticeably affected by direct human activities.

Historical flow* or *recorded flow is the discharge recorded at a hydrometric station. It may include a combination of regulated and natural flows. The current study used historical daily mean flow data published by the Water Survey of Canada (WSC). Information available from WSC includes an assessment of whether flow at a station is regulated or natural, and if regulated, the year in which regulation began.

Naturalized flow is an estimate of the natural flow at a site, calculated by adjusting the historical flow record to remove the effects of regulation. The current study used naturalized discharges as published by Alberta Environment (1998 and updates) at a weekly time increment. Alberta Environment's naturalized flows included estimated discharges to fill portions of the record when historical data was missing, and are available to the end of 2001 only. Much of the naturalization, extension and transfer of data were carried out using computerized procedures in which daily flows were moved through the system using the U.S. Army Corps of Engineers Streamflow Synthesis and Reservoir Regulation (SSARR) routing model. The calculations account for the effects of major reservoirs, irrigation withdrawals and return flows for irrigation districts, and municipal withdrawals and return flows at major urban centers. In instances where the extension or transfer of data could not be completed with the use of routing procedures, the extension or transfers were carried out by correlation with natural flows at other stations.

Alberta Environment's naturalized flows were supplemented using naturalized flows calculated by the Prairie Provinces Water Board (PPWB, pers. comm., 2008) for the South Saskatchewan River at Medicine Hat for the period 2002–2006. The PPWB calculations do not consider minor withdrawals such as municipal demands and therefore are not identical to the Alberta Environment estimates.

Water supply was characterized using eight selected locations on the major rivers in the South Saskatchewan basin in Alberta, as listed in **Table 3.2** and shown in **Figure 3.1**. Historical and naturalized flows are compared in some of the figures in the following sections. Some minor differences between the historical and naturalized flows arise from the fact that the historical flow data is at a daily increment, while the naturalized flow data is weekly.

TABLE 3.2
Hydrometric Station Records Selected for Analysis

Number	Name	Period of Record	Years of Record	Gross Catchment Area (km^2)	Effective Catchment Area (km^2)	Regulation Status[1]	Used by Seneka (2004)	Used by Rood (2005)	Used by Martz[2] (2007)
05BB001	Bow River at Banff	1909–2006	98	2 210	2 210	Natural		√	√
05CC002	Red Deer River at Red Deer	1912–2006	93	11 600	11 100	Reg (1983)	√	√	√
05CE001	Red Deer River at Drumheller	1915–2006	62	24 900	19 200	Reg (1983)			√
05BH004	Bow River at Calgary	1911–2006	95	7 870	7 740	Reg (1913)	√	√	√
05AA023	Oldman River near Waldron's Corner	1949–2006	57	1 450	1 450	Natural		√	√
05AD007	Oldman River near Lethbridge	1911–2006	87	17 000	15 500	Reg (1910)	√		√
05AE006	St. Mary River near Lethbridge	1911–2006	95	3 530	3 310	Reg (1911)			√
05AJ001	South Saskatchewan River at Medicine Hat	1911–2006	95	56 400	41 300	Reg	√	√	√

Notes:
1. Reg = Regulated (since year) according to WSC.
2. Martz *et al* (2007) conducted a study on the effects of climate change on water supply in the SSRB as discussed in Section 9.0.

Table 3.2 shows that historical discharges are available since the early 1900s in most cases. Most of the station's monitor flows have been regulated for much of their history, but flows at a few of the stations have been natural throughout their history. The table also identifies the stations that have been reviewed in previous studies on streamflow trends (Seneka, 2004; Rood, 2005; Martz, 2007).

Several water supply indices were selected for examination in this study, considering the various perspectives from which water supply is important. These perspectives include irrigation, municipal and domestic water supply, in-stream flow needs, interprovincial apportionment, and storage development.

Annual flow volume is simply the total volume of flow for an entire year. Annual flow volume is possibly the most commonly used and simplest statistic of water supply, and is of particular interest for storage development. However, it does not capture the seasonality of the flow, or flow variability within the year, which are important for in-stream flow needs and for water supply in situations where there is little or no system storage. Therefore other indices were also computed, as discussed below.

Summer flow volume is of particular interest for irrigation because irrigation water demands occur primarily in the summer. For the current study, the summer period was defined as 01 May–31 October.

Summer low flow is of interest for in-stream flow needs and for irrigation, particularly for irrigators dependent on water supply directly from the river or from a canal where there is no storage reservoir upstream. The statistic used to characterize the summer low flow is the lowest 7-day mean discharge during the May–October period.

Winter low flow is generally lower than the summer low flow, and is of interest for in-stream flow needs and for year-round water demands such as municipal, domestic and industrial needs. The statistic used to characterize the winter low flow is the lowest 7-day mean discharge during the November–March period.

Multi-year flow volume is important for systems that include significant reservoir storage, or for planning large reservoir storage. The 3-year running average is used to characterize multi-year flow volume.

The first four statistics – annual volume, summer volume, summer low flow and winter low flow – are presented in both graphical and tabular format in the sections below. The graphs show the entire period of record available, but the values shown in the tables are based on only the last 30 years of available records (1972–2001), in order to reflect relatively current development conditions. Some of the historical changes in monitored data may be due to technological changes and analytical procedures in monitoring.

Records for many of the stations illustrated in the following stations included significant periods of missing data. No instances of zero discharge have been recorded for any of the monitored streams; a graphical indication of zero flow actually indicates missing data.

4.0 RED DEER RIVER SUB-BASIN

4.1 Precipitation and Evapotranspiration

Annual precipitation at Red Deer is illustrated in **Figure 4.1**. Mean annual precipitation at Red Deer is 476 mm, of which 362 mm (76%) normally occurs during the May–October period. Annual precipitation depths were highly variable in the early part of the record, but much less variable since 1938. Annual precipitation depths of less than 350 mm have been recorded five times since 1934.

Net precipitation (precipitation at Red Deer minus evapotranspiration at Lacombe), illustrated in **Figure 4.2**, averages 77 mm. Net precipitation depths are generally positive, although some years with negative net precipitation have been recorded. Distribution of precipitation and evapotranspiration through the year is shown in **Figure 4.3**. The figure shows that on average, the greatest moisture deficit occurs in July.

Net precipitation is defined for this study as the total precipitation minus areal evapotranspiration. It is a measure of the water available from the precipitation, after abstractions for evaporation and evapotranspiration. Available water contributes to groundwater re-charge and streamflow.

4.2 Streamflow

Water supply in the Red Deer River Sub-basin is characterized in **Table 4.1** using the Red Deer River flow at Red Deer and at Drumheller. Flow in the Red Deer River has been regulated since the construction of Dickson Dam and Gleniffer Lake in 1983.

TABLE 4.1
Red Deer River Water Supply Statistics (1972–2001)

Statistic*	Red Deer River at Red Deer		Red Deer River at Drumheller	
	Naturalized	Historical	Naturalized	Historical
Annual Volume				
- Mean (dam^3)	1 349 000	1 333 000	1 574 000	1 556 000
- Minimum (dam^3)	723 000	683 000	787 000	757 000
- Coefficient of Variation (%)	31%	32%	32%	32%
Summer Volume (dam^3)				
- Mean (dam^3)	1 025 000	978 000	1 140 000	1 091 000
- Minimum (dam^3)	534 000	421 000	561 000	452 000
- Coefficient of Variation (%)	36%	39%	36%	39%
Summer Low Flow (m^3/s)				
- Mean (m^3/s)	19.9	20.3	22.6	23.1
- Minimum (m^3/s)	8.73	11.8	6.47	13.0
- Coefficient of Variation (%)	25%	21%	29%	24%
Winter Low Flow (m^3/s)				
- Mean (m^3/s)	5.32	10.8	5.06	10.3
- Minimum (m^3/s)	0.84	3.16	0.10	4.43
- Coefficient of Variation (%)	42%	43%	48%	40%

* See Section 3 for definitions and data sources.

Annual flow volumes at Red Deer and at Drumheller are illustrated in **Figures 4.4 and 4.5**, respectively. Although the gross catchment area above Red Deer is less than half of the gross catchment area above Drumheller, there is little difference in the annual flows at the two locations, illustrating the low runoff rates experienced in the central region of the sub-basin. Regulation has had little effect on annual flow volumes, but it has increased the summer low flows by a small amount, and winter low flows substantially, as illustrated by the figures and in **Table 4.1**. Flow volumes are highly variable from year to year, with a coefficient of variation of 31% to 32%, and sustained periods of above- or below-average annual volumes are typical, as shown by the 3-year moving averages in the figures.

The *coefficient of variation* is the standard deviation divided by the mean, and is therefore a dimensionless measure of variability.

Both stations show an apparent decreasing trend in both naturalized and recorded annual volumes, as shown in **Figures 4.4 and 4.5**. After examining the records of the Red Deer station, Seneka (2004) concluded that the apparent trend was not significant, but Rood *et al* (2005) concluded that there was a statistically significant downward trend. The differing conclusions in the two studies may be due to the use of slightly different data sets. Seneka used the naturalized flow dataset that included a relatively dry period during the 1930s, which was missing from the historical flow dataset analyzed by Rood.

The seasonal distribution of flow at Red Deer is shown in **Figure 4.6** and at Drumheller in **Figure 4.7**. Stream flows are generally low through the winter, rising in March and April and often peaking in June or July.

Summer low flows at Red Deer and at Drumheller are illustrated in **Figures 4.8 and 4.9**, respectively. Summer low flows are marginally higher at Drumheller than at Red Deer. The operation of Dickson Dam has had little apparent effect on summer low flows.

Winter low flows, on the other hand, have been highly influenced by the operation of Dickson Dam, as illustrated in **Figure 4.10** for Red Deer and **Figure 4.11** for Drumheller. Since 1983, winter low flows at Red Deer have averaged 14.0 m^3/s, compared to the pre-1983 average of 6.37 m^3/s. The effect of the dam is also shown by the changes in the flow-duration curve at Red Deer (**Figure 4.12**).

5.0 BOW RIVER SUB-BASIN

5.1 Precipitation and Evapotranspiration

Annual precipitation at Banff in the headwaters of the Bow River Sub-basin is illustrated in **Figure 5.1**, and at Calgary in **Figure 5.2**. Mean annual precipitation at Banff is 476 mm.

The mean annual precipitation at Calgary is 421 mm, somewhat lower than at Banff. There appears to be no increasing or decreasing trend in the annual precipitation at Calgary. At Banff there is an apparent slight downward trend, but the trend is not statistically significant (Seneka, 2004).

There is an apparent trend of decreasing year-to-year variability in annual precipitation at Calgary, and to a lesser extent at Banff (Seneka, 2004). The lowest recorded 3-year average precipitation of 370 mm at Banff occurred in 2000–2002. At Calgary, precipitation was somewhat below normal during those years, but many other 3-year periods were equally dry or drier. The 3-year average has been below 300 mm twice in the Calgary record, both times before 1920.

Net precipitation (precipitation minus evapotranspiration) at Calgary, as illustrated in **Figure 5.3**, is slightly positive, with an average value of 11 mm. Negative depths of more than 100 mm have been observed, but in the second half of the record, net precipitation has tended to be less extreme (either positive or negative) than in the first half.

Monthly distribution of precipitation and evapotranspiration is shown in **Figure 5.4** for Banff and **Figure 5.5** for Calgary. At both locations, monthly precipitation is greater in the summer than in winter, but the difference between summer and winter is less pronounced at Banff than at Calgary. Moisture deficits at both locations are greatest in July.

5.2 Stream Flow

Water supply in the Bow River Sub-basin is characterized in **Table 5.1** using the Bow River flow at Banff and at Calgary. The Calgary hydrometric station is upstream of the Elbow River and the WID diversion. It is downstream of Calgary's Bearspaw water intake and upstream of both of Calgary's wastewater treatment plants. Flow in the Bow River is unregulated at Banff but at Calgary and all hydrometric stations downstream of Calgary, flows are influenced by a variety of hydropower, irrigation and water supply projects on the Bow and its tributaries. Some of the projects affecting flow in the Bow River (AENV, 1998) are listed below.

- Western Irrigation District began diverting water from the Bow River before 1912.
- Diversions from the Highwood River to the Little Bow River (in the Oldman River Sub-basin) via the Little Bow Canal began before 1912.
- A dam was constructed at the outlet of Lake Minnewanka in 1895, and a second dam in 1912 (Parks Canada, 2004).
- The Eastern Irrigation District began diverting water from the Bow River at Bassano in 1914.
- The Bow River Irrigation District began diverting water from the Bow River to fill the McGregor and Travers Reservoirs in 1918.
- Ghost Reservoir on the Bow River was constructed for hydropower in 1929.
- Glenmore Reservoir on the Elbow River was constructed in 1932 for municipal water supply.
- Upper Kananaskis Lake was controlled beginning in 1932, primarily to provide a steady flow for floating logs down the Kananaskis River.
- Lake Minnewanka and Upper Kananaskis Lake were raised significantly in 1942.
- Bearspaw Reservoir was created on the Bow River for hydropower in 1954.
- Lower Kananaskis Lake was controlled starting in 1955.

None of these developments impacted recorded flows at Banff; therefore, only historical flows are presented for Banff in the figures and tables below. Flows at Calgary are impacted by Bearspaw Reservoir, Calgary's water supply from Bearspaw, and all other developments upstream of Calgary.

TABLE 5.1
Bow River Water Supply Statistics 1972–2001

Statistic[1]	Bow River at Banff	Bow River at Calgary	
	Historical	Naturalized	Historical
Annual Volume			
- Mean (dam^3)	1 206 000	2 782 000	2 708 000
- Minimum (dam^3)	897 000	2 030 000	1 942 000
- Coefficient of Variation (%)	14%	16%	16%
Summer Volume (dam^3)			
- Mean (dam^3)	1 047 000	2 259 000	1 852 000
- Minimum (dam^3)	767 000	1 587 000	1 259 000
- Coefficient of Variation (%)	16%	18%	22%
Summer Low Flow (m^3/s)			
- Mean (m^3/s)	14.6	42.0	50.7
- Minimum (m^3/s)	8.88	31.9	31.7
- Coefficient of Variation (%)	24%	15%	16%
Winter Low Flow (m^3/s)			
- Mean (m^3/s)	6.81	18.1	40.7
- Minimum (m^3/s)	4.81	11.8	28.9
- Coefficient of Variation (%)	13%	17%	14%

* See Section 3 for definitions and data sources. Flows in the Bow River at Banff are unregulated.

Annual flow volumes at Banff and at Calgary are illustrated in **Figures 5.6 and 5.7**, respectively. Flow at both stations is relatively consistent from year to year, with a coefficient of variation of 14% to 16%, about half of the value for the Red Deer River. Regulation has had little effect on annual flow volume at Calgary, as illustrated by the figures and in **Table 5.1**. Nonetheless, Seneka (2004) found that the minor effect of regulation was enough to cause a significant negative trend to appear in the recorded flow data, despite the lack of a statistically significant trend in the natural flow data at Calgary or the recorded flow data at Banff. Rood *et al* (2005), on the other hand, concluded that both stations showed a statistically significant negative trend in recorded flows. Reasons for the differing conclusions are not known.

The seasonal distribution of flow at Banff is very similar to that at Calgary, as shown in **Figures 5.8 and 5.9**. June and July are generally the highest flow months. At Calgary, natural winter flows are on average approximately a quarter of summer flows; whereas, recorded winter flows are about a third of natural. At Banff, the winter flow is relatively much smaller, at approximately 7% of summer flow.

Recorded summer low flows at Banff, shown in **Figure 5.10**, average about 14 m^3/s, and have frequently fallen below 10 m^3/s. At Calgary, upstream regulation has generally increased summer low flows, as shown in **Figure 5.11**. However, there have been occasional years when the regulated summer low flow was less than it would have been naturally. Over the 1972–2001 period, summer flows have been 20% higher on average because of regulation. Both recorded and naturalized summer low flows have been above 30 m^3/s consistently since the mid-1950s; before that, that summer low flow was apparently much more variable.

Winter low flow in the Bow River at Banff has been in the range of 5 to 8 m^3/s fairly consistently, as shown in **Figure 5.12**. At Calgary, upstream regulation has raised winter low flows significantly above natural conditions, particularly since the mid-1950s, as shown in **Figure 5.13**. Winter low flows are currently more than double their natural values, as shown in **Table 5.1**.

6.0 OLDMAN RIVER SUB-BASIN

6.1 Precipitation and Evapotranspiration

Annual precipitation at Lethbridge in the Oldman River Sub-basin is illustrated in **Figure 6.1**. Mean annual precipitation at Lethbridge is 403 mm, marginally lower than at Calgary. Based on visual inspection, there is no apparent trend in either the total amount of precipitation or in its variability, although Seneka (2004), working with the period 1938–2000, concluded that there was a downward trend in annual precipitation. The driest individual year occurred in 1918, but the driest 3-year period occurred in 1999–2001. In 2000 and 2001, the precipitation was approximately half of normal amounts.

Seasonal distribution of precipitation and evapotranspiration is illustrated in **Figure 6.2**. Of the annual precipitation, 32% occurs in the November–April period. Mean monthly evapotranspiration is more than mean monthly precipitation from April through August, and particularly in July. Annual net precipitation at Lethbridge averages -13 mm, but is highly variable from year to year, as illustrated in **Figure 6.3**. Over the period of record, there have been prolonged periods when the annual evapotranspiration was greater than the annual precipitation.

6.2 Stream Flow

Water supply in the Oldman River Sub-basin is characterized in **Table 6.1** using three stations. Oldman River near Waldron's Corner is unaffected by development, while flows recorded at the Oldman River near Lethbridge, and St. Mary River near Lethbridge, have been significantly affected by storage reservoirs and withdrawals for irrigation purposes. Major projects that have affected flow in the Oldman River and its tributaries include the following (AENV, 1998):

- St. Mary River Irrigation District (SMRID) (including Magrath, Raymond and Taber Irrigation Districts) began diverting water from the St. Mary River before 1912.
- Lake Sherbourne, a reservoir in the headwaters of the St. Mary River in Montana, and the U.S. St. Mary Diversion to the Milk River began operating before 1917.

- Lethbridge Northern Irrigation District (LNID) began operations in 1923.
- United Irrigation District (UID) began withdrawing water from Belly River in 1924.
- Mountain View, Leavitt, and Aetna Irrigation Districts (MVLA) began diverting water from Belly River in 1931.
- St. Mary Dam was completed in 1951.
- Diversions from Belly River to the St. Mary Reservoir began after completion of the Belly-St. Mary Diversion Canal in 1959.
- Waterton Reservoir began filling in 1965.
- Diversions from Waterton River to the Belly River, for eventual use in the SMRID, began after completion of the Waterton-Belly Diversion Canal in 1968.
- Oldman Reservoir began filling in 1991.

The Oldman River at Lethbridge is affected by all the noted developments. The St. Mary River is affected by all of the developments except the LNID, UID, and MVLA diversions and the Oldman Dam.

TABLE 6.1
Oldman River Water Supply Statistics 1972–2001

Statistic[1]	**Oldman River Near Waldron's Corner**	**St. Mary River near Lethbridge**		**Oldman River near Lethbridge**	
	Historical[2]	**Naturalized**	**Historical**	**Naturalized**	**Historical**
Annual Volume					
- Mean (dam^3)	379 000	834 000	362 000	3 267 000	2 066 000
- Minimum (dam^3)	170 000	425 000	63,600	1 515 000	526 000
- Coefficient of Variation (%)	40%	29%	69%	36%	55%
Summer Volume (dam^3)					
- Mean (dam^3)	320 000	652 000	268 000	2 576 000	1 565 000
- Minimum (dam^3)	133 000	338 000	31 600	1 136 000	282 000
- Coefficient of Variation (%)	46%	31%	86%	39%	66%
Summer Low Flow (m^3/s)					
- Mean (m^3/s)	4.16	6.28	2.72	29.9	16.6
- Minimum (m^3/s)	1.81	1.16	1.02	8.45	2.40
- Coefficient of Variation (%)	32%	56%	49%	46%	72%
Winter Low Flow (m^3/s)					
- Mean (m^3/s)	1.59	3.08	1.70	13.4	9.57
- Minimum (m^3/s)	0.59	0.65	0.35	4.29	2.40
- Coefficient of Variation (%)	30%	46%	68%	42%	58%

Notes:
1. See Section 3 for definitions and data sources.
2. Flow in the Oldman River near Waldron's Corner is unregulated.

Flow in the Oldman River at Waldron's Corner is highly variable from year to year, as shown in **Figure 6.4**, with a coefficient of variation of 40% (slightly higher variation than the Red Deer and much higher than the Bow). Seven years in the record have an annual volume in the range of half of normal. The historical record (1950–2006) indicates an apparent downward trend in the data, and Rood *et al* (2005) did report that a trend exists, although it is statistically weak. But when the record is extended using flow data estimated for Alberta Environment's (1998) natural flow analysis, no trend is evident.

The St. Mary River historical annual flow volume is also highly variable, as shown in **Figure 6.5**, and has a coefficient of variation of 69%. The flow is strongly influenced by the operation of the St. Mary Dam and by irrigation diversions, with the recorded flow in the 1972–2001 period being less than half of the naturalized flow.

The historical annual volume of flow in the Oldman River near Lethbridge, illustrated in **Figure 6.6**, has averaged 2.1 million dam^3 (over the 1972–2001 period), which is 63% of the naturalized flow. Recorded annual volumes have been less than 1.0 million dam^3 ten times during the full period of record (1912–2006), including three times since 2000. The lowest 3-year average volume was 917 000 dam^3, recorded in 1983–1985.

The Oldman and St. Mary Rivers tend to peak in late-May to early-June (**Figures 6.7, 6.8 and 6.9**). The peak is earlier and less sustained than on the Bow River. July flow is significantly less than June, and by August the flow generally recedes nearly to winter levels.

Recorded and natural summer low flows in the Oldman River near Waldron's Corner, shown in **Figure 6.10**, average about 4 m^3/s, and have occasionally fallen below 2 m^3/s. In the St. Mary River and the Oldman River near Lethbridge, upstream regulation significantly reduced summer low flows over most of the period of record, as shown in **Figures 6.11 and 6.12**. Over the 1972–2001 period, summer flows have been 44% lower than natural on average because of regulation. However, since approximately 1990, summer low flows have increased at both stations, both in terms of discharge and as a percentage of the natural flow. In the Oldman River, there were three years since 1990 when the summer low flow was significantly higher than it would have been naturally.

Winter low flow in the Oldman River near Waldron's Corner has generally been in the range of 1 m to 2.5 m^3/s, as shown in **Figure 6.13**. In the St. Mary River, historical winter low flows were significantly less than naturalized flows for much of the available record, but since about 1990 have increased significantly (**Figure 6.14**). In the Oldman River near Lethbridge (**Figure 6.15**), the effect of regulation on winter flows was less pronounced than in the St. Mary, but again a tendency toward higher flows is apparent since the early 1990s.

The higher minimum flows observed since the early 1990s in both summer and winter are due to a combination of factors (AENV, Don Maclean, pers. comm., 2008):

- completion of the Oldman River Dam;
- greater awareness of in-stream flow needs and water quality demands;
- more intensive system management using statistical analysis, modelling and frequent operating season communication with Irrigation Districts to support increased minimum river flow (and improved quality) with minimal impact on storage;
- a decision by Alberta Environment to operate the dams and diversions to maintain flows in the St. Mary, Belly and Oldman Rivers consistently somewhat higher than legislated minimum flow requirements in order to reduce the risk of falling below the minimum flow; and,
- end of the drought years of the 1980s.

Small hydro plants constructed at Waterton and St. Mary Dams around the same time took advantage of the higher minimum flows.

7.0 SOUTH SASKATCHEWAN RIVER SUB-BASIN

7.1 Precipitation and Evapotranspiration

Of the precipitation stations included in this memorandum, Medicine Hat has the least precipitation and the largest deficit in net precipitation. Annual precipitation, illustrated in **Figure 7.1**, averages 335 mm, and annual net precipitation, illustrated in **Figure 7.2**, averages -24 mm. The lowest annual (water-year) precipitation in the record was 150 mm, which occurred in 2000–2001. Seneka (2004) suggested that the data indicates a trend of decreasing year-to-year variability, although the trend is weaker at Medicine Hat than at Calgary or Red Deer.

Monthly distributions of precipitation and evapotranspiration are shown in **Figure 7.3**. Of the total precipitation, 104 mm (31%) typically occurs in winter (November–April).

7.2 Stream Flow

Water supply in the South Saskatchewan River is characterized in **Table 7.1** using the flow at Medicine Hat. Flow in the South Saskatchewan is regulated by developments on the Bow and Oldman sub-basins upstream.

Annual flow volume at Medicine Hat is illustrated in **Figure 7.4**. The mean annual historical flow volume over the 1972–2001 period was 4.8 million dam^3, compared to the average over the entire period of record of 5.8 million dam^3. Annual volumes close to 2.0 million dam^3 have occurred more frequently in the past 30 years, and the lowest recorded volume of 1.7 million dam^3 occurred in 2001. Seneka (2004) found a significant decreasing trend in the recorded data; however, the naturalized flow volumes did not indicate any long-term trends. The lowest natural flow volume was 3.7 million dam^3 in 1944.

TABLE 7.1
South Saskatchewan River Water Supply Statistics 1972–2001

Statistic *	South Saskatchewan River at Medicine Hat	
	Naturalized	Historical
Annual Volume		
- Mean (dam^3)	7 002 000	4 803 000
- Minimum (dam^3)	4 181 000	1 739 000
- Coefficient of Variation (%)	26%	41%
Summer Volume (dam^3)		
- Mean (dam^3)	5 595 000	3 270 000
- Minimum (dam^3)	3 279 000	826 000
- Coefficient of Variation (%)	28%	53%
Summer Low Flow (m^3/s)		
- Mean (m^3/s)	99.9	49.1
- Minimum (m^3/s)	29.2	16.9
- Coefficient of Variation (%)	28%	52%
Winter Low Flow (m^3/s)		
- Mean (m^3/s)	23.2	34.8
- Minimum (m^3/s)	5.30	13.4
- Coefficient of Variation (%)	49%	36%

* See Section 3 for definitions and data sources.

The seasonal distribution of flow at Medicine Hat is shown in **Figure 7.5**. The highest flows typically occur in June, with relatively low flows from August through April.

The effect of regulation has been a fairly consistent decrease in summer low flow, as illustrated in **Figure 7.6**. Low flow in summer currently (1972–2001) averages 49 m^3/s, about half of its naturalized value. The lowest naturalized summer low flow was 29.2 m^3/s in 1991, and the lowest recorded summer low flow was 14.4 m^3/s in 1929. Winter low flow, on the other hand, with a current average value of 34.8 m^3/s, is 50% higher than natural values, as illustrated in **Figure 7.7**. Winter flow is estimated to have been as low as 1.8 m^3/s under natural conditions (in 1937), but historically the lowest observed weekly winter flow was 13.4 m^3/s in 1985.

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8.0 INTERJURISDICTIONAL APPORTIONMENT

Water in the South Saskatchewan River Basin is shared between the United States, Alberta and Saskatchewan under the 1909 Boundary Waters Treaty and the 1969 Master Agreement on Apportionment.

8.1 Water Sharing with the United States

Canada and the United States signed the Boundary Waters Treaty in 1909 to provide the principles and mechanisms for preventing and resolving water-related disputes along the entire Canada-United States Boundary. Article VI of the Treaty dealt specifically with the St. Mary and Milk Rivers in Alberta, Saskatchewan and Montana. The Treaty stipulated that the St. Mary and Milk Rivers are to be treated as one stream for the purposes of apportionment, and the combined flow should be shared equally between Canada and the United States. However, during the irrigation season (April–October, inclusive), Canada is entitled to a prior appropriation of 500 cfs (14.15 m^3/s) of the flow of the St. Mary River, or 75% of its natural flow, whichever is less. A reciprocal arrangement was made on the Milk River in favour of the United States.

The two countries could not agree on how the 1909 Treaty was to be interpreted and implemented. The matter was referred to the International Joint Commission (IJC) and, following information gathering and public hearings, the IJC issued an Order in 1921 clarifying the apportionment arrangement. With respect to the St. Mary River, the 1921 Order stipulated that during the irrigation season when the natural flow in the St. Mary River is 666 cfs (18.86 m^3/s) or less, Canada is entitled to 75% of the natural flow. Any natural flow in excess of 500 cfs (14.15 m^3/s), and the natural flow outside of the irrigation season is to be shared equally between the two countries. Reciprocal arrangements were made for the Milk River flows.

St. Mary River flows apportioned and received by the two countries during the past 55 years (1950 to 2004) are summarized in **Table 8.1**.

TABLE 8.1
Summary of Apportioned and Received St. Mary River Natural Flows 1950–2004

	St. Mary Flows Apportioned to and Received by Canada (dam^3)			
	Apportioned	**% Apportioned**	**Received**	**% Received**
Maximum	719 800		1 167 800	
Mean	478 600	59%	604 600	75%
Minimum	277 900		290 900	
	St. Mary Flows Apportioned to and Received by United States			
	Apportioned	**% Apportioned**	**Received**	**% Received**
Maximum	546 500		326 800	
Mean	332 600	41%	206 500	25%
Minimum	154 700		98 500	

In summary, during the years 1950 to 2004, Canada received 26% more than its share of the natural flow of the St. Mary River. This was offset, at least in part, by the United States receiving more than its share of the Milk River flow. Under current administrative arrangements and diversion works in Montana, the United States has not been able to fully divert its entitlement. The original capacity of the 1917 diversion works was 850 cfs (24.1 m^3/s). The works have deteriorated and the current capacity is in the order of 650–675 cfs (18.4–19.1 m^3/s).

In April 2003, the Governor of Montana requested the IJC to review the administrative arrangements set out in the 1921 Order. After a series of public meetings, the IJC established the St. Mary/Milk Rivers Administrative Task Force to examine opportunities to improve administration of apportionment arrangements to ensure more beneficial and optimal use of the waters in both Canada and United States. The Task Force reported in April 2006. Work is proceeding on implementation of recommendations by the Task Force. In addition, Montana is considering rehabilitation and possible enlargement of the St. Mary diversion works.

8.2 Water Sharing with Saskatchewan

The general principle of the 1969 Master Agreement on Apportionment is that the waters of eastward-flowing rivers are to be divided equitably between Alberta and Saskatchewan. Alberta is entitled to consume or store one-half of the natural flow of the South Saskatchewan River and Red Deer River (minus upstream U.S. diversions). Alberta has the option of considering the South Saskatchewan and Red Deer River basins as a single basin for apportionment calculations. The agreement includes a clause that allows Alberta to take a minimum annual volume of 2 590 000 dam^3 (2,100,000 acre-feet) from the combined basins even if that amount is more than 50% of the annual volume, provided that a minimum flow of 42.5 m^3/s (1500 cfs) or 50% of the instantaneous natural flow (whichever is less) is maintained at the provincial boundary.

Apportionable flows, Saskatchewan entitlements, and actual deliveries to Saskatchewan over the period since the apportionment agreement (1970–2006) are illustrated in **Figure 8.1**. The required delivery shown in the figures is computed simply as 50% of the apportionable flow of the combined South Saskatchewan and Red Deer River rivers. The figure shows that Alberta has met its commitments and that surplus deliveries have been made each year since the agreement was implemented. Surplus deliveries have averaged 2 573 000 dam^3, varying from 350 000 dam^3 in 2001 to 5 498 000 dam^3 in 2005. On average, Alberta has passed 81% of the apportionable flow to Saskatchewan compared to the 50% required under the agreement.

***Apportionable flow*:** Natural flow minus U.S. withdrawals from the St. Mary River system in Montana.

The relationship between apportionable annual volume and actual deliveries is illustrated in **Figure 8.2**. In wet years, the surplus delivery to Saskatchewan has been larger than in dry years.

Monthly distribution of surplus deliveries (assuming the 50% delivery requirement is applied consistently throughout the year) is illustrated in **Figure 8.3**. The figure shows that on average, surplus deliveries are highest in June and lowest in August. Surplus deliveries typically occur throughout the winter.

Alberta Environment (2002) examined the recorded and naturalized flows of the major rivers in the South Saskatchewan River basin to evaluate their relative contribution to Alberta's apportionment commitments. The analysis was based on the period 1975–1995 which was the latest 21-year period for which natural flow calculations were available at the time. Alberta Environment drew the following conclusions:

- The Red Deer River sub-basin passes a relatively constant 98% of its natural flow to Saskatchewan.
- The Bow River sub-basin delivery to Saskatchewan has varied from 58% to 86% of its natural flow, with an average of 72%.
- The Oldman River sub-basin has delivered between 41% and 92% of its apportionable flow, with an average of 69%.
- Alberta's surplus deliveries during dry years could increase in the future as a result of minimum in-stream flow requirements implemented for the South Saskatchewan River through Medicine Hat as well as other reaches of the system.

9.0 CLIMATE CHANGE

The National Water Research Institute (Martz *et al*, 2007) used hydrologic modelling to assess the effect of forecasted climate change on stream flows in the South Saskatchewan River basin in Alberta and Saskatchewan. A range of climate forecasts for a period centered on 2050 was used to predict the potential range of impacts on surface water supply. Conclusions related to water supply included the following:

- The downscaled climate model predictions of future annual precipitation ranged from a decrease of 3.8% to an increase of 11.5%, with an average increase of 3.6%. Temperature increases ranged from 1.5°C to 2.8°C.
- Despite the increased precipitation, stream flows were predicted to decrease by 8.4%, averaged across the sub-basins and the various climate models.
- Natural flows under a range of future climate models and future economic and environmental scenarios were projected to change as shown in **Table 9.1**.

TABLE 9.1
Projected Changes in Natural Flow Due to Climate Change*

Location	Projected Change in Natural Annual Volume (%)		
	Minimum Scenario	Mean	Maximum Scenario
Red Deer River at Red Deer	-30%	-13%	+10%
Red Deer River at Drumheller	-32%	-13%	+12%
Bow River at Banff	-12%	-5%	+1%
Bow River at Calgary	-19%	-10%	0%
Oldman River at Waldron's Corner	-18%	-6%	+4%
St. Mary River near Lethbridge	-15%	-4%	+7%
Oldman River near Lethbridge	-14%	-3%	+7%
South Saskatchewan River at Medicine Hat	-17%	-6%	+6%

* Source: Martz *et al*, 2007

Clearly the various model and scenario results reflect a wide range of potential future conditions. However, on average the simulations indicate future reductions in flow in all of the sub-basins of the SSRB.

10.0 KEY FINDINGS

Historical and natural average annual water flow in the major streams of the SSRB for the period 1972–2001 is illustrated in **Figure 10.1**. The figure shows the proportion of the flow that occurs currently (based on the 1972–2001 period) compared to naturalized flow for the same period. Similarly, the summer flow volume is illustrated in **Figure 10.2**, summer low flow in **Figure 10.3**, and winter low flow in **Figure 10.4**. The width of the flow is proportional to the mean value of the flow statistic illustrated in each figure.

Water flow in the SSRB has been significantly affected by human activity in the watershed over the past century. In general the effects have been a reduction in flow, although winter low flows have increased due to regulation in some of the rivers.

Analyses for trends in the natural flow data and projections of future water supply changes due to climate change are inconclusive. However, tentative indications of trends within the period of record, as well as climate change studies conducted by the National Water Research Institute, indicate that future reductions in natural stream flows are more likely than increases in all of the sub-basins in the SSRB.

Alberta has consistently met its apportionment commitments and has delivered surplus water to Saskatchewan even in dry years, indicating that water may be available for use in Alberta. However, water supply for use in Alberta may be constrained by in-stream flow requirements.

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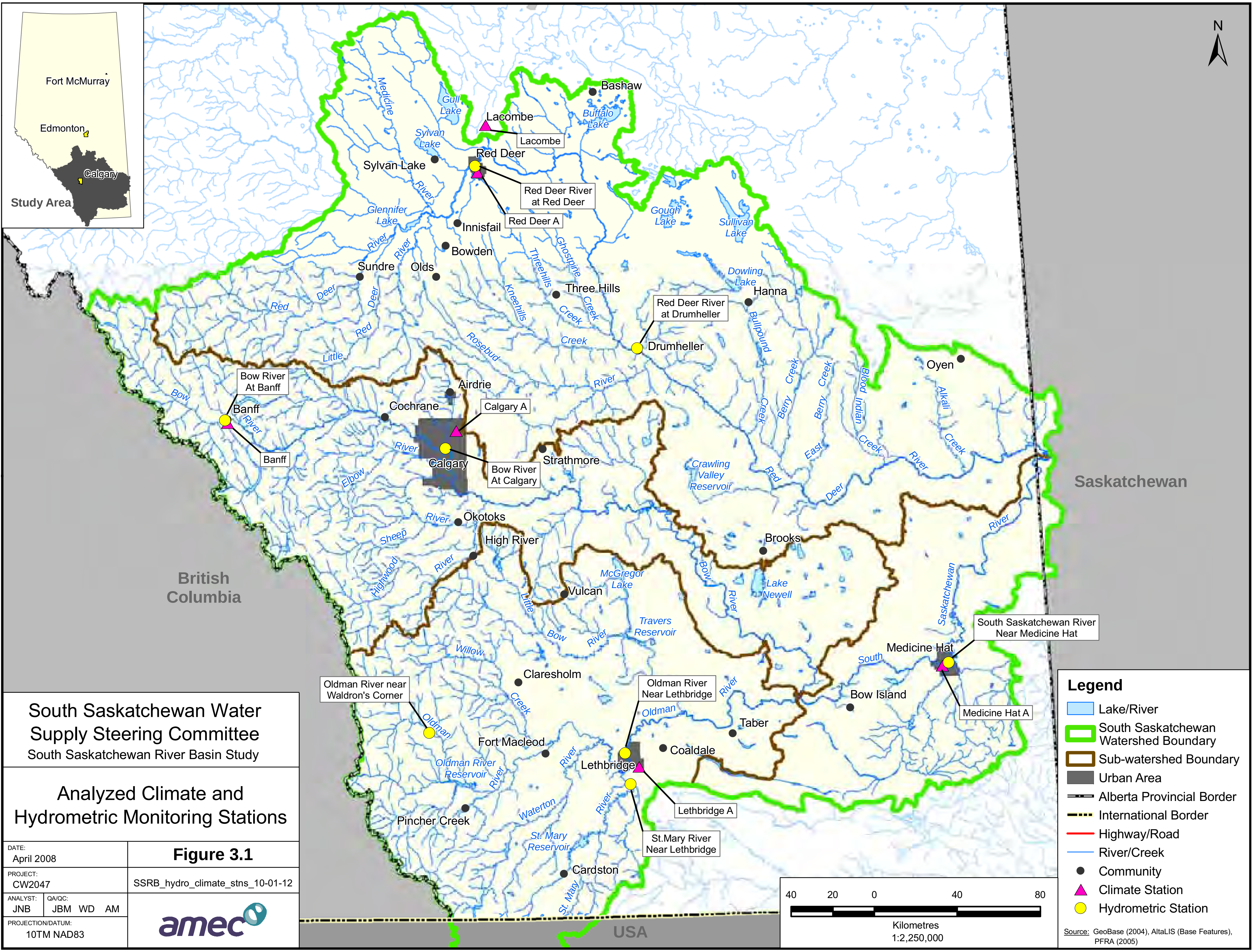
Appendix of Figures



Source: GeoBase (2004), AltaLIS (Base Features), PFRA (2005)

South Saskatchewan Water Supply Steering Committee

South Saskatchewan River Basin Study

Analyzed Climate and Hydrometric Monitoring Stations

DATE: April 2008	**Figure 3.1**
PROJECT: CW2047	SSRB_hydro_climate_stns_10-01-12
ANALYST: JNB	QA/QC: JBM WD AM
PROJECTION/DATUM: 10TM NAD83	

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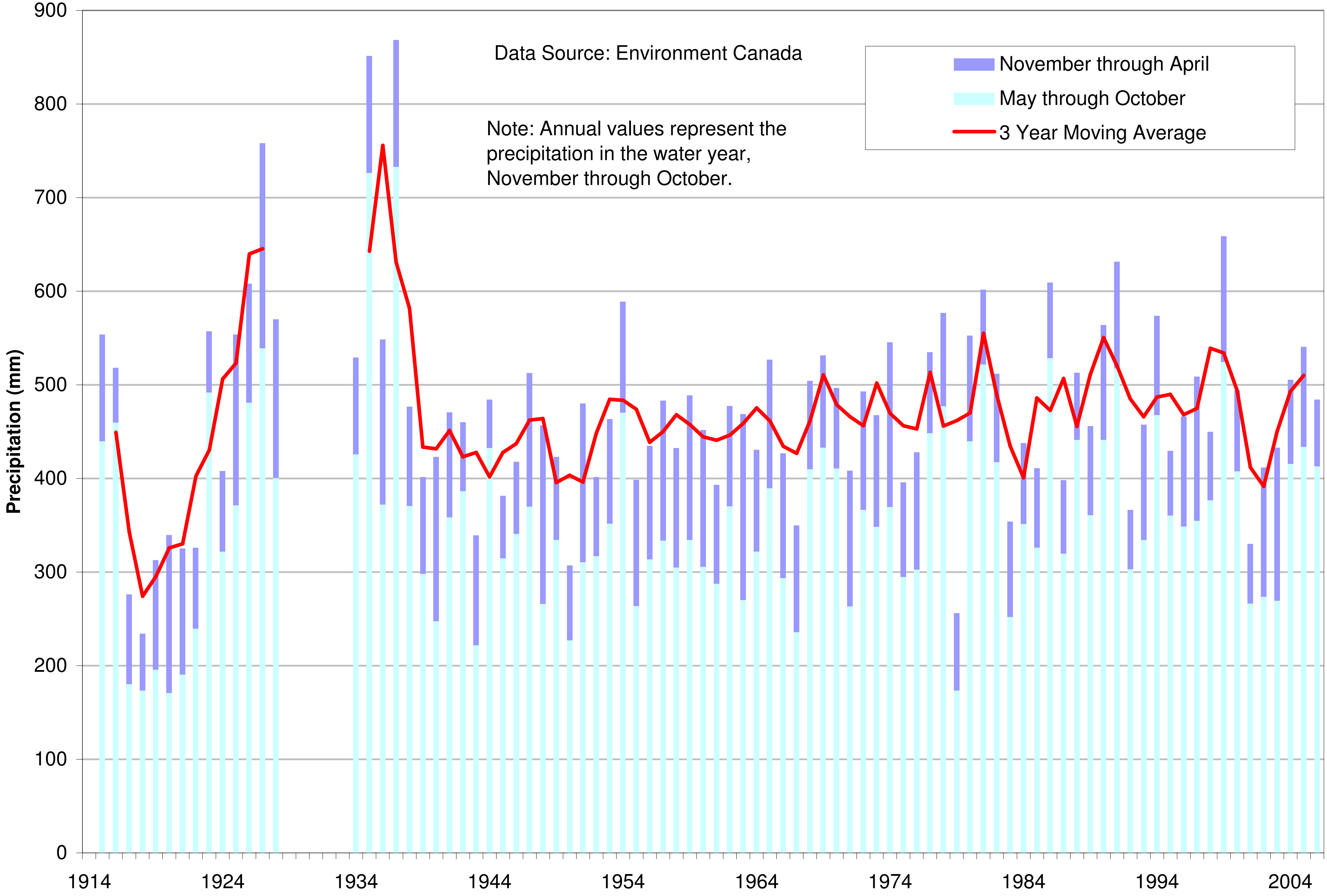
Figure 4.1
Annual Precipitation at Red Deer



Data Source: Environment Canada

Note: Annual values represent the precipitation in the water year, November through October.

Figure 4.2
Annual Net Precipitation at Red Deer

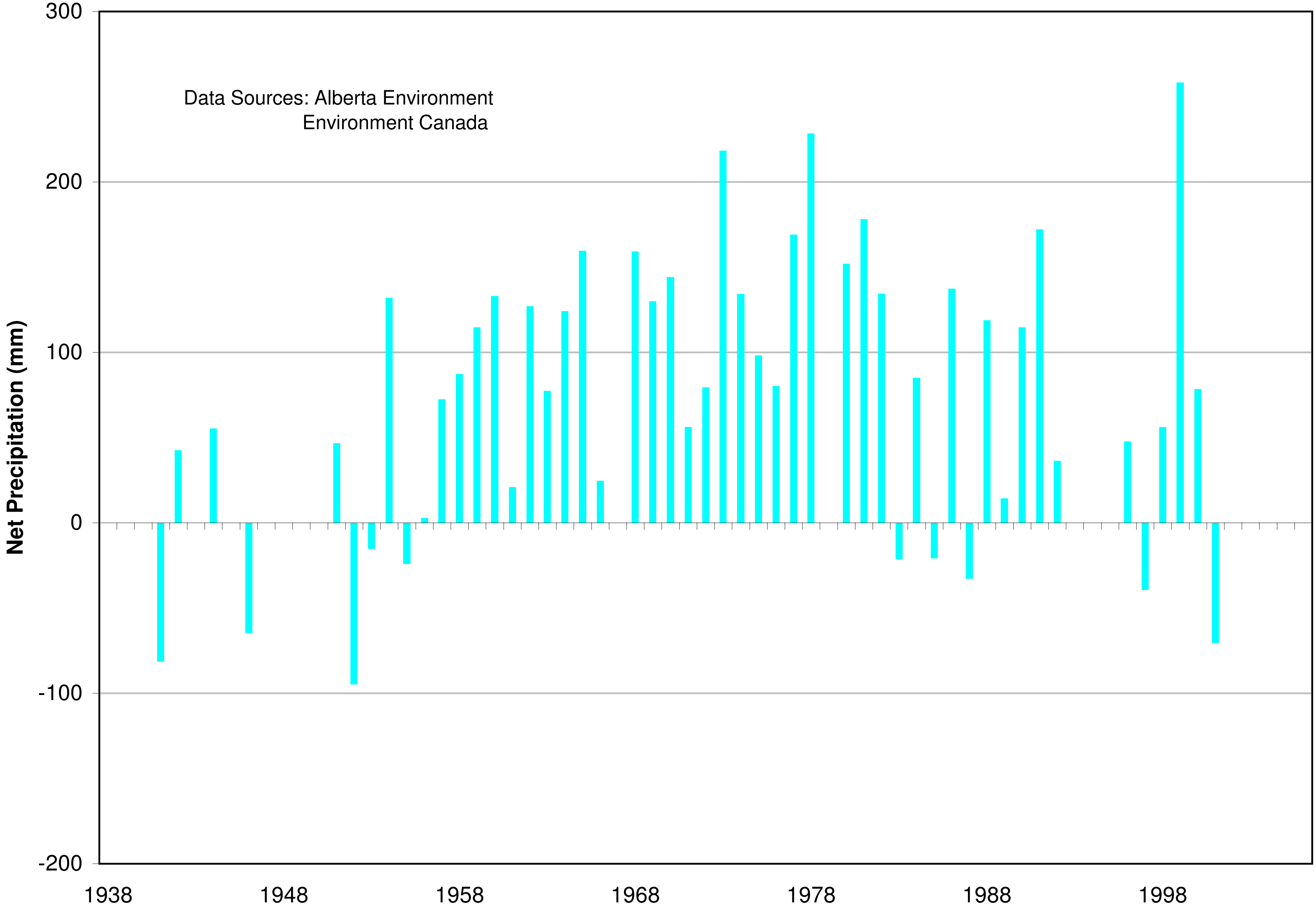


Figure 4.3
Mean Monthly Precipitation and Evapotranspiration at Red Deer

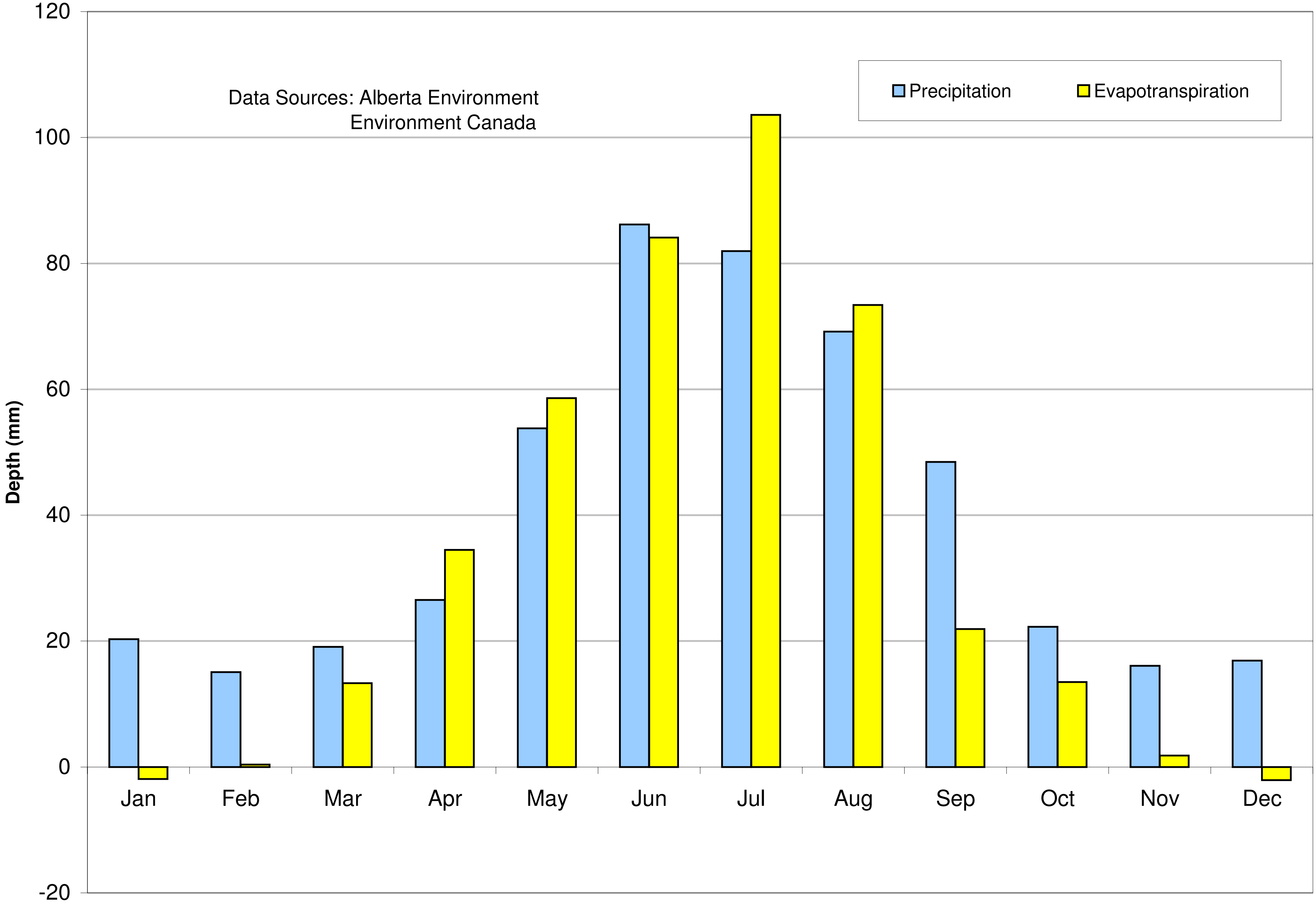


Figure 4.4
Annual Flow Volume
Red Deer River at Red Deer

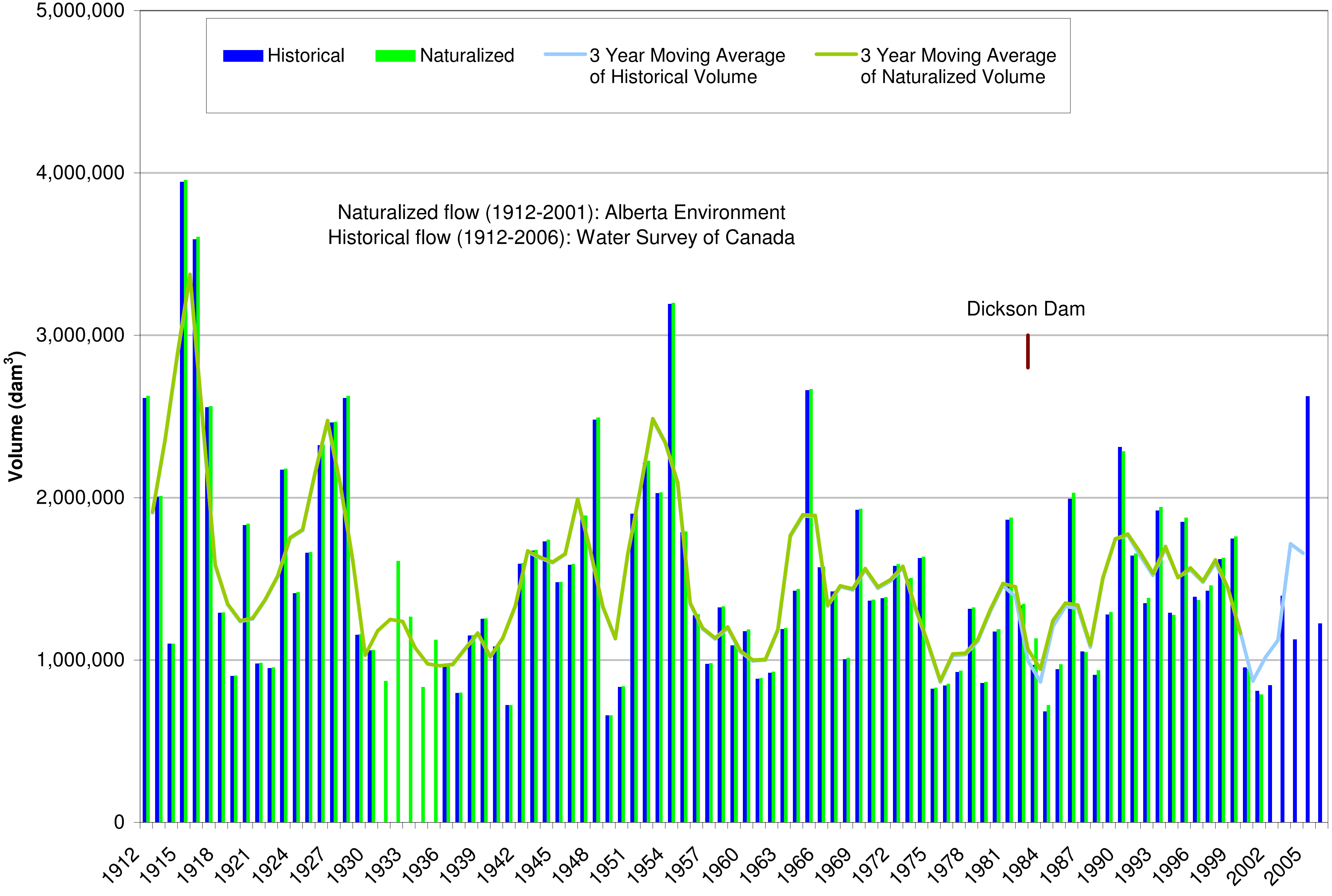


Figure 4.5
Annual Flow Volume
Red Deer River at Drumheller

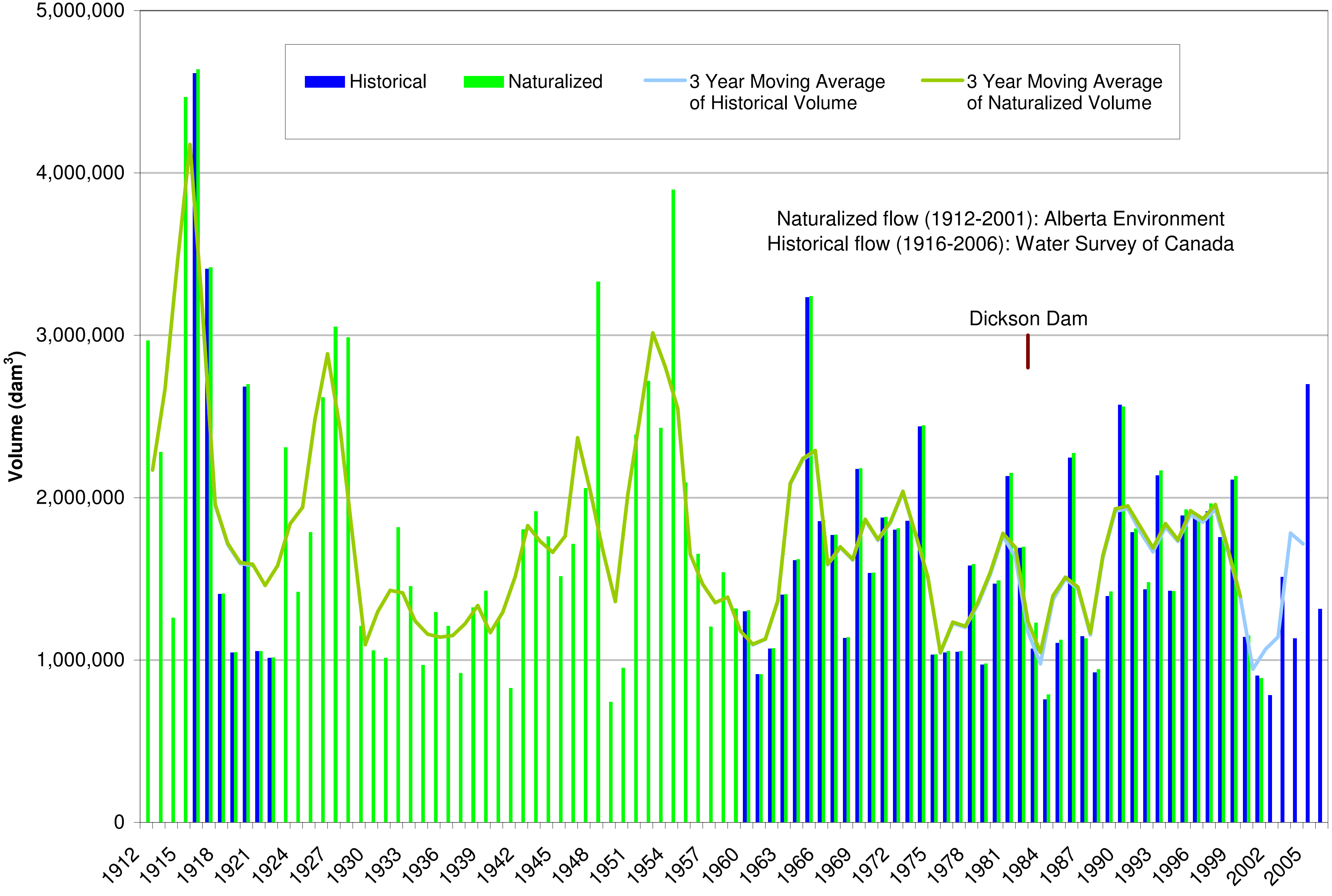


Figure 4.6
Historical Discharge Quantiles for
Red Deer River at Red Deer, 1912 - 2006

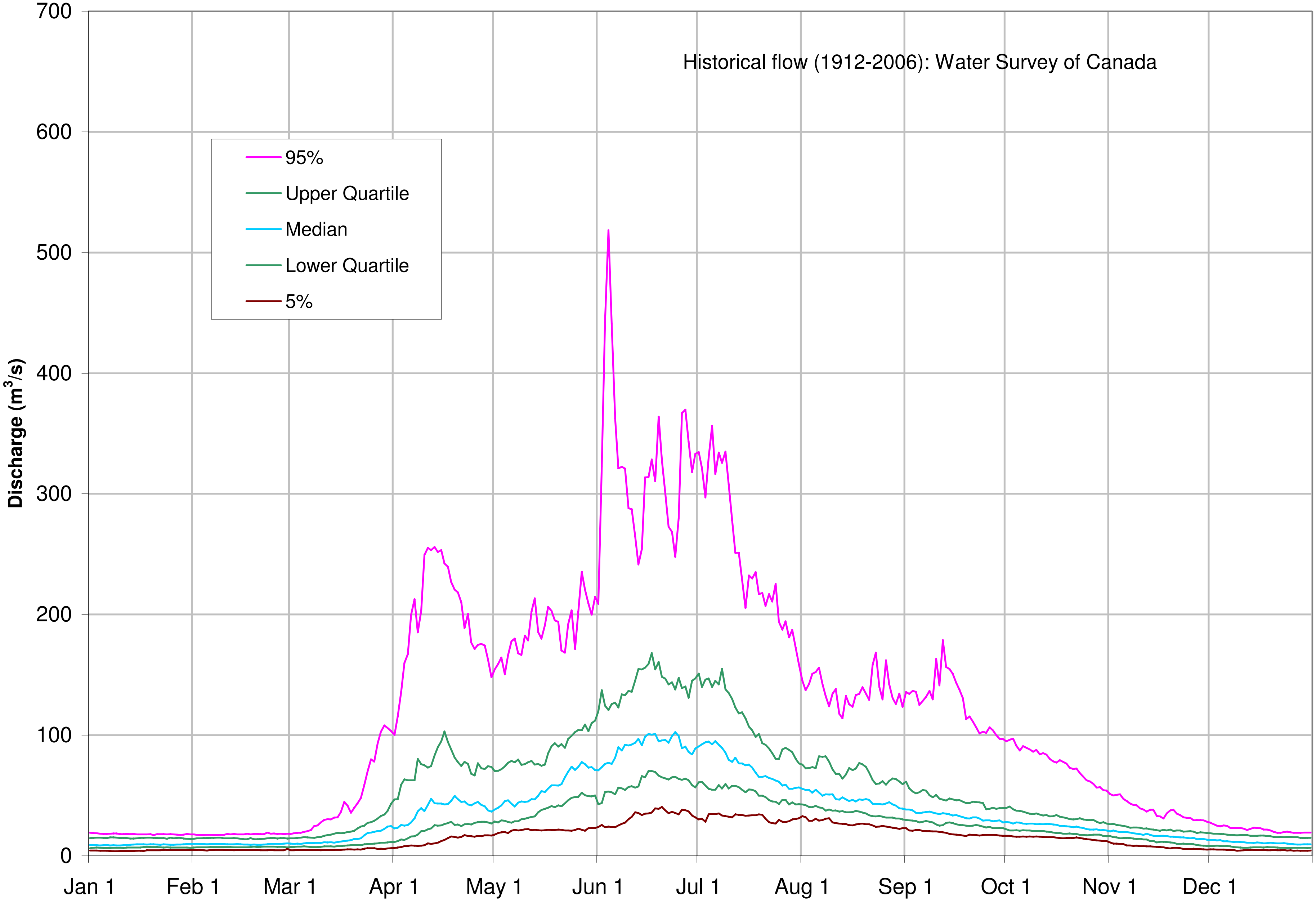


Figure 4.7
Historical Discharge Quantiles for Red Deer River at Drumheller, 1916 - 2006

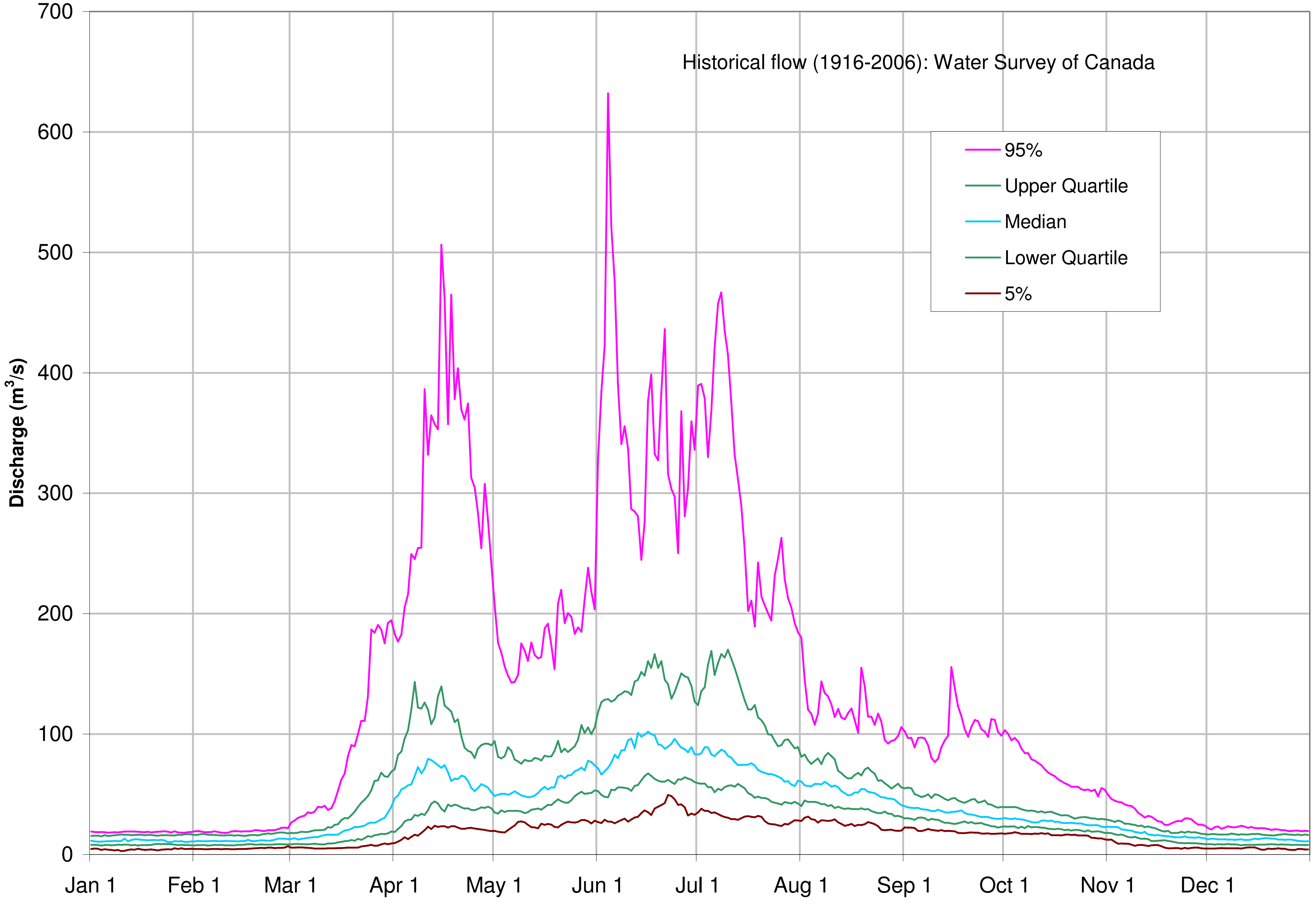
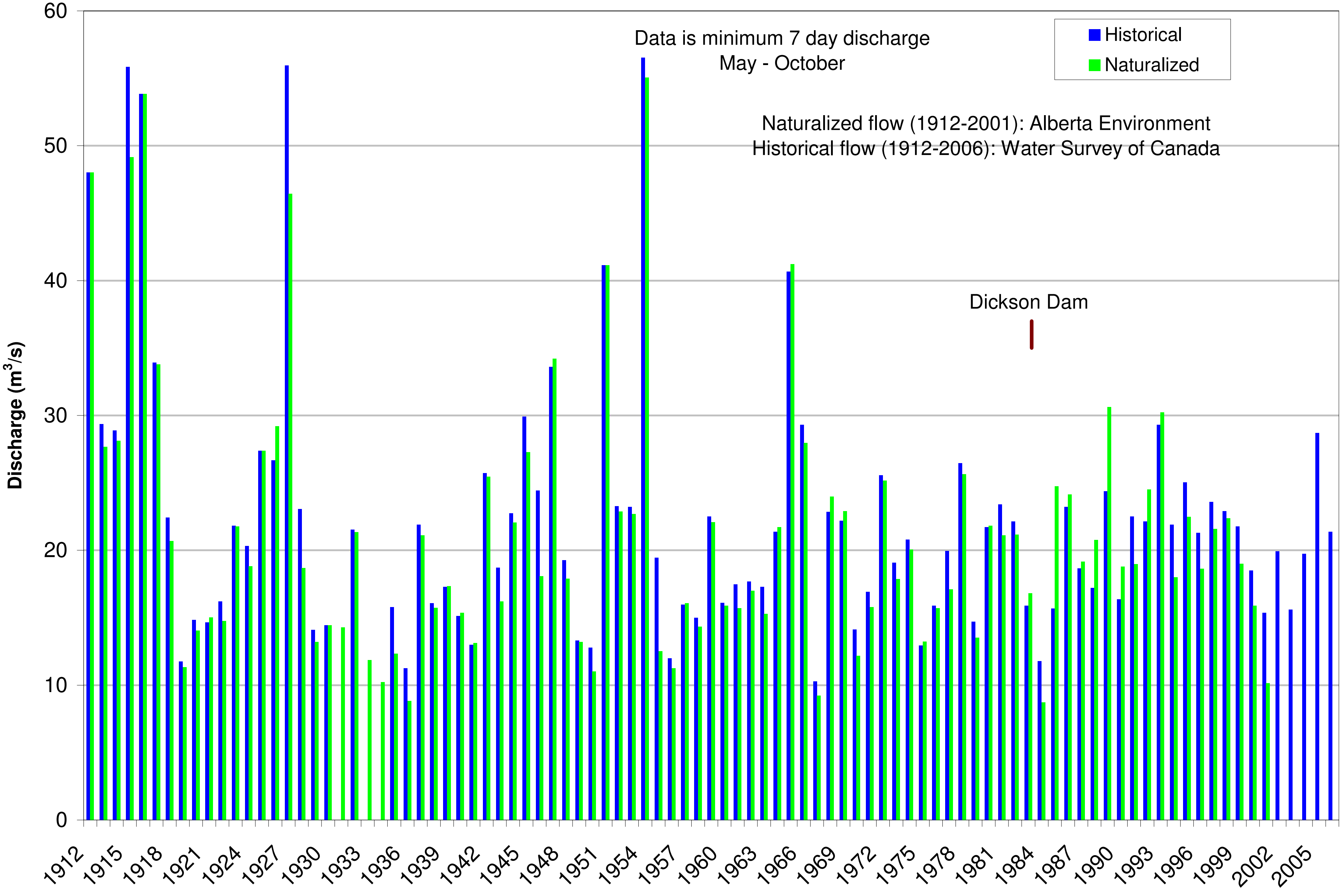


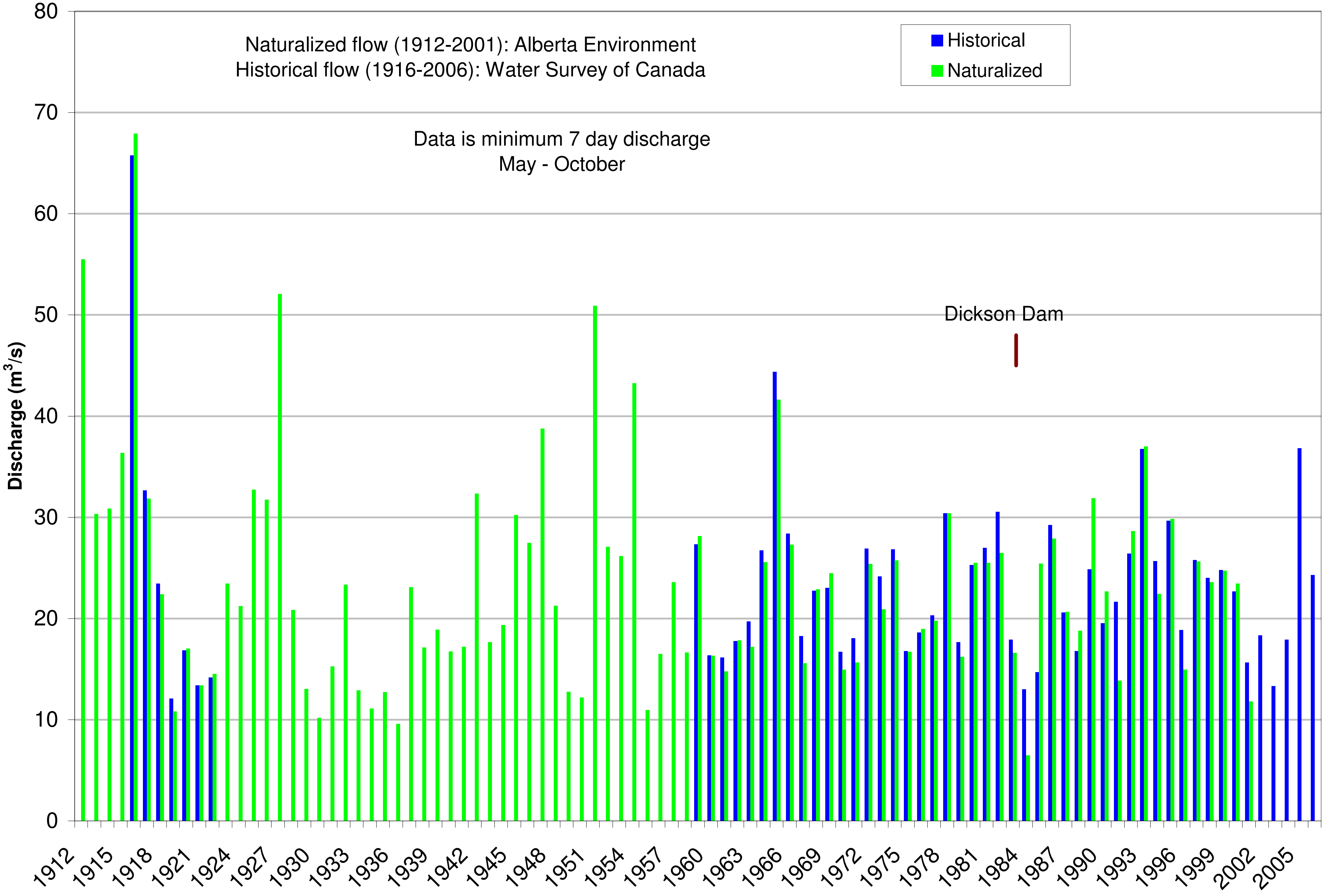
Figure 4.8
Summer Low Flow
Red Deer River at Red Deer



Data is minimum 7 day discharge
May - October

Naturalized flow (1912-2001): Alberta Environment
Historical flow (1912-2006): Water Survey of Canada

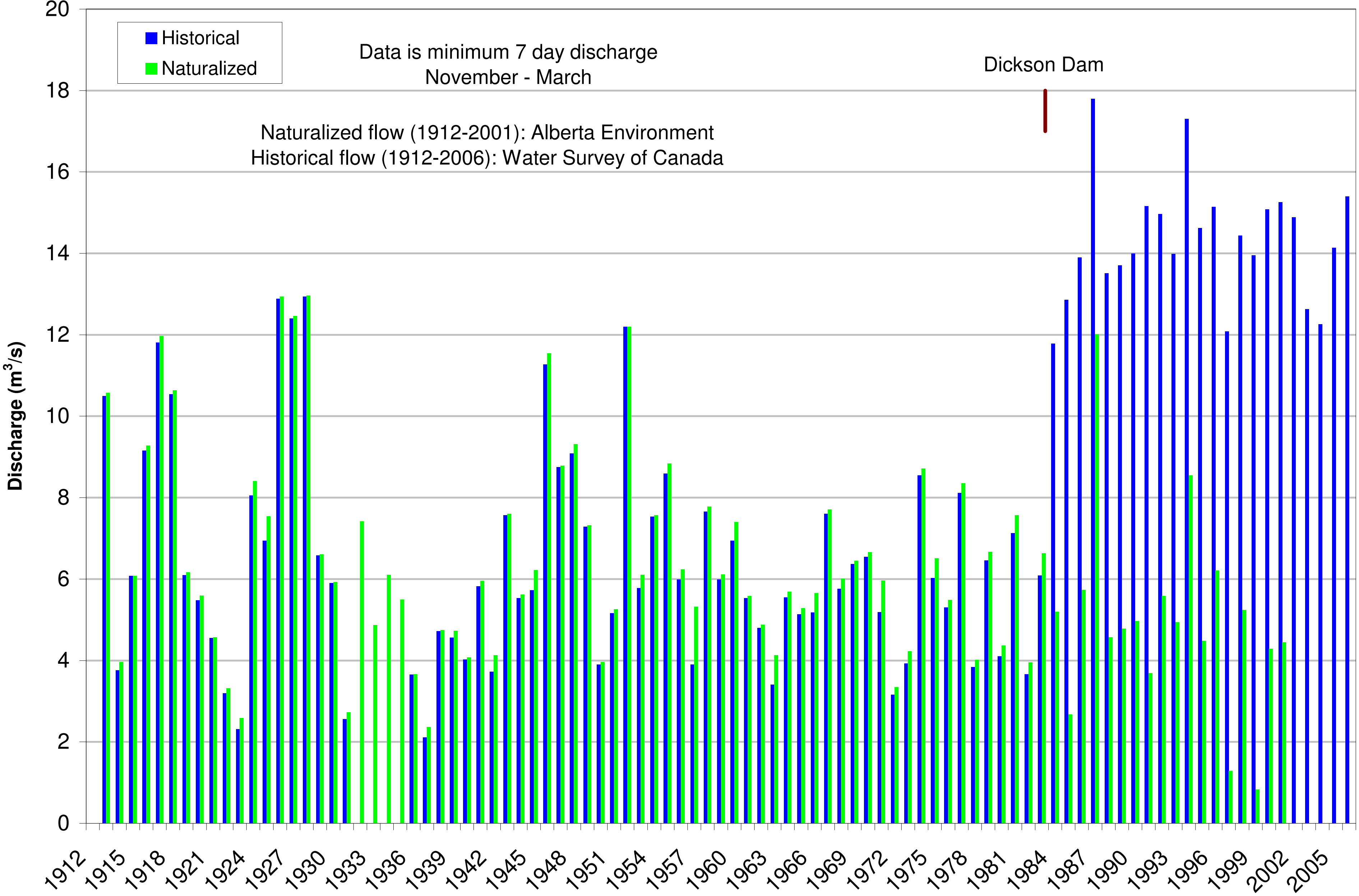
Figure 4.9
Summer Low Flow
Red Deer River at Drumheller



Naturalized flow (1912-2001): Alberta Environment
Historical flow (1916-2006): Water Survey of Canada

Data is minimum 7 day discharge
May - October

Figure 4.10
Winter Low Flow
Red Deer River at Red Deer



Data is minimum 7 day discharge
November - March

Naturalized flow (1912-2001): Alberta Environment
Historical flow (1912-2006): Water Survey of Canada

Figure 4.11
Winter Low Flow
Red Deer River at Drumheller

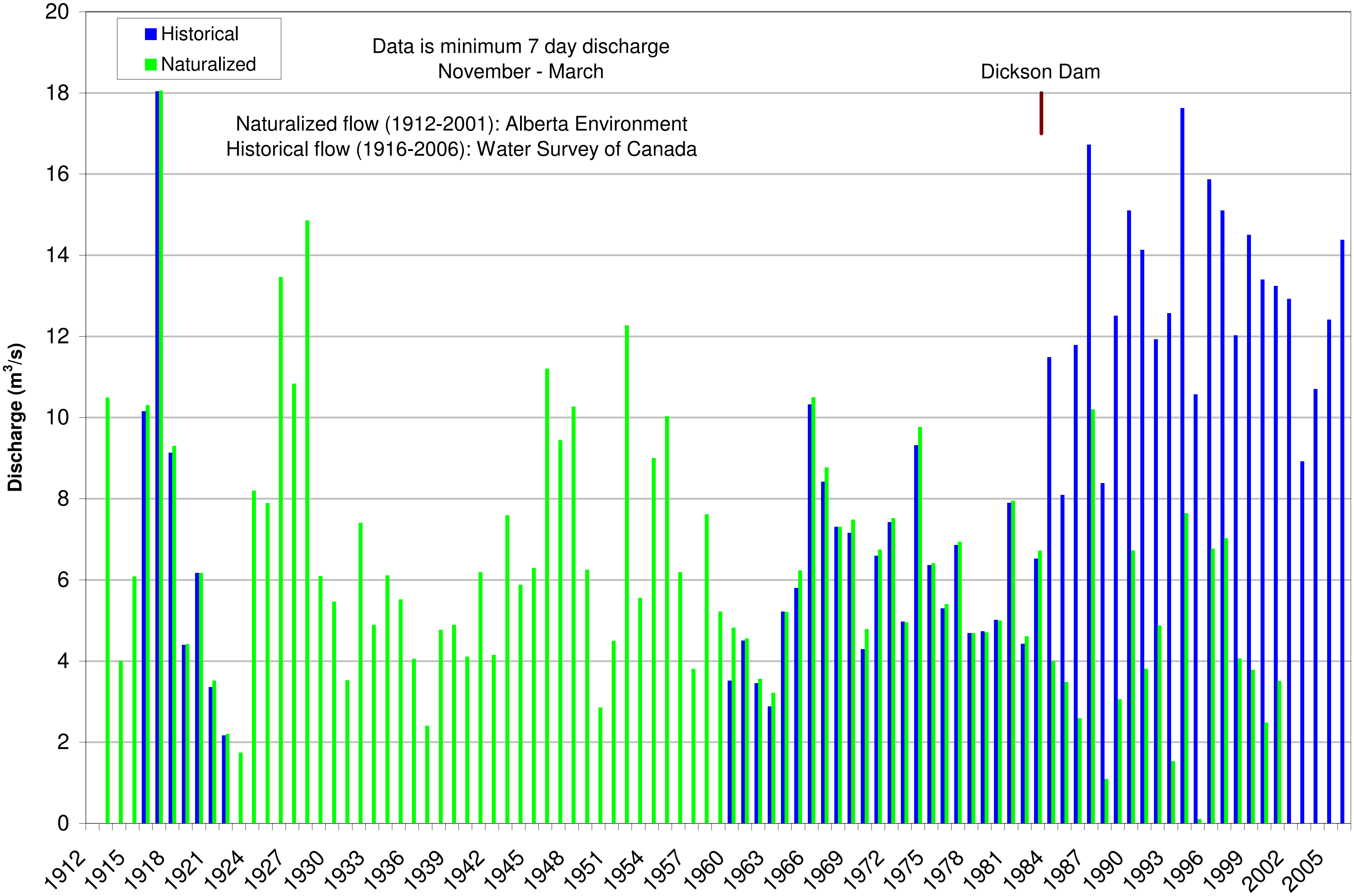
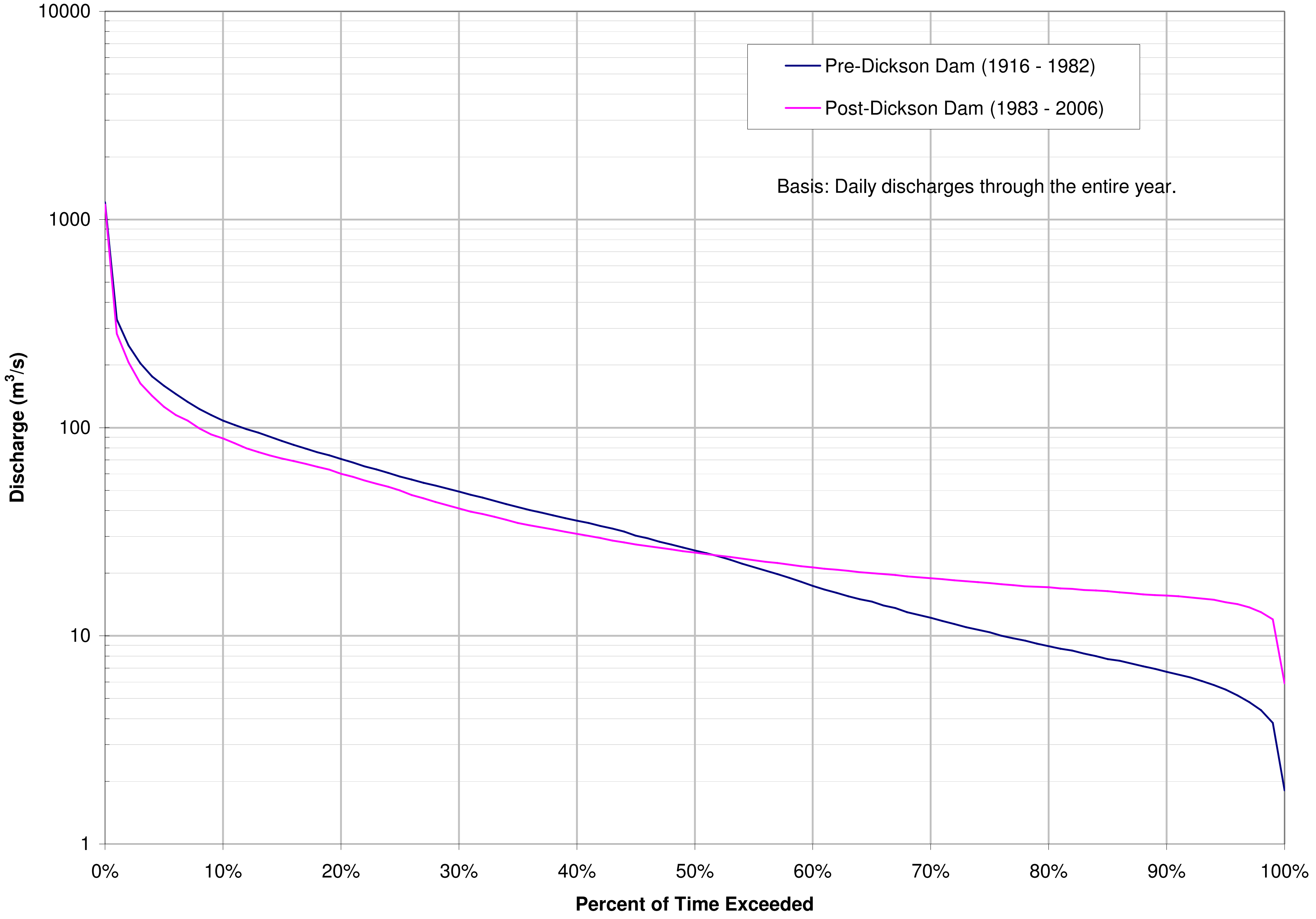


Figure 4.12
Flow-Duration Curve: Red Deer River at Red Deer



Basis: Daily discharges through the entire year.

Figure 5.1
Annual Precipitation at Banff

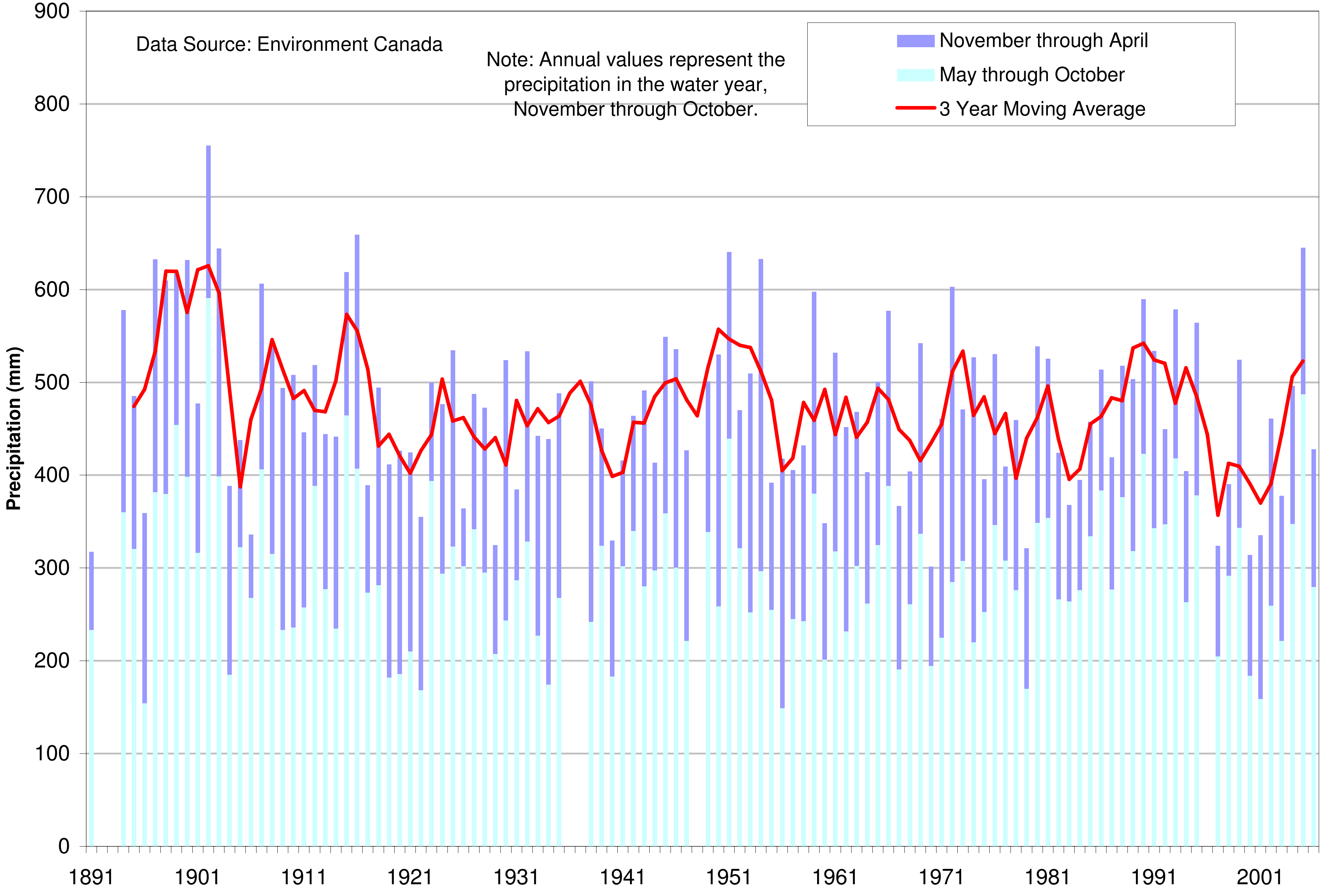


Figure 5.2
Annual Precipitation at Calgary

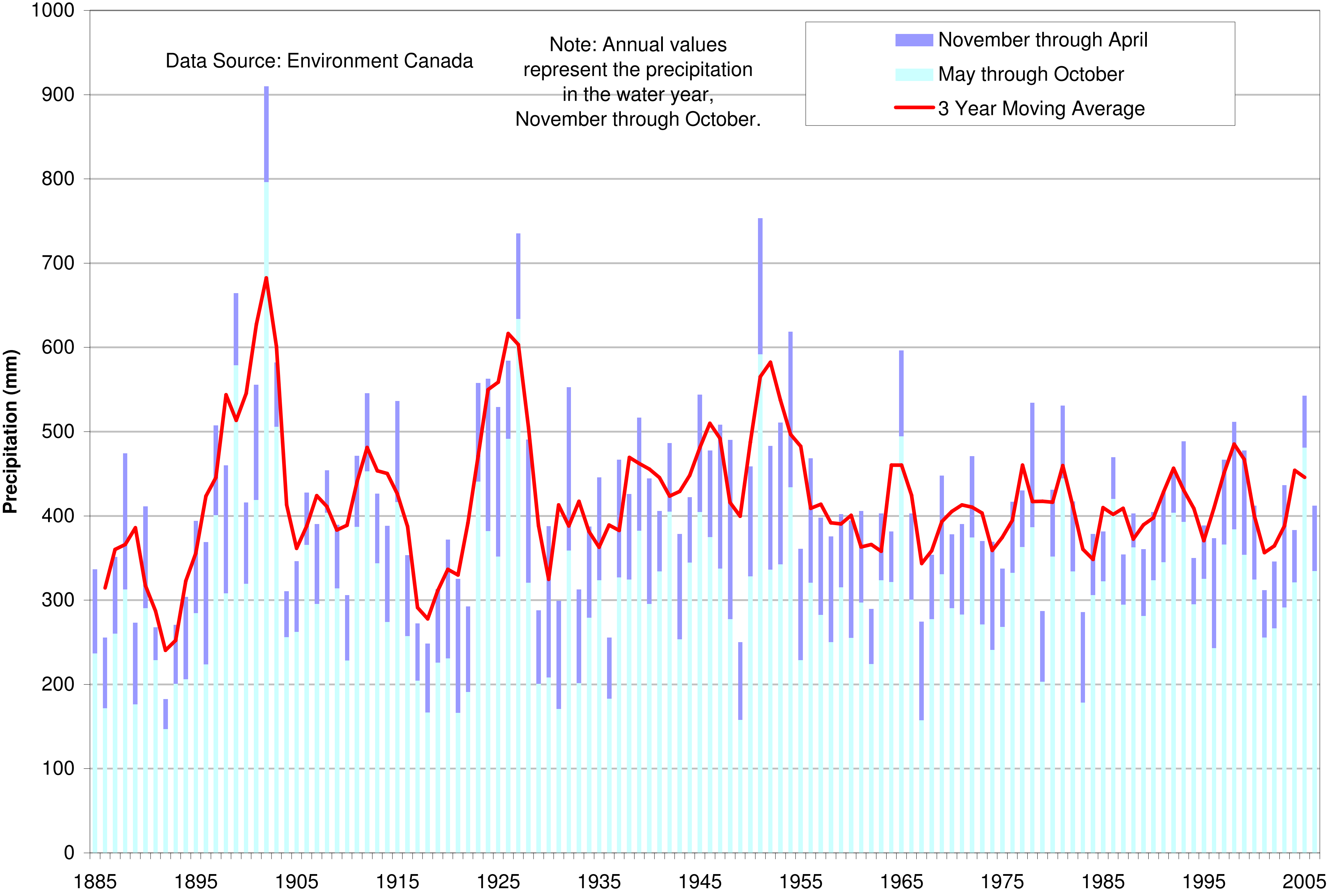


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Figure 5.3
Annual Net Precipitation at Calgary

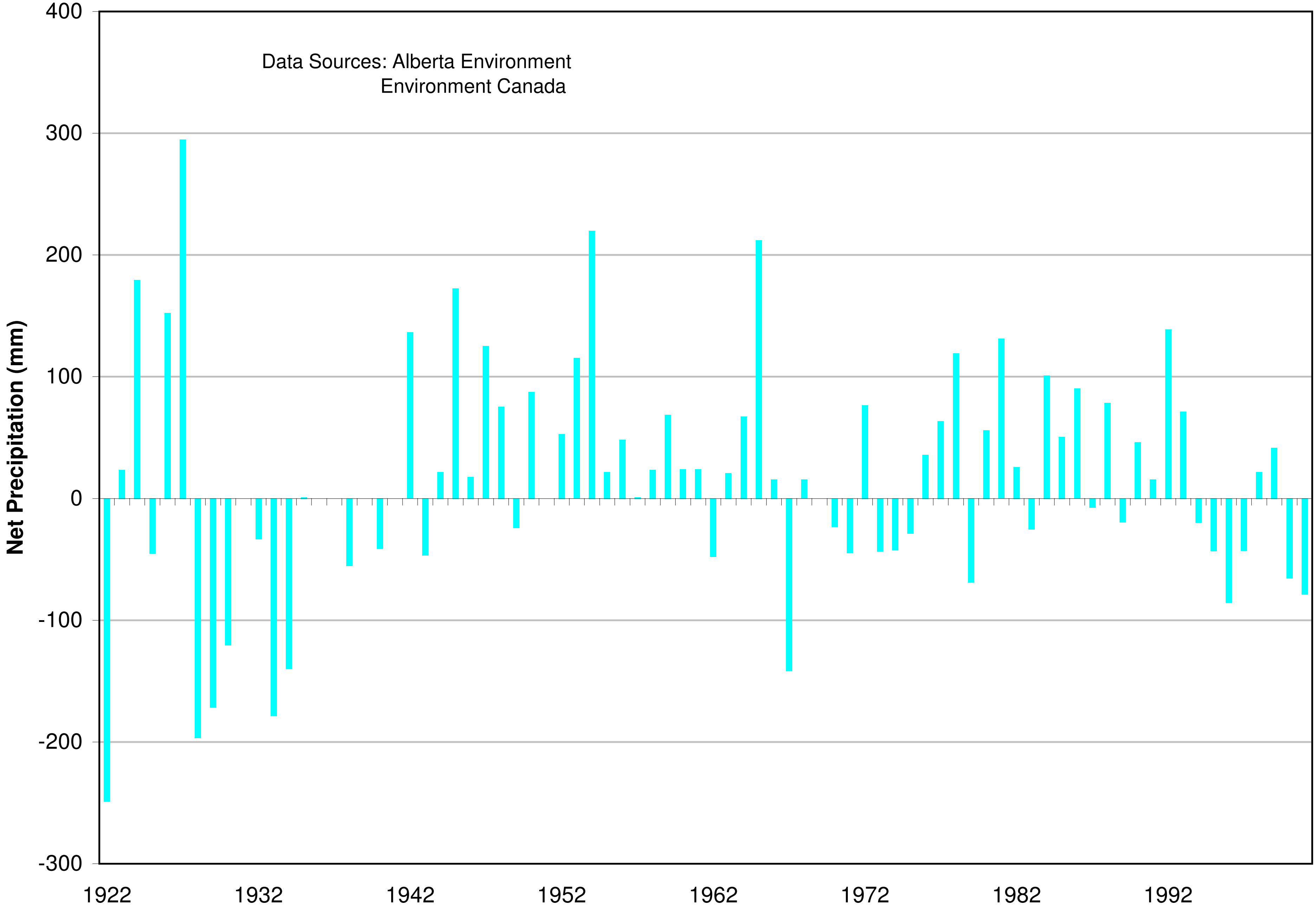


Figure 5.4
Mean Monthly Precipitation and Evapotranspiration at Banff

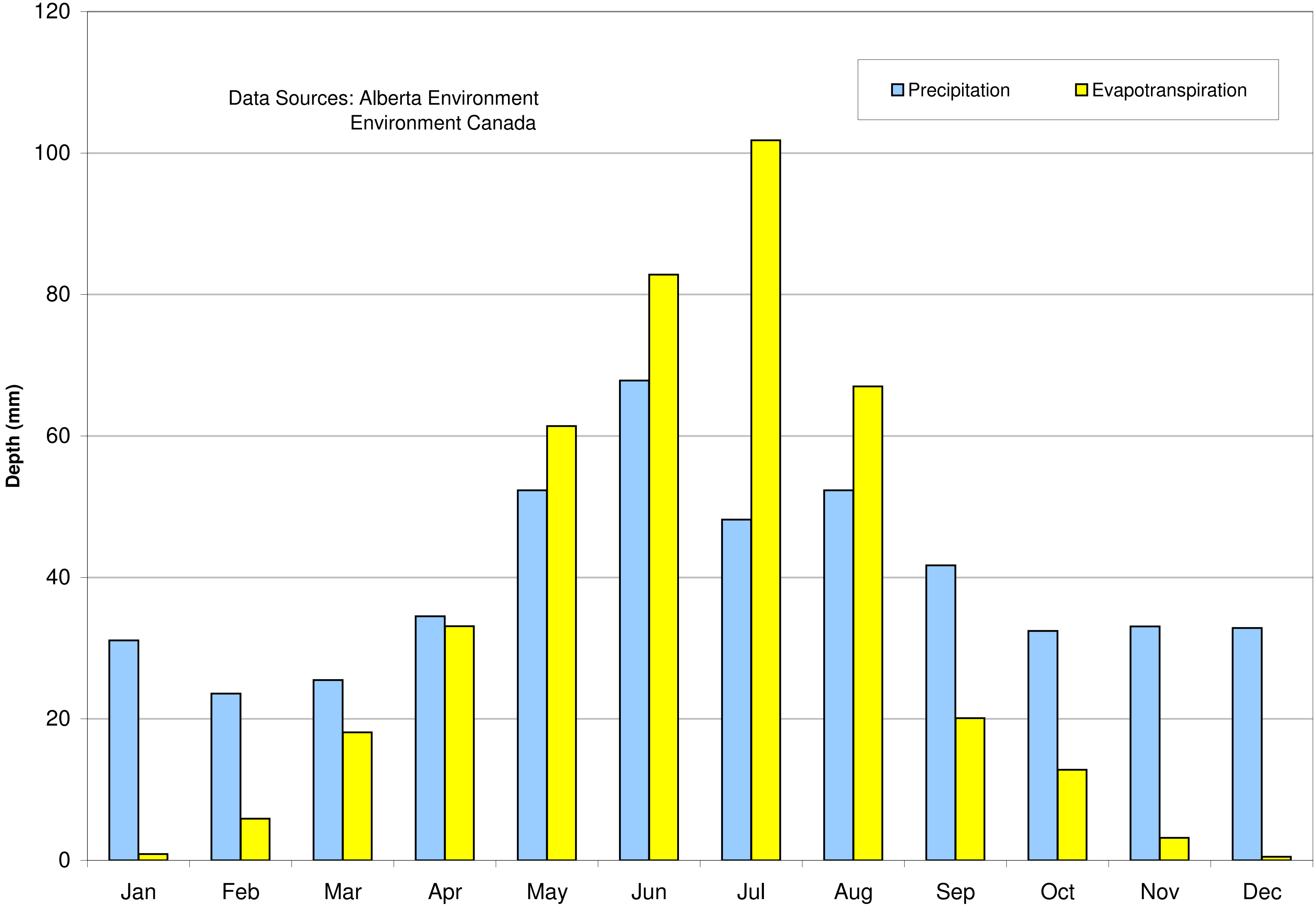


Figure 5.5
Mean Monthly Precipitation and Evapotranspiration at Calgary

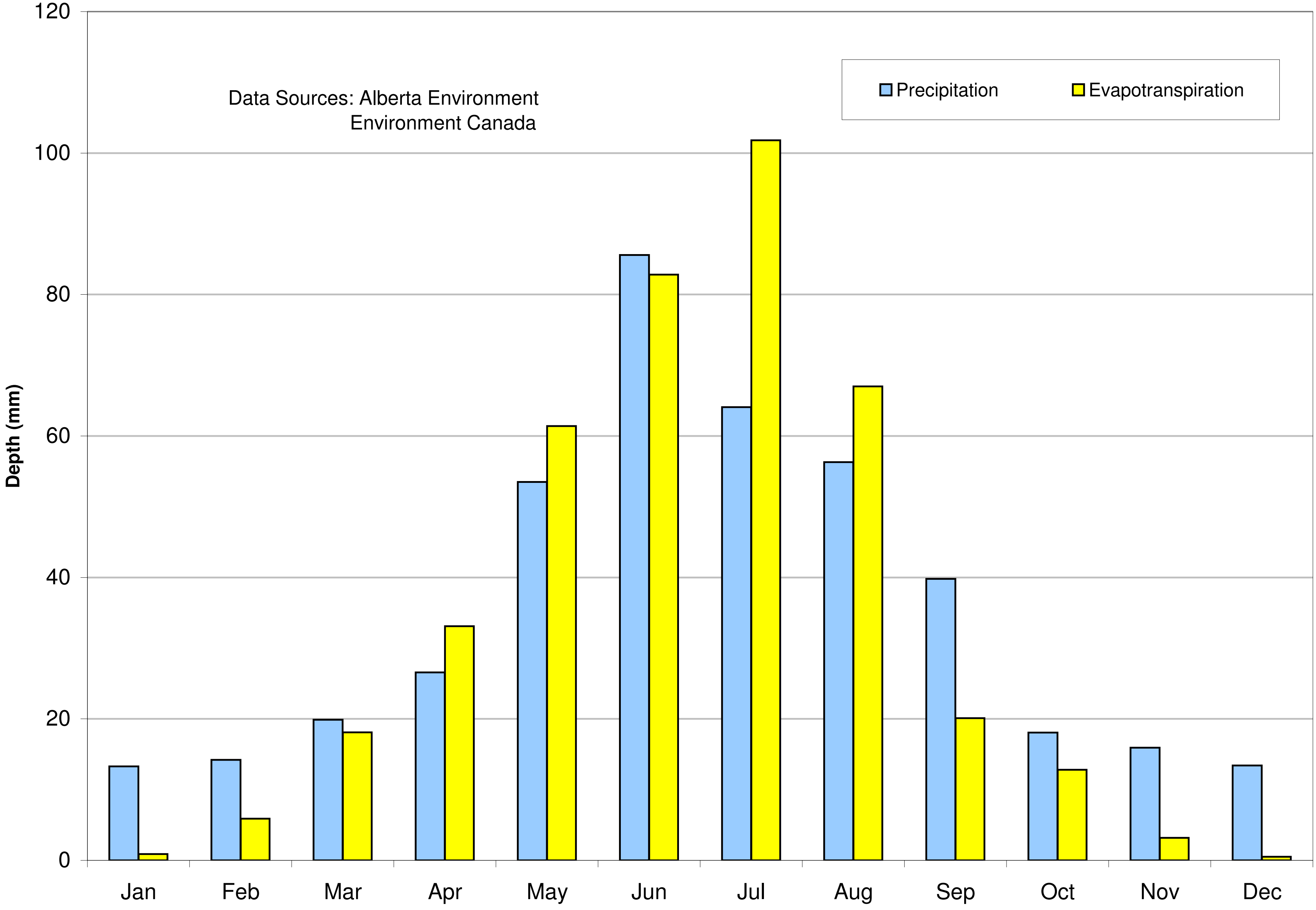


Figure 5.6
Annual Flow Volume
Bow River at Banff

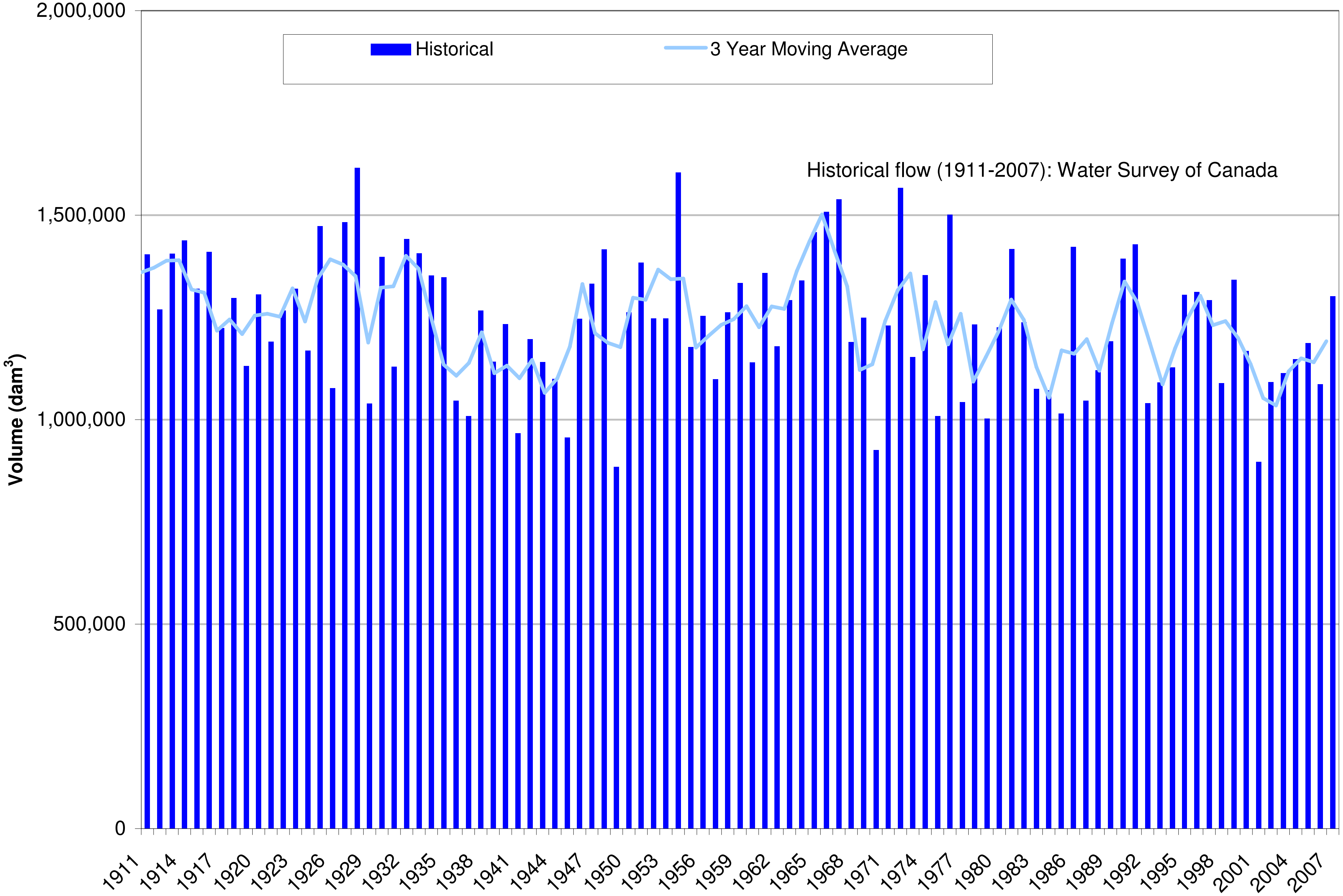


Figure 5.7
Annual Flow Volume
Bow River at Calgary

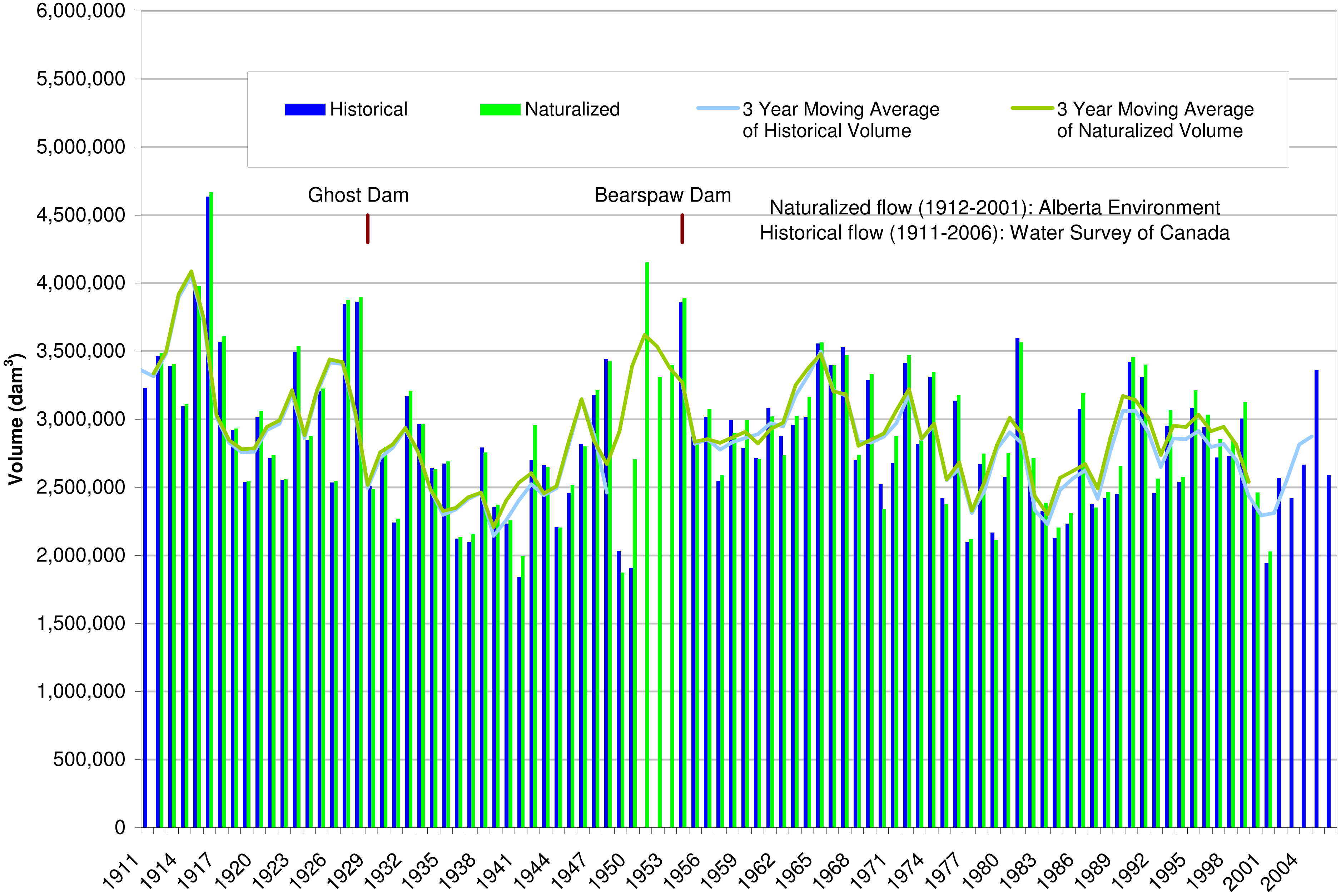


Figure 5.8
Historical Discharge Quantiles for Bow River at Banff, 1911 - 2007

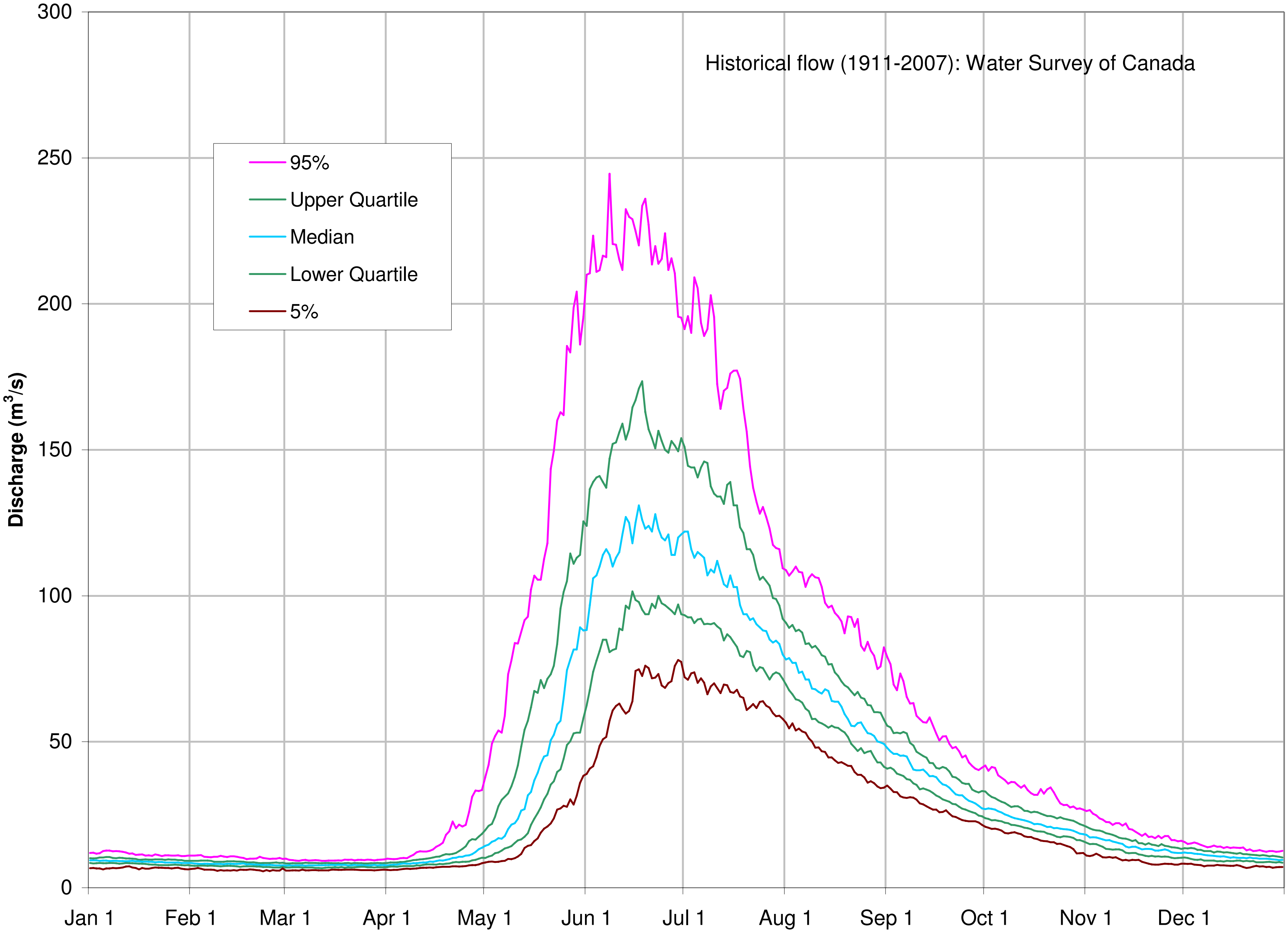


Figure 5.9
Historical Discharge Quantiles for Bow River at Calgary, 1911 - 2006

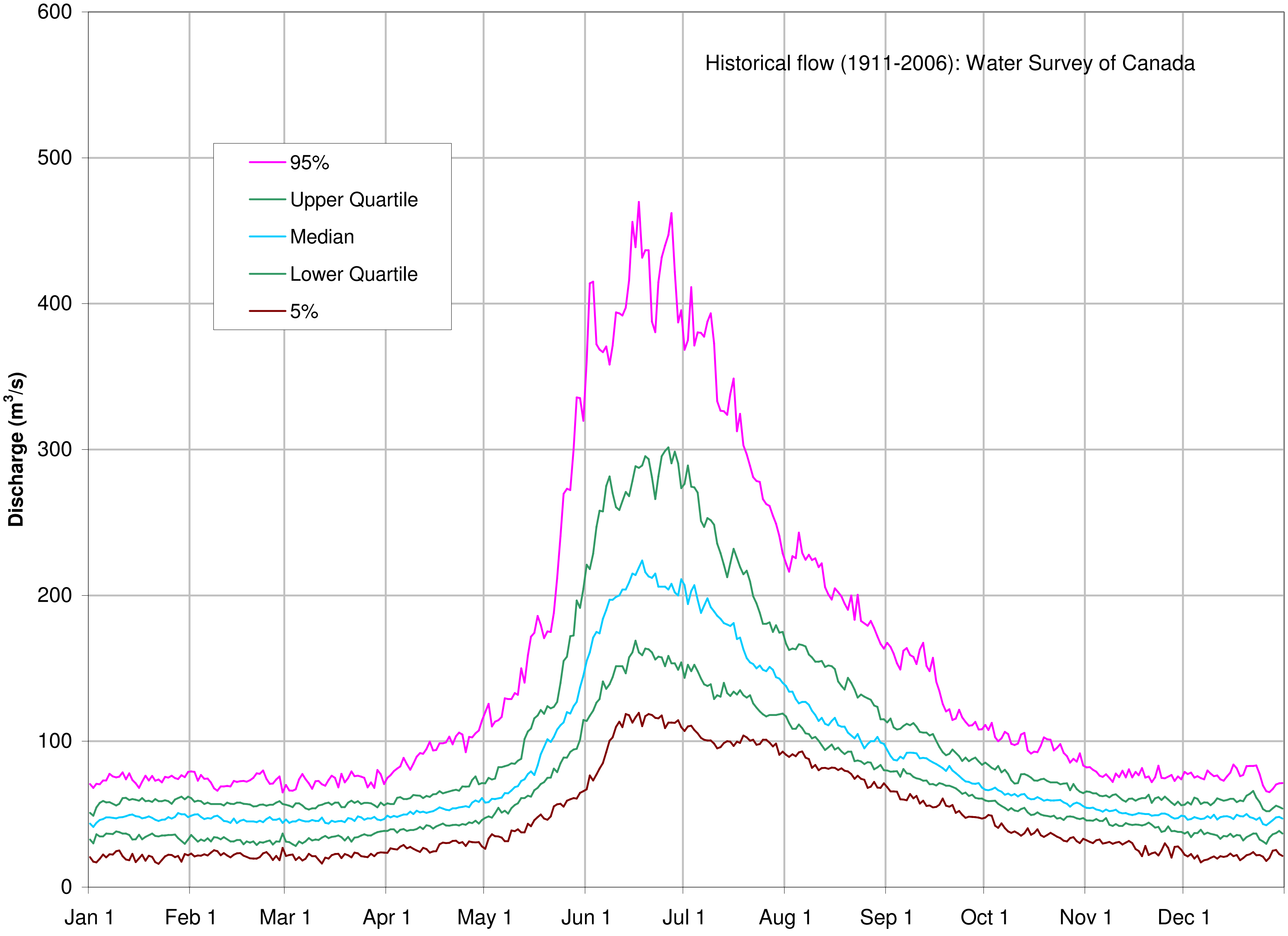


Figure 5.10
Summer Low Flow
Bow River at Banff

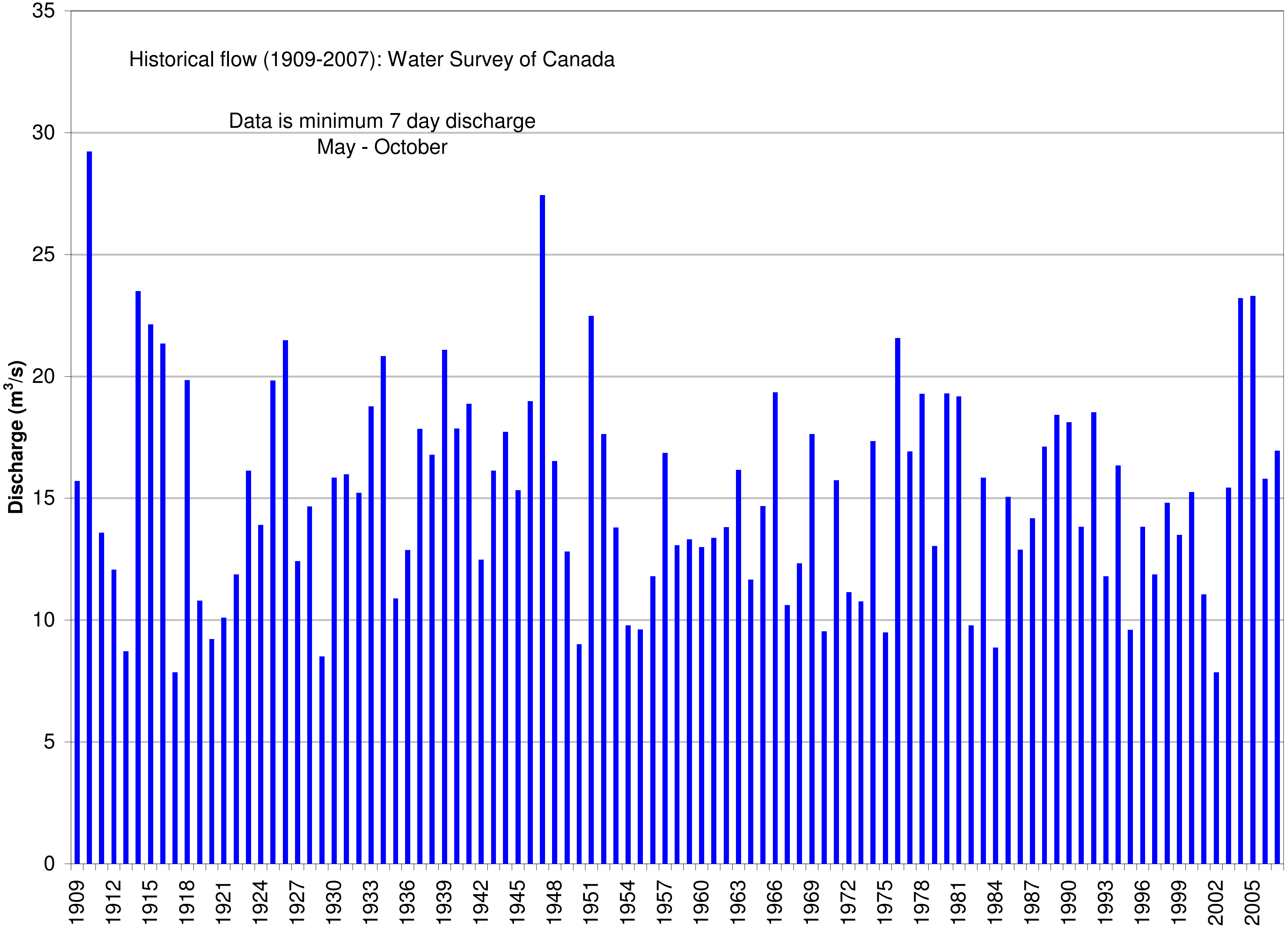


Figure 5.11
Summer Low Flow
Bow River at Calgary

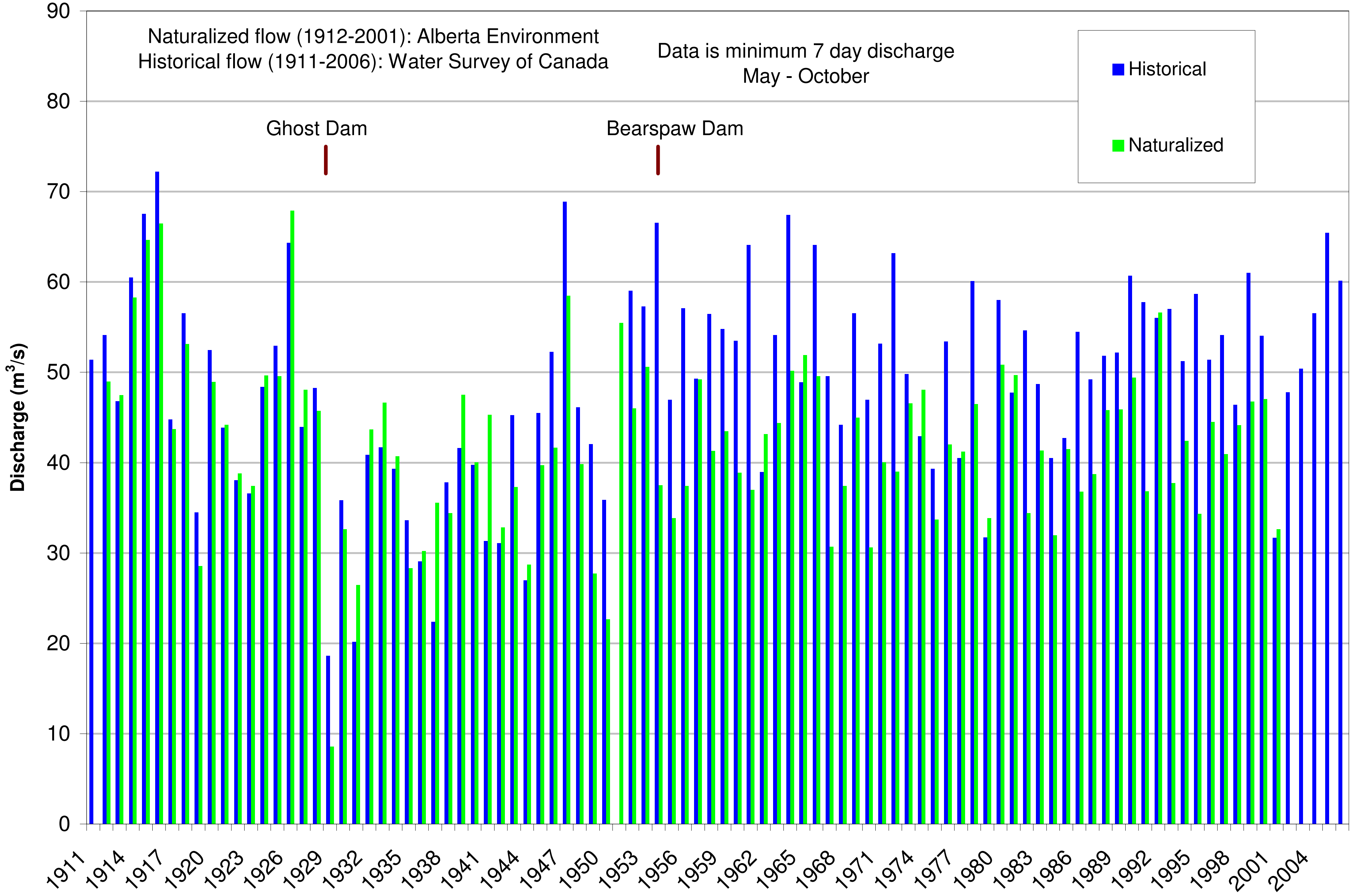


Figure 5.12
Winter Low Flow
Bow River at Banff

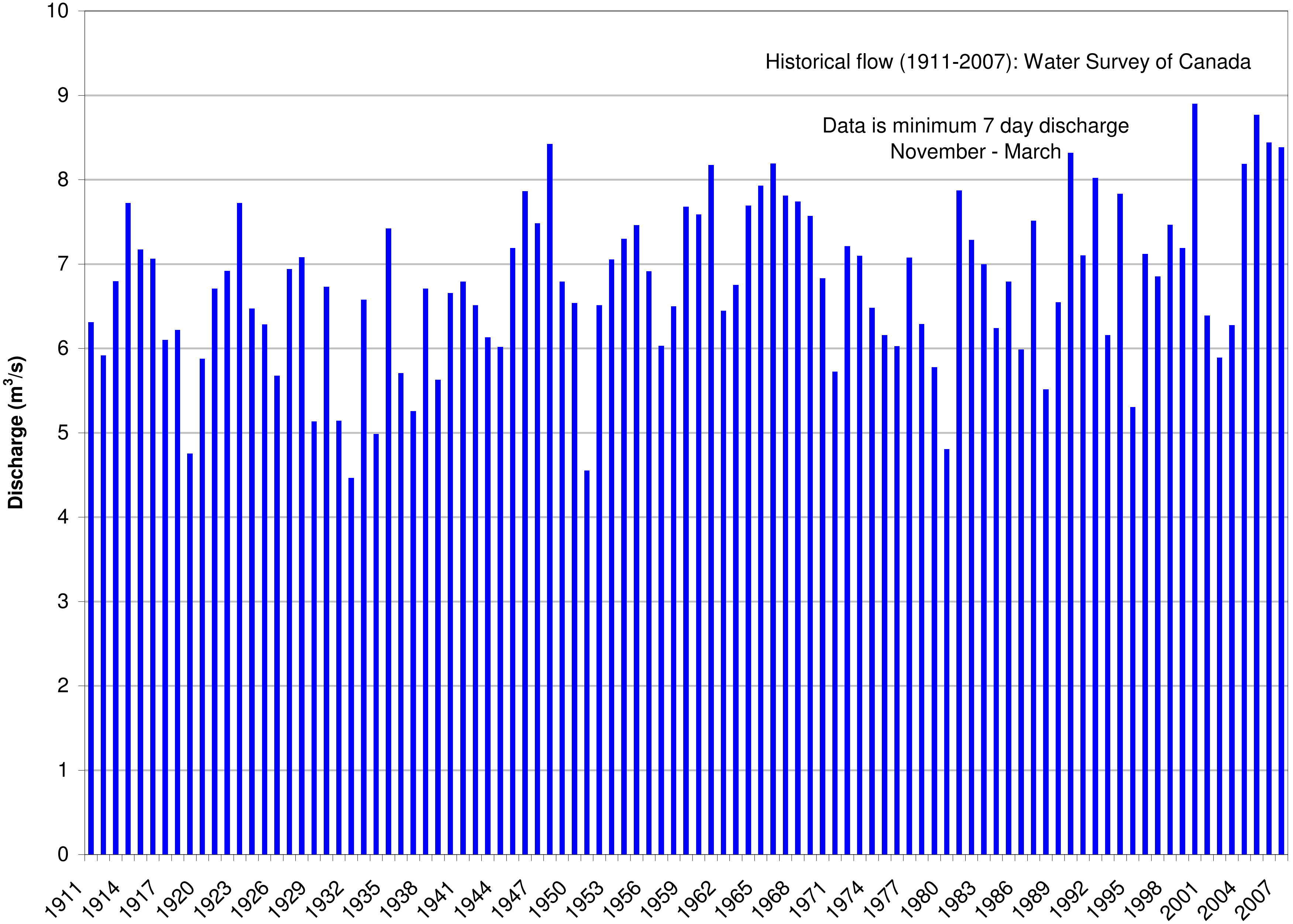


Figure 5.13
Winter Low Flow
Bow River at Calgary

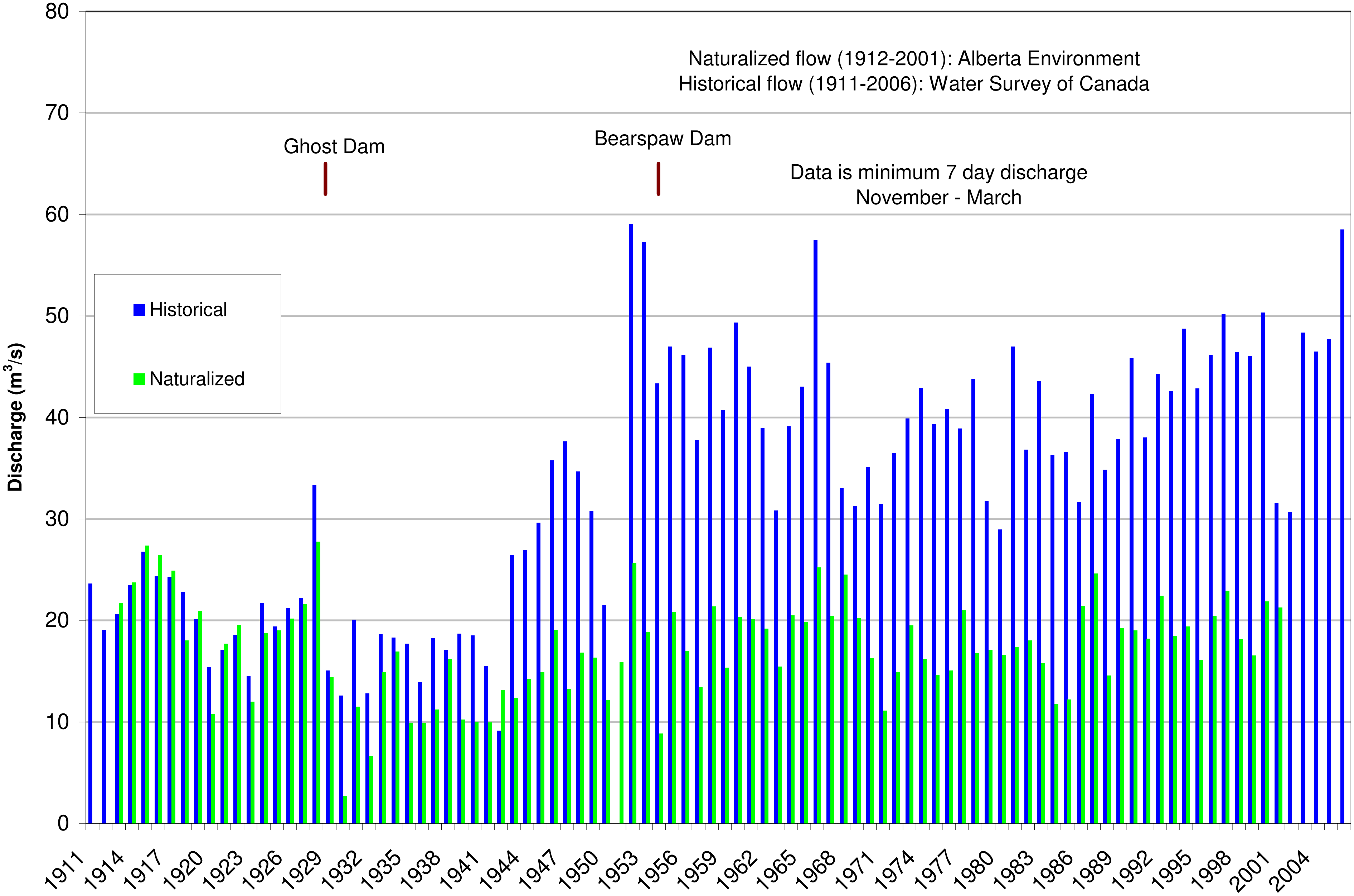
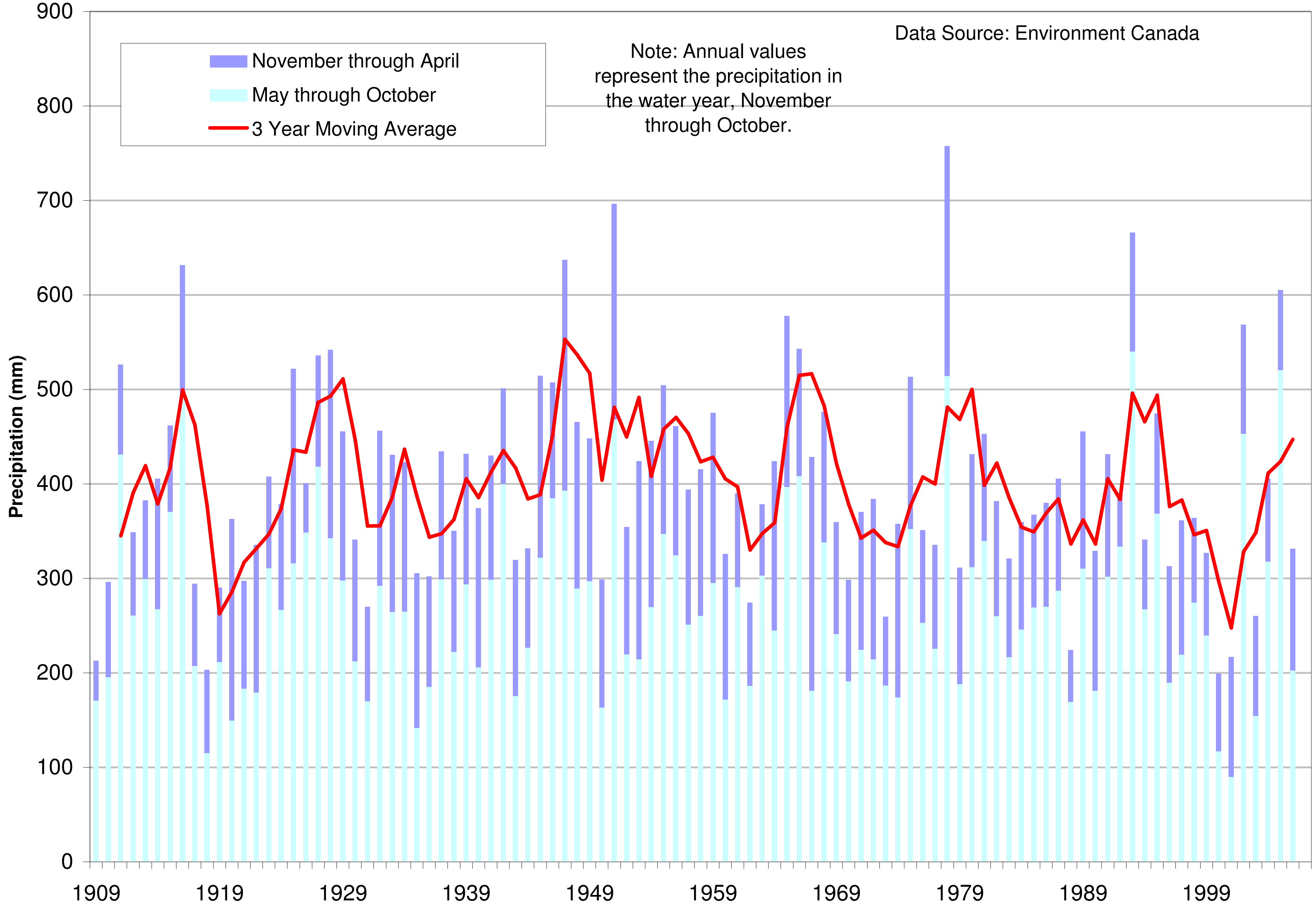


Figure 6.1
Annual Precipitation at Lethbridge



Data Source: Environment Canada

Note: Annual values represent the precipitation in the water year, November through October.

Figure 6.2
Mean Monthly Precipitation and Evapotranspiration at Lethbridge

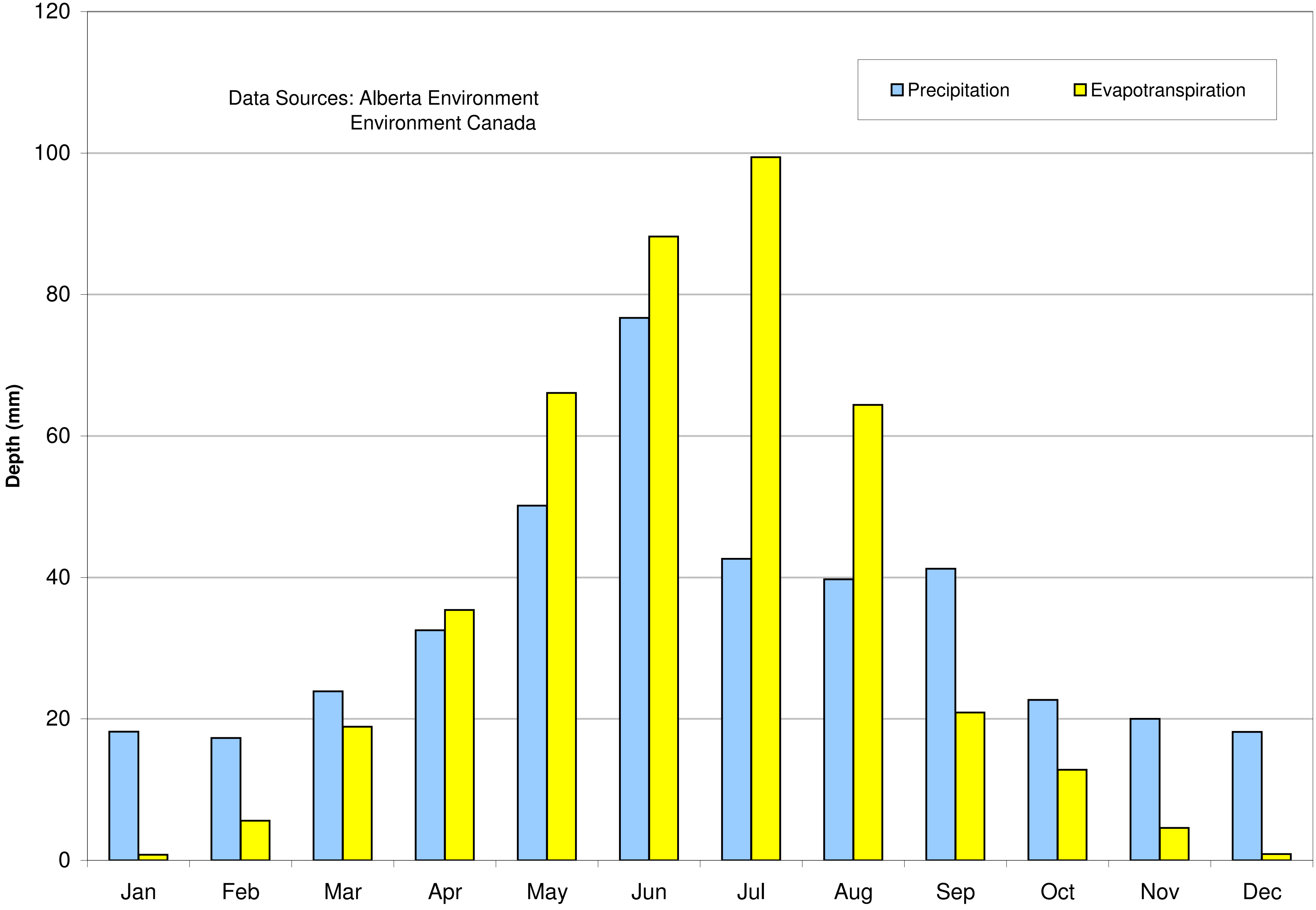


Figure 6.3
Annual Net Precipitation at Lethbridge

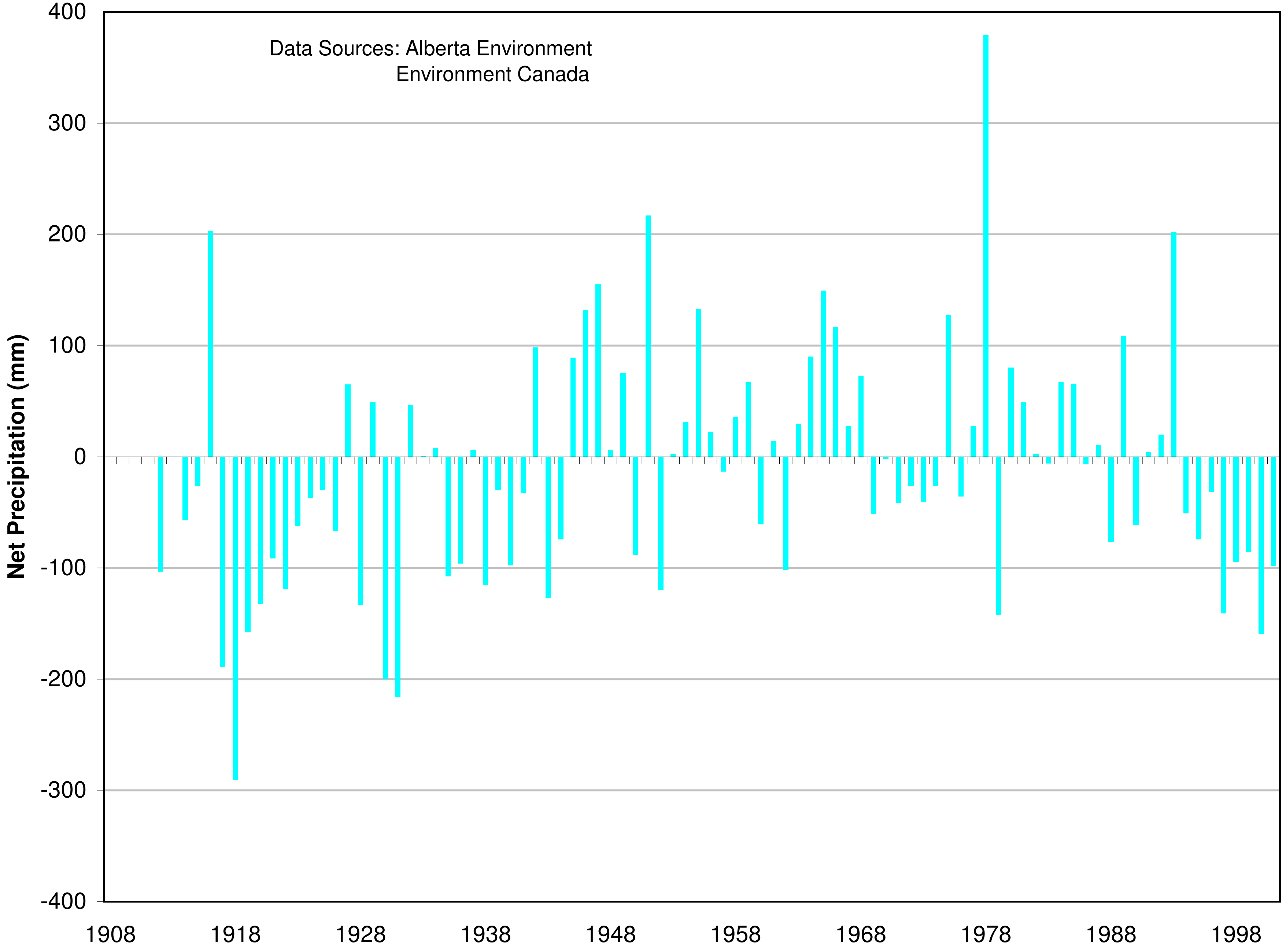


Figure 6.4
Annual Flow Volume
Oldman River near Waldron's Corner

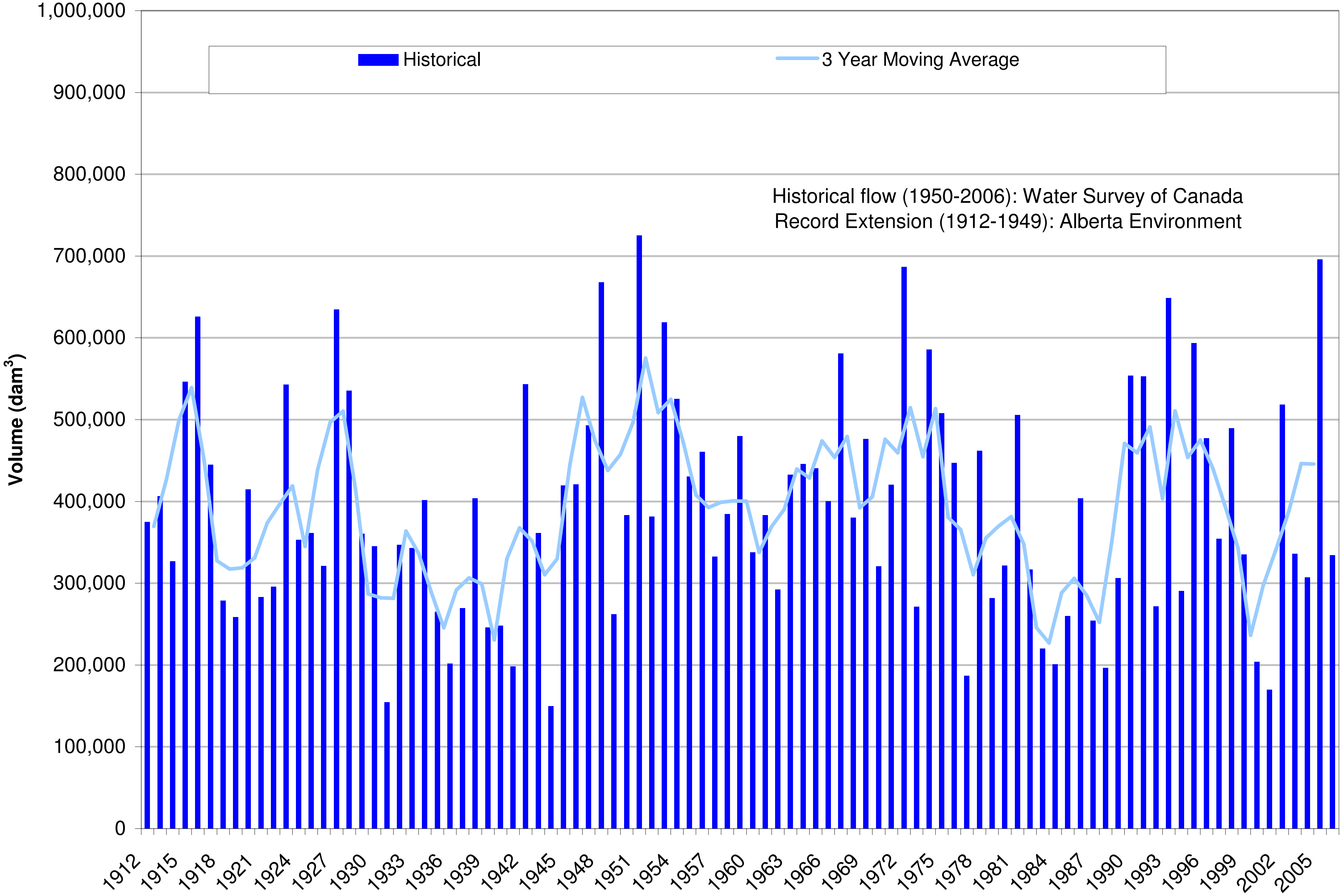


Figure 6.5
Annual Flow Volume
St. Mary River near Lethbridge

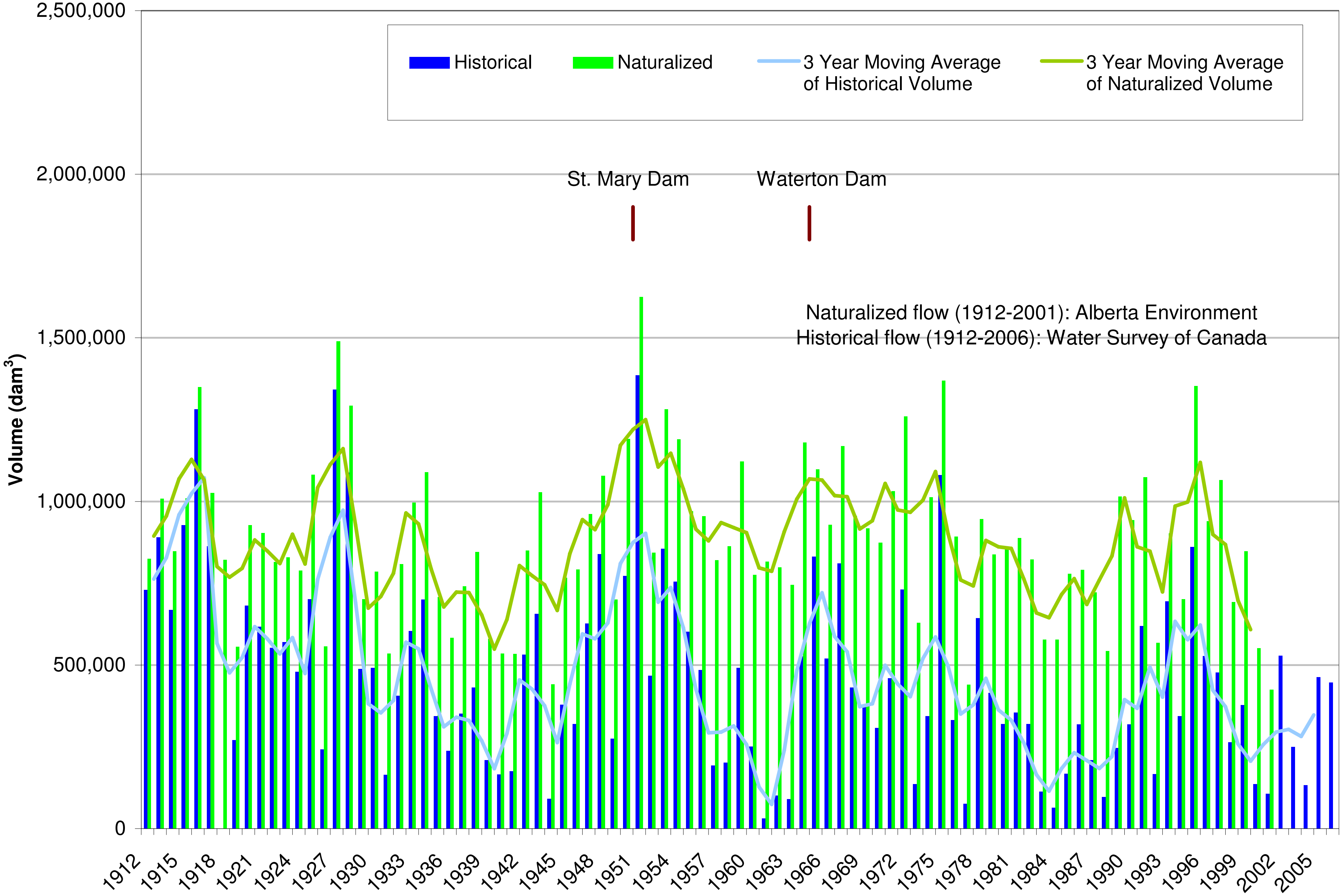


Figure 6.6
Annual Flow Volume
Oldman River near Lethbridge

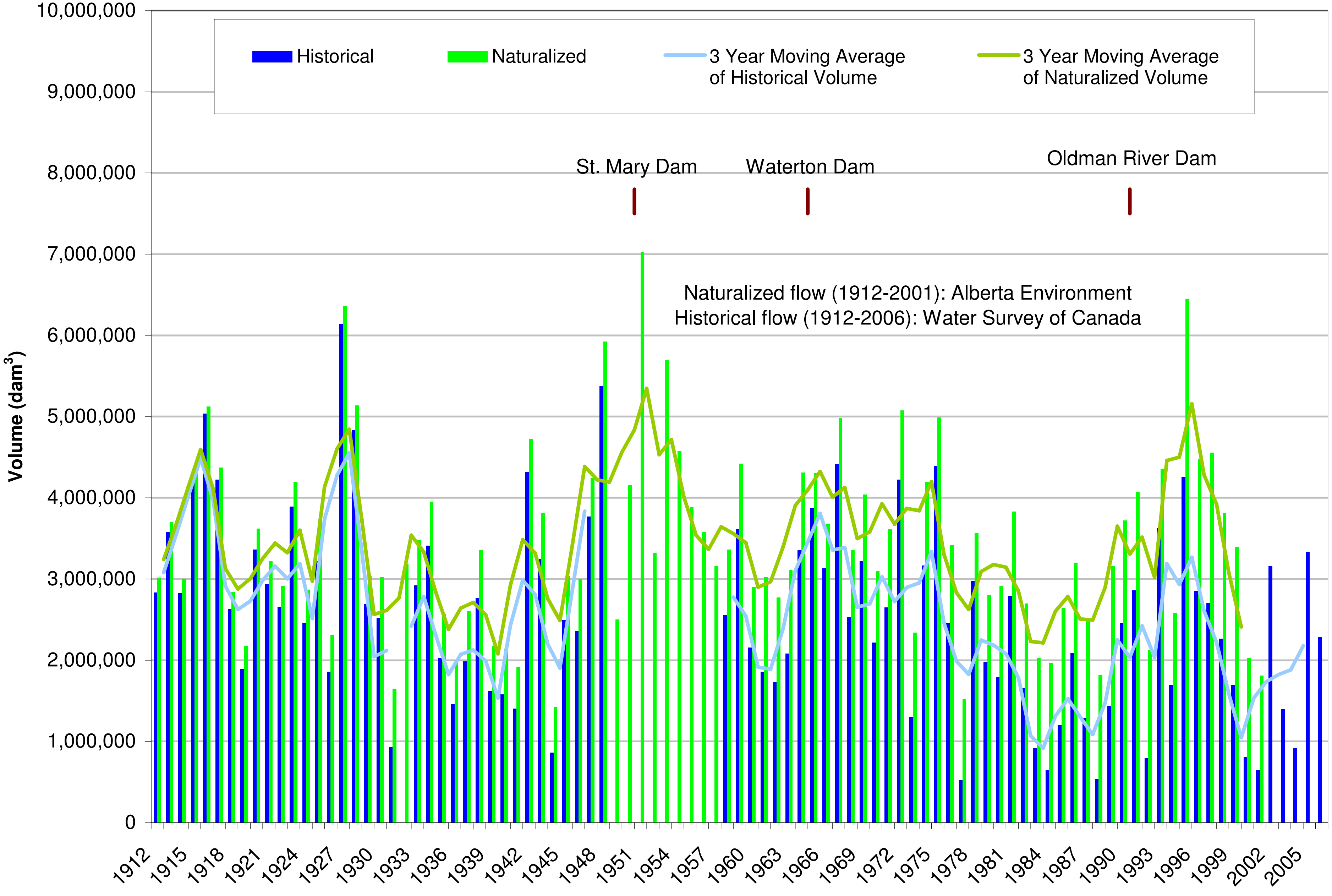


Figure 6.7
Historical Discharge Quantiles for Oldman River near Waldron's Corner, 1950 - 2006

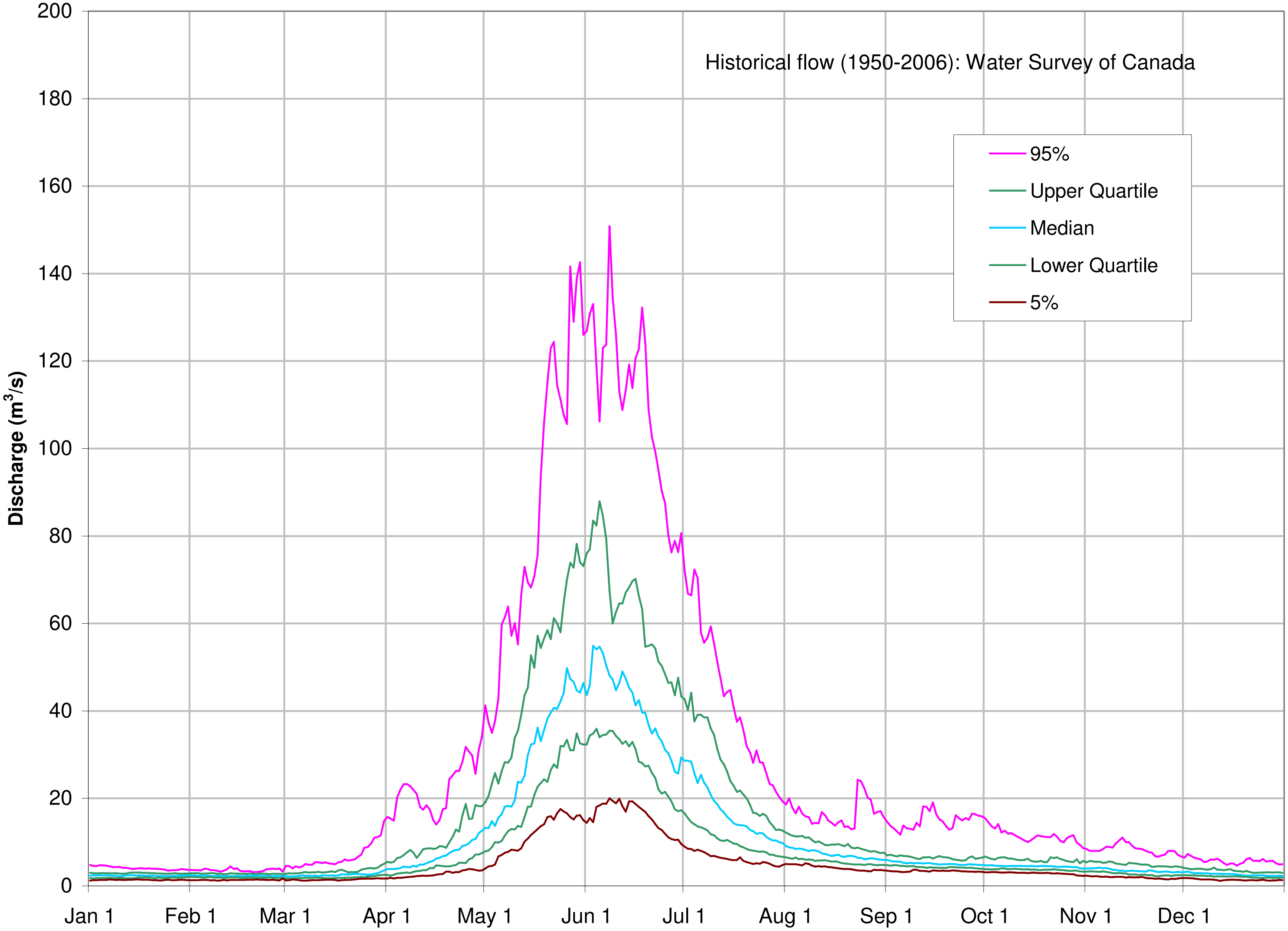


Figure 6.8
Historical Discharge Quantiles for
St. Mary River near Lethbridge, 1912 - 2006

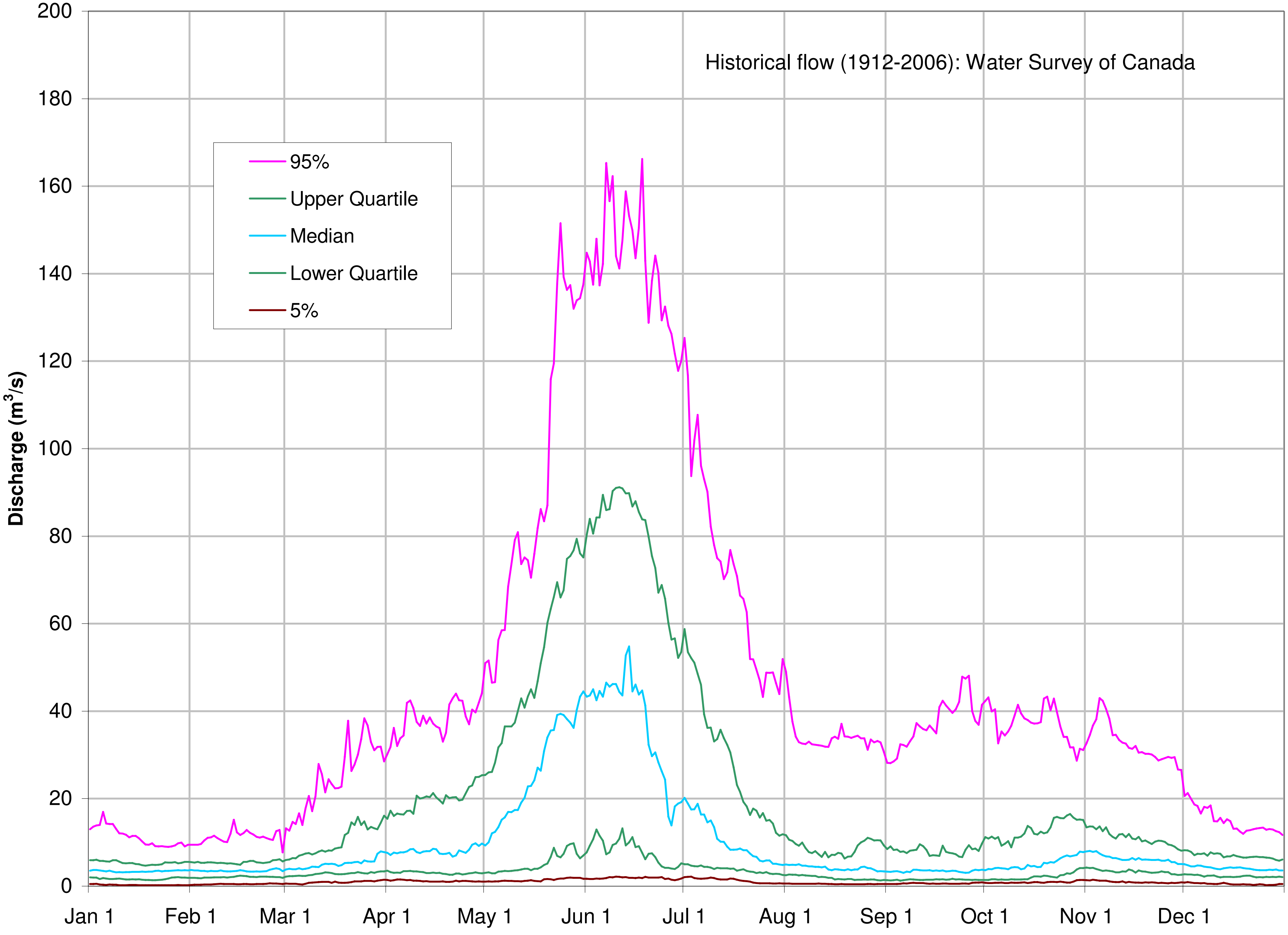


Figure 6.9
Historical Discharge Quantiles for Oldman River near Lethbridge, 1912 - 2006

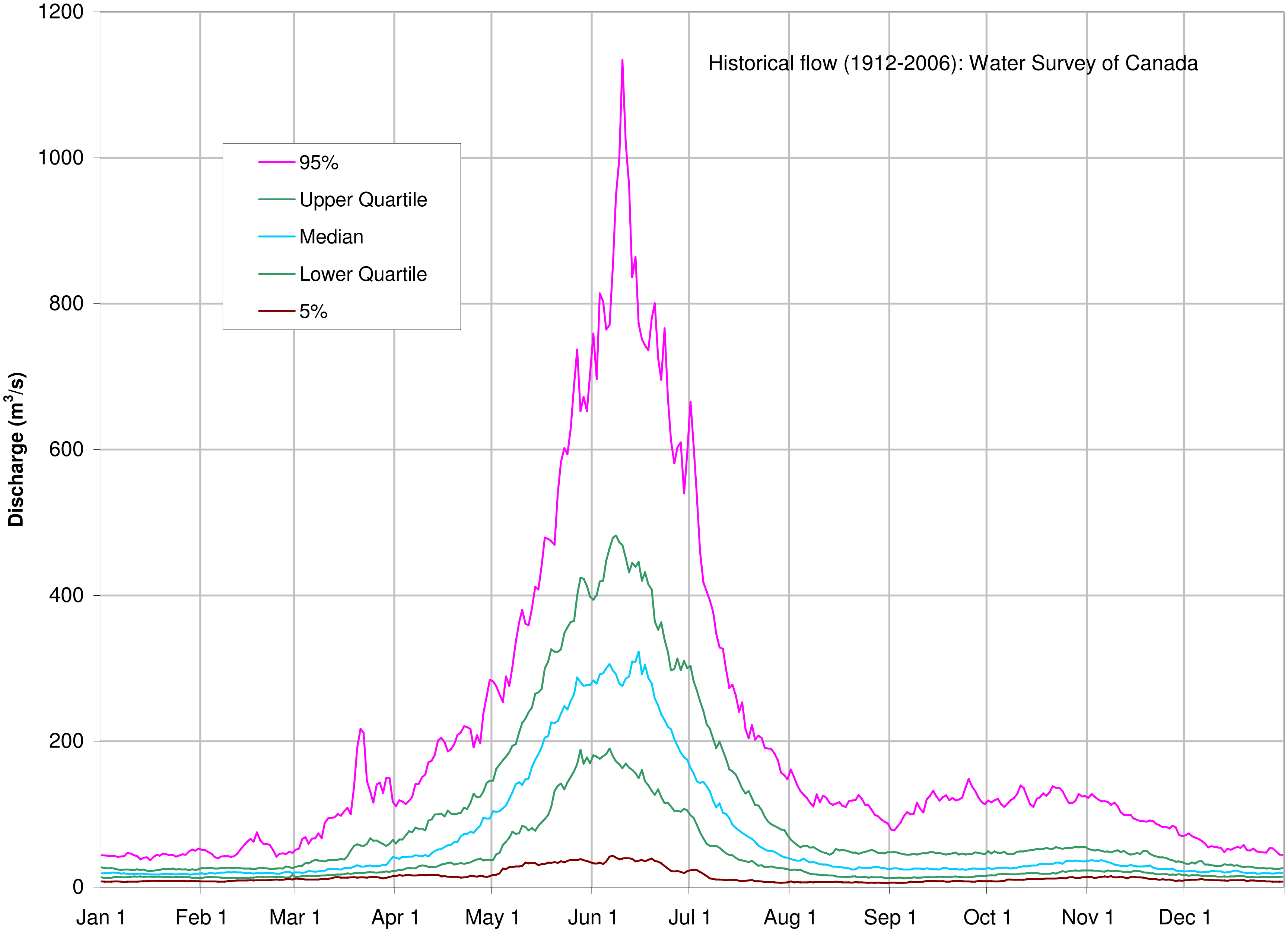


Figure 6.10
Summer Low Flow
Oldman River near Waldron's Corner

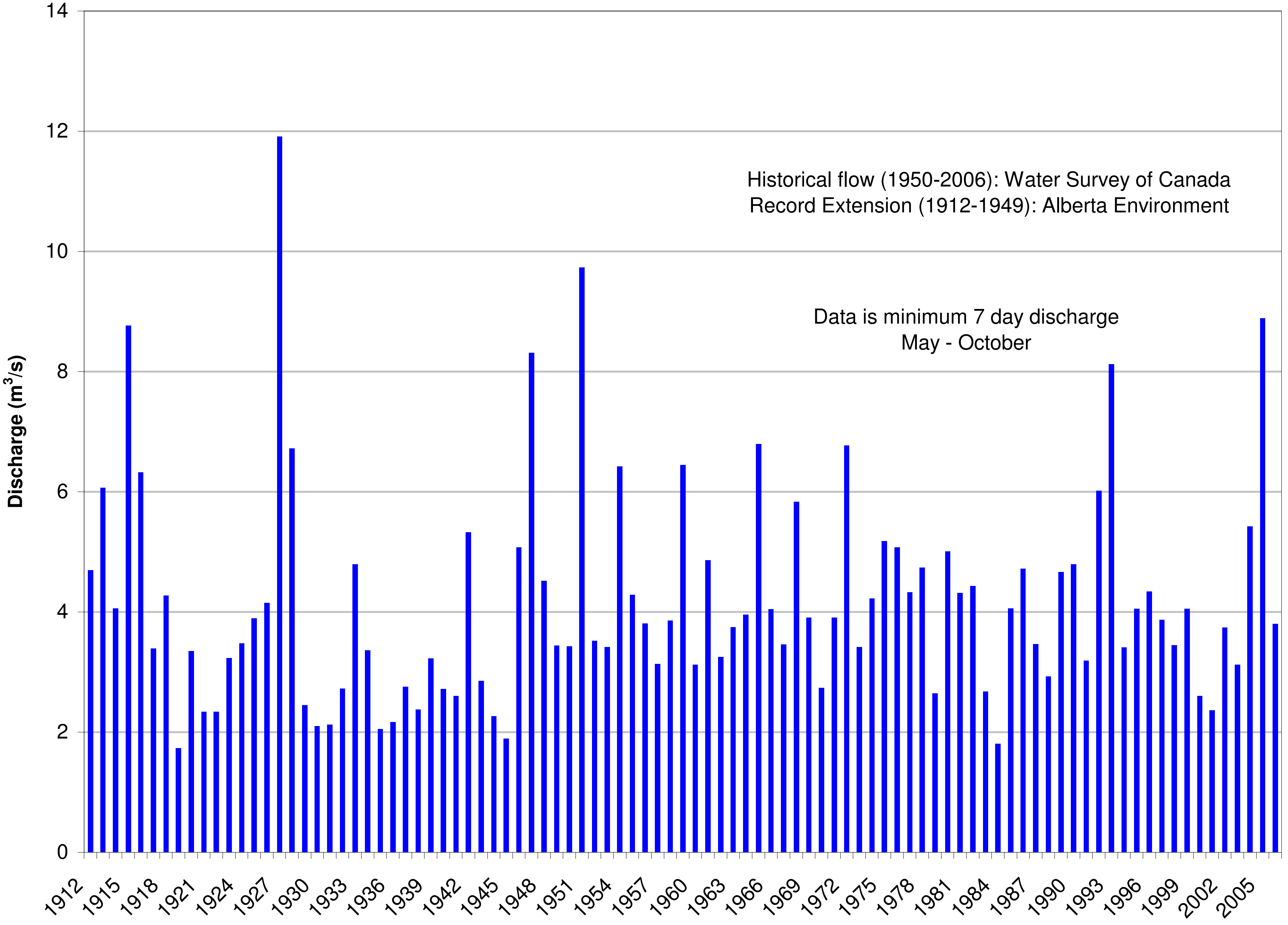


Figure 6.11
Summer Low Flow
St. Mary River near Lethbridge

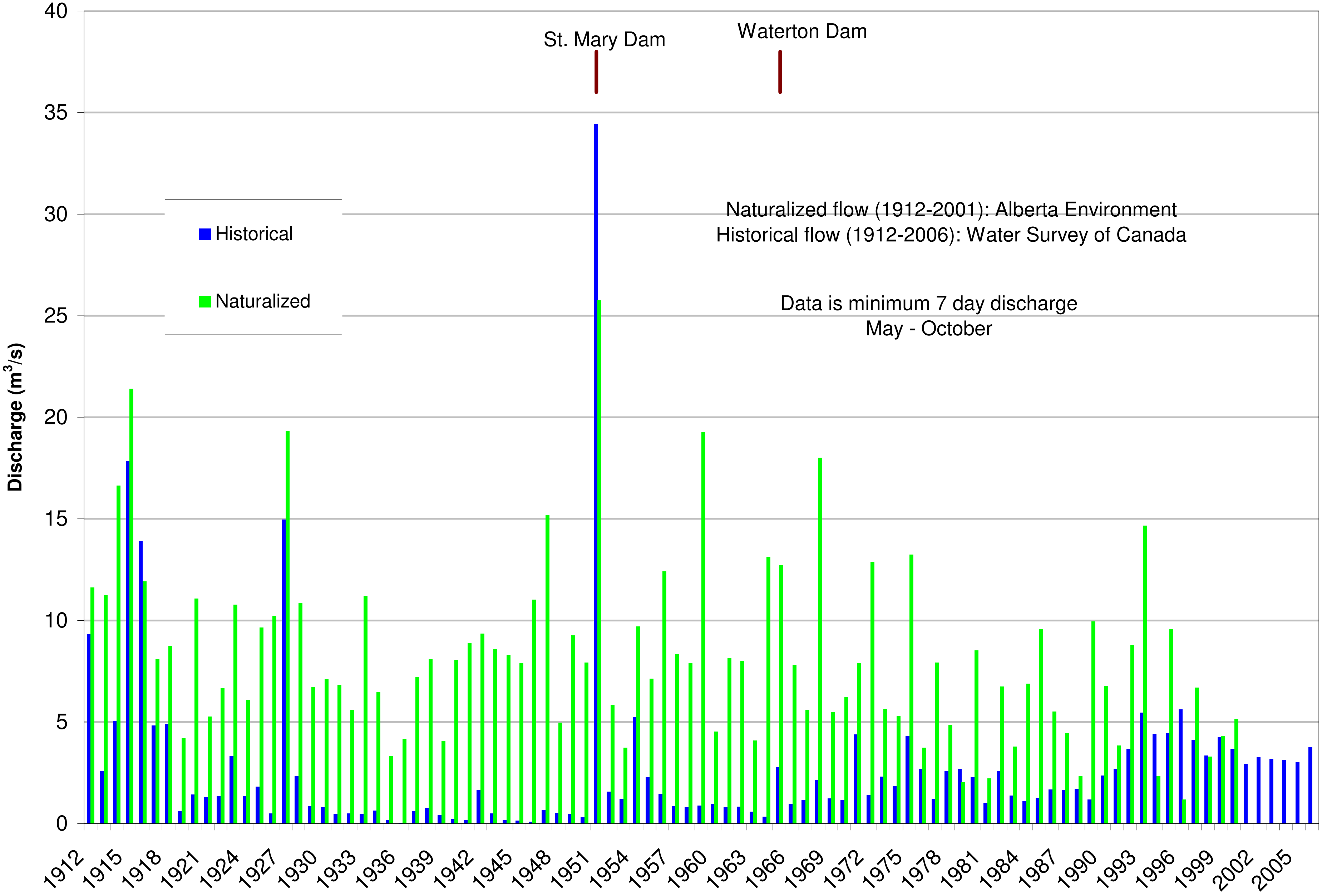


Figure 6.12
Summer Low Flow
Oldman River near Lethbridge

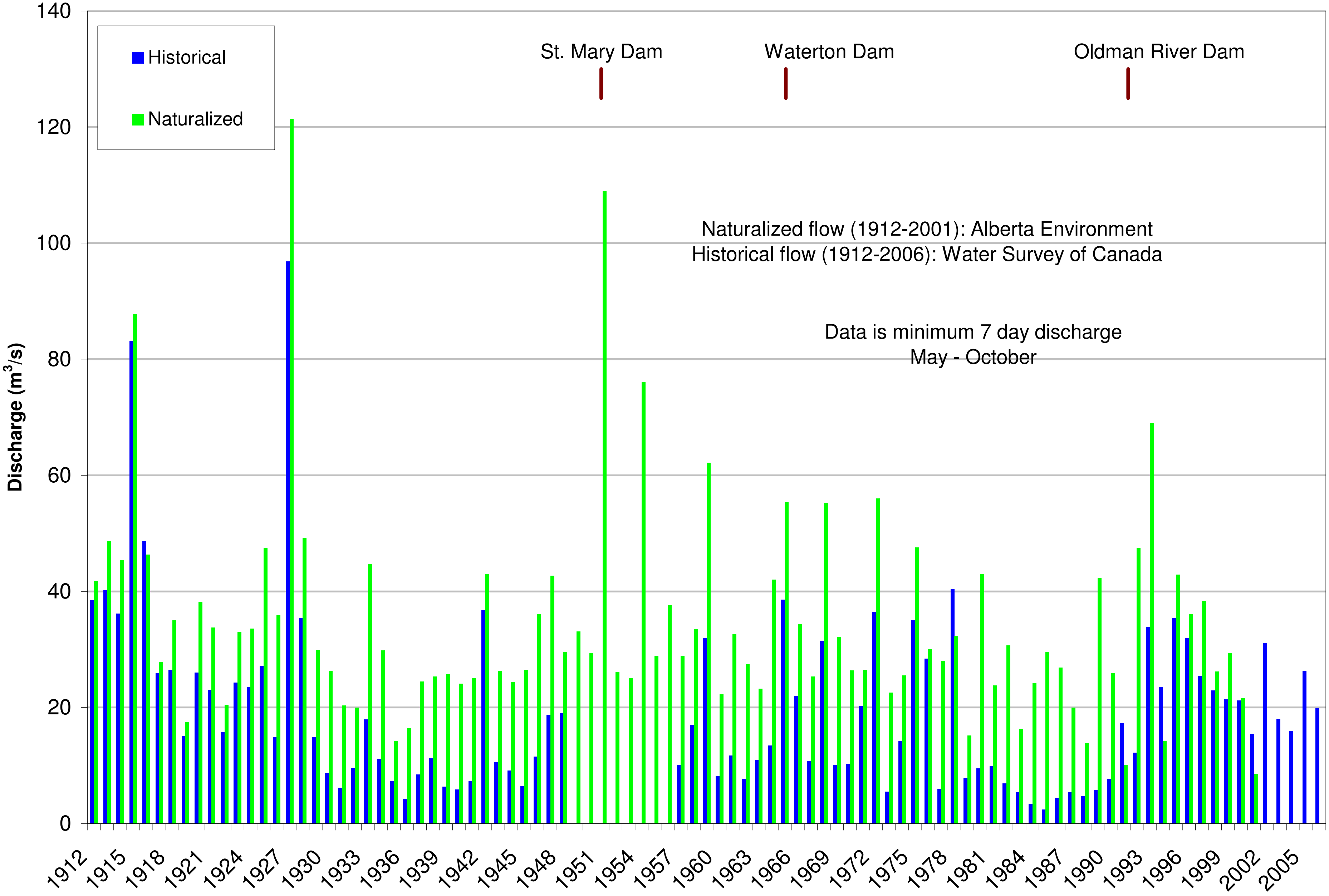
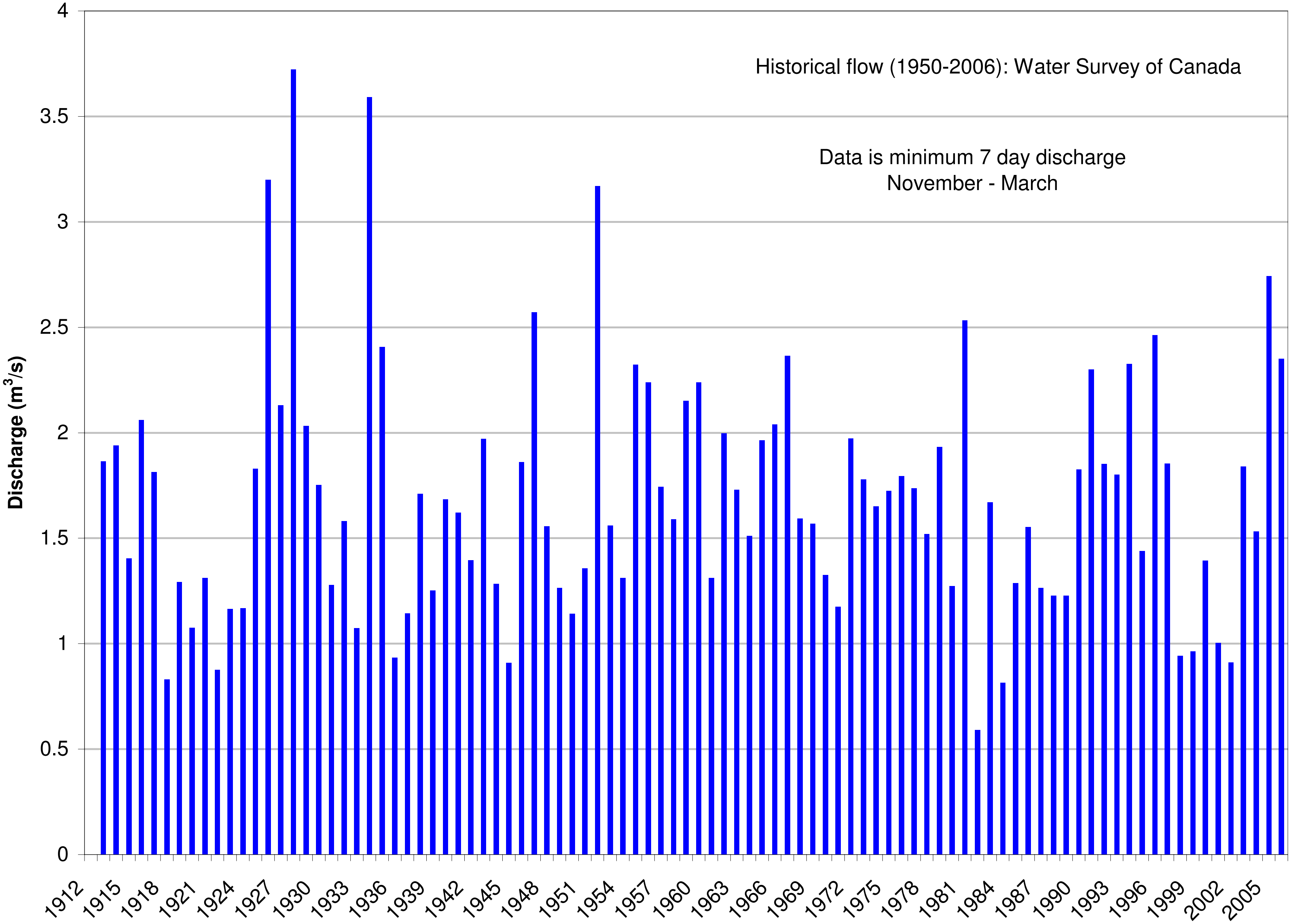
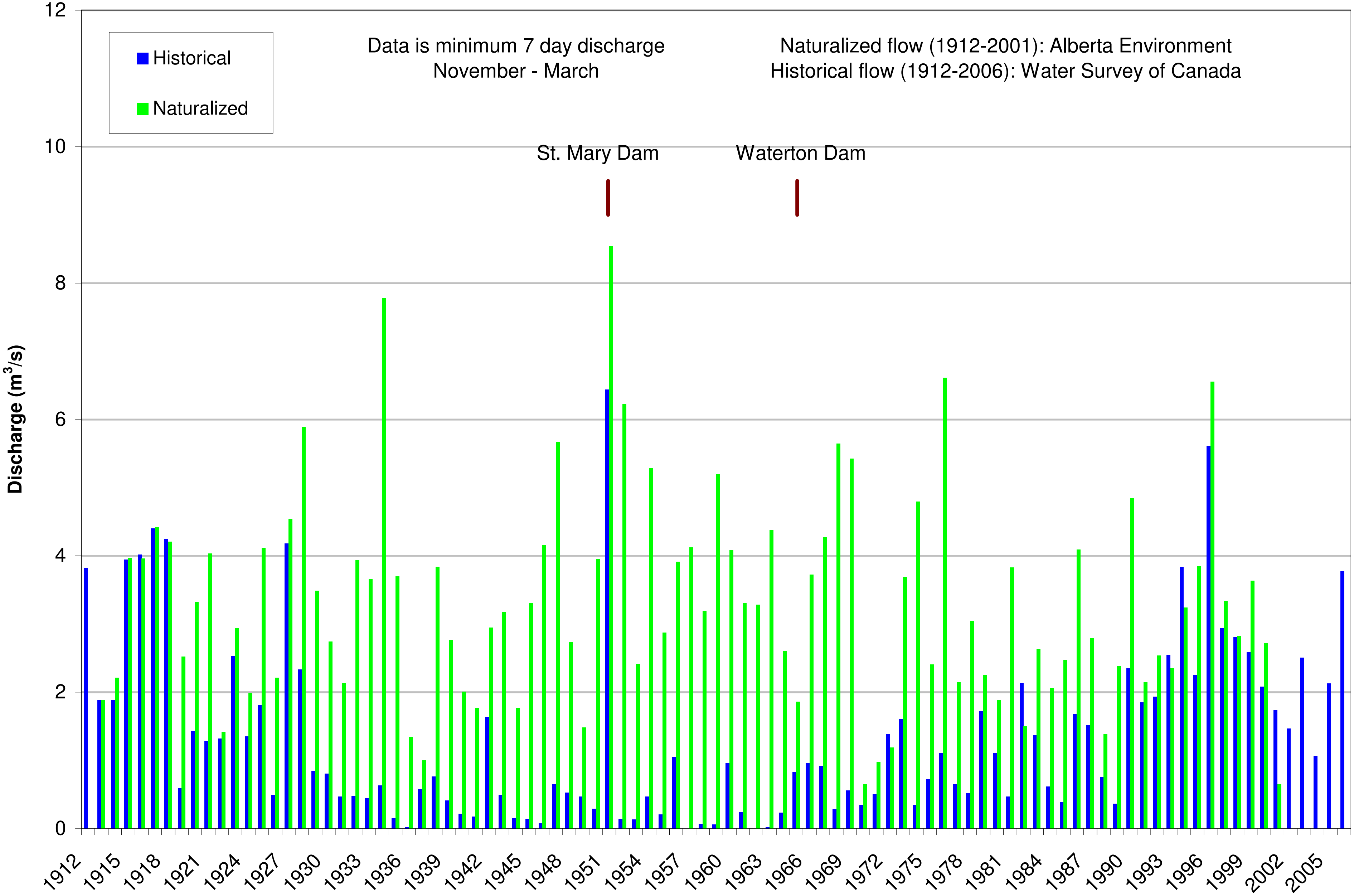


Figure 6.13
Winter Low Flow
Oldman River near Waldron's Corner



Klohn Crippen Berger

Figure 6.14
Winter Low Flow
St. Mary River near Lethbridge



Klohn Crippen Berger

Figure 6.15
Winter Low Flow
Oldman River near Lethbridge

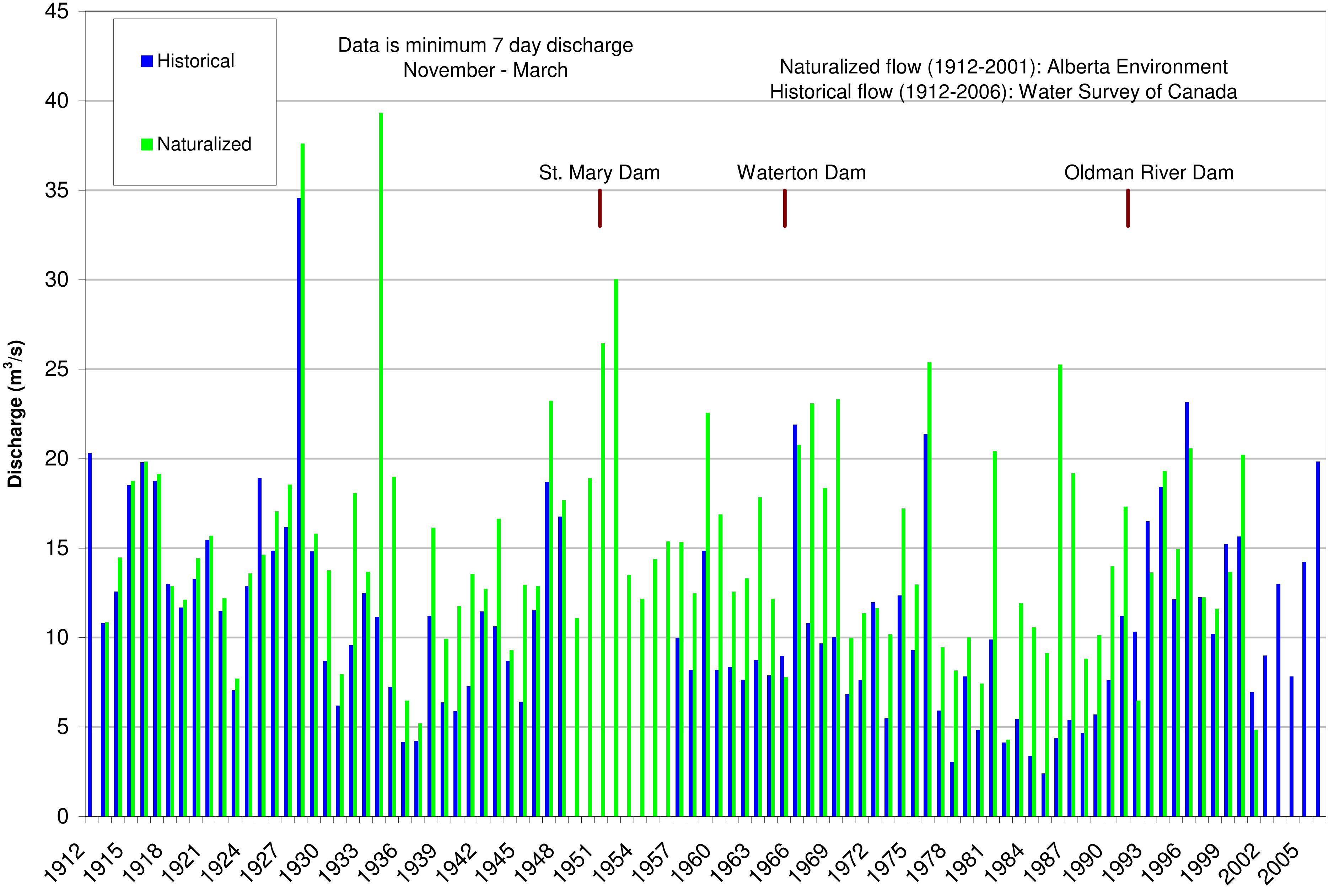


Figure 7.1
Annual Precipitation at Medicine Hat

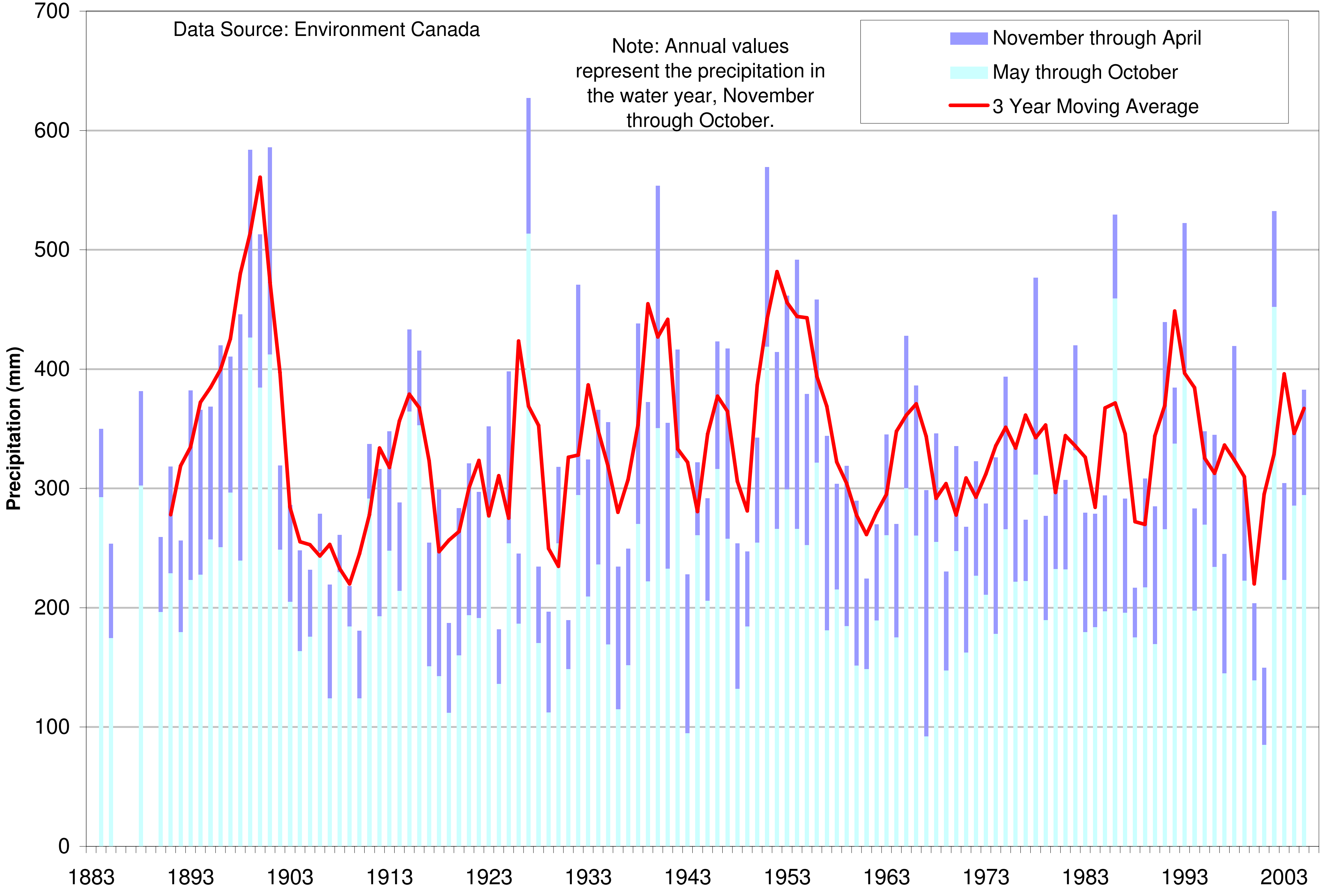


Figure 7.2

Annual Net Precipitation at Medicine Hat

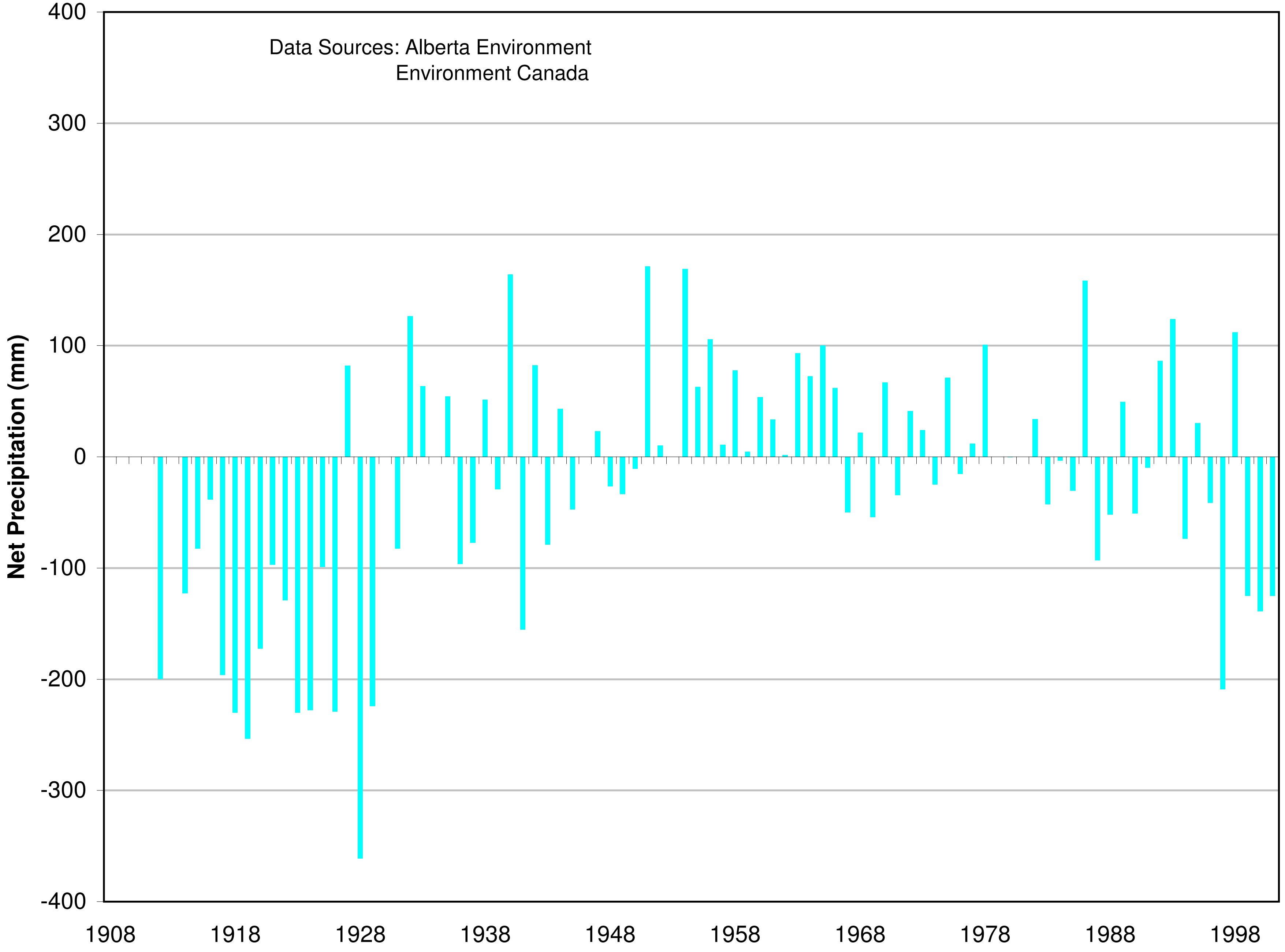
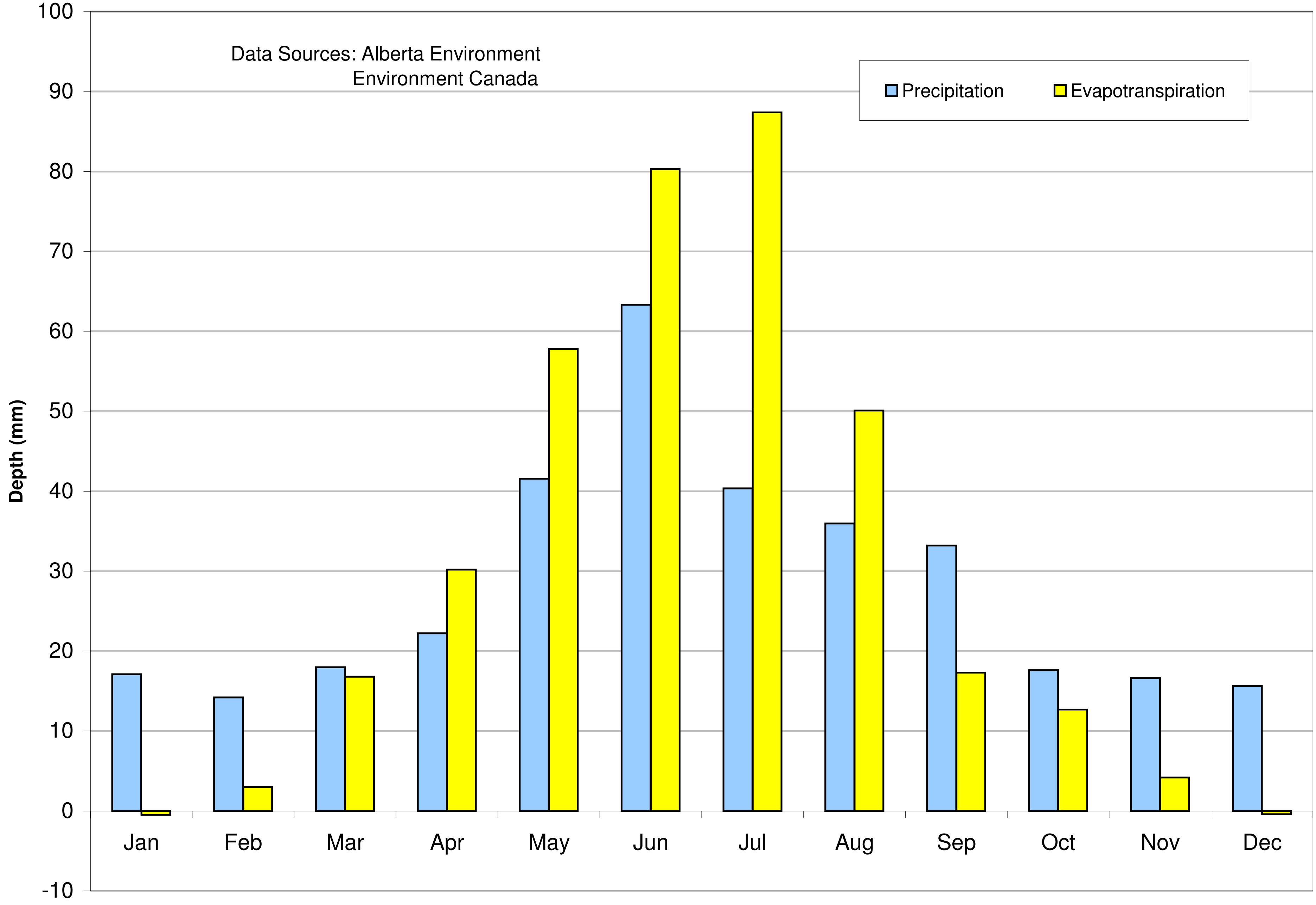


Figure 7.3
Mean Monthly Precipitation and Evapotranspiration at Medicine Hat



Klohn Crippen Berger

Figure 7.4
Annual Flow Volume
South Saskatchewan River at Medicine Hat

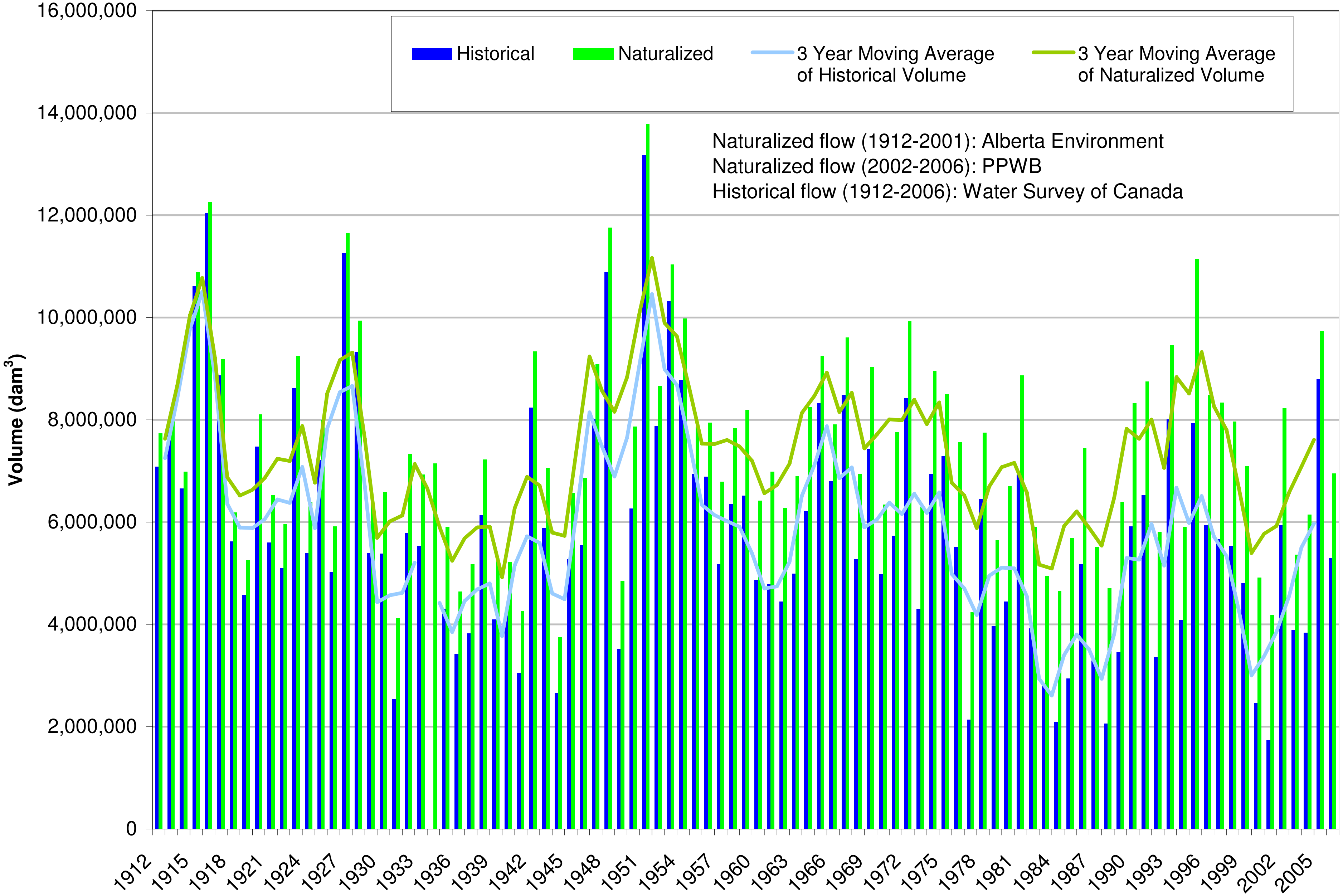


Figure 7.4
Annual Flow Volume
South Saskatchewan River at Medicine Hat

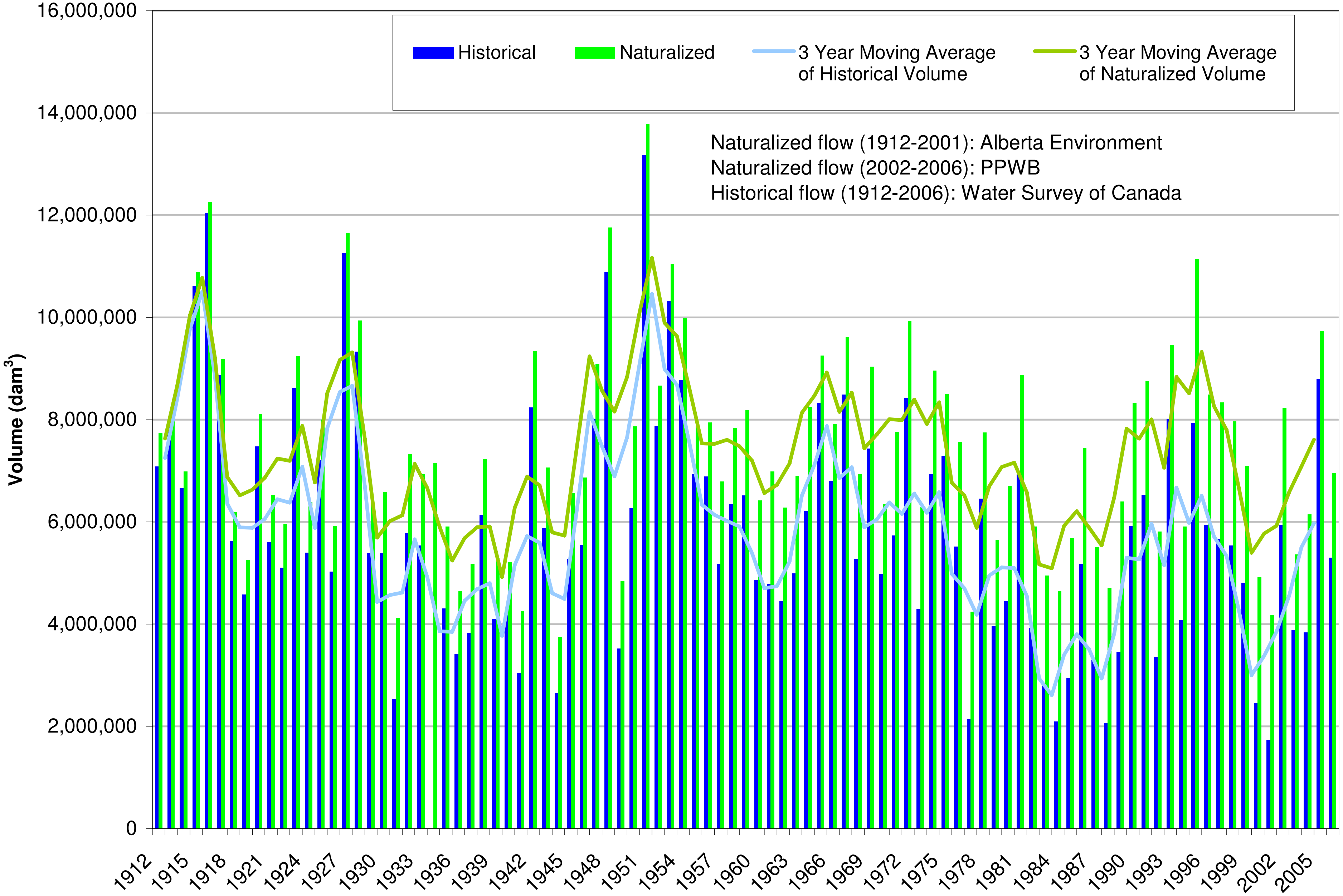


Figure 7.5
Historical Discharge Quantiles for South Saskatchewan River at Medicine Hat, 1912 - 2006

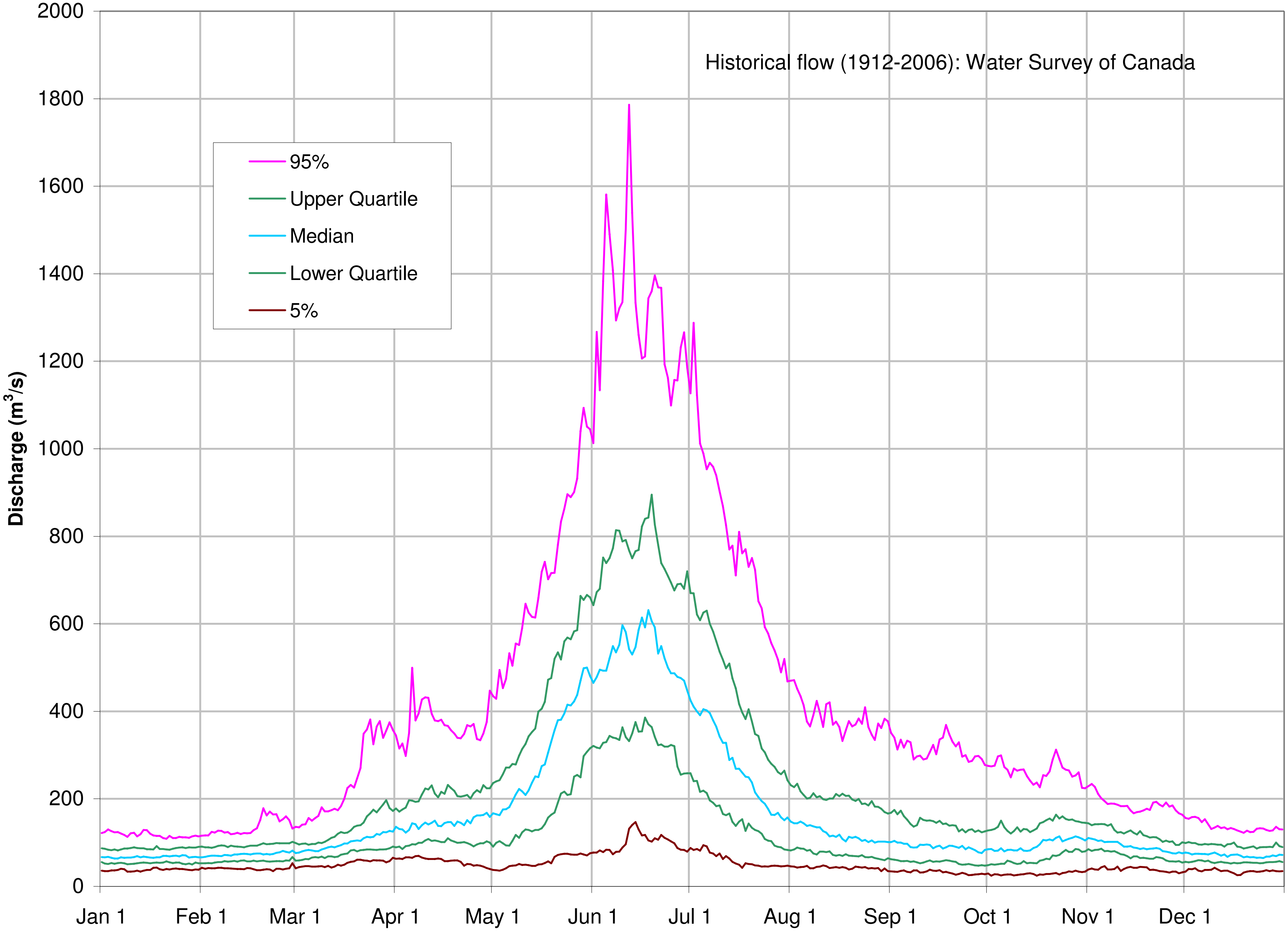
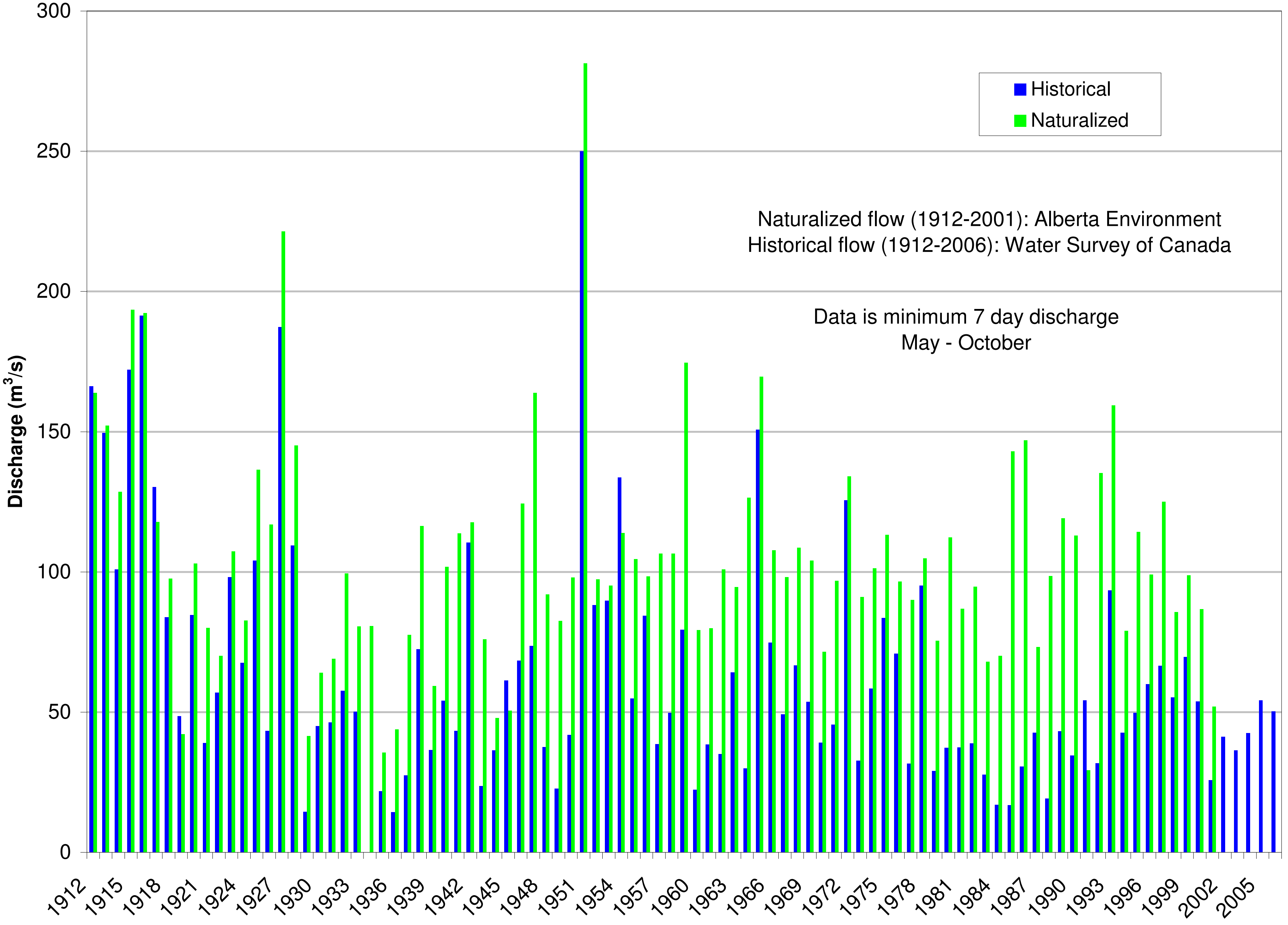


Figure 7.6
Summer Low Flow
South Saskatchewan River at Medicine Hat



Naturalized flow (1912-2001): Alberta Environment
Historical flow (1912-2006): Water Survey of Canada

Data is minimum 7 day discharge
May - October

Figure 7.7
Winter Low Flow
South Saskatchewan River at Medicine Hat

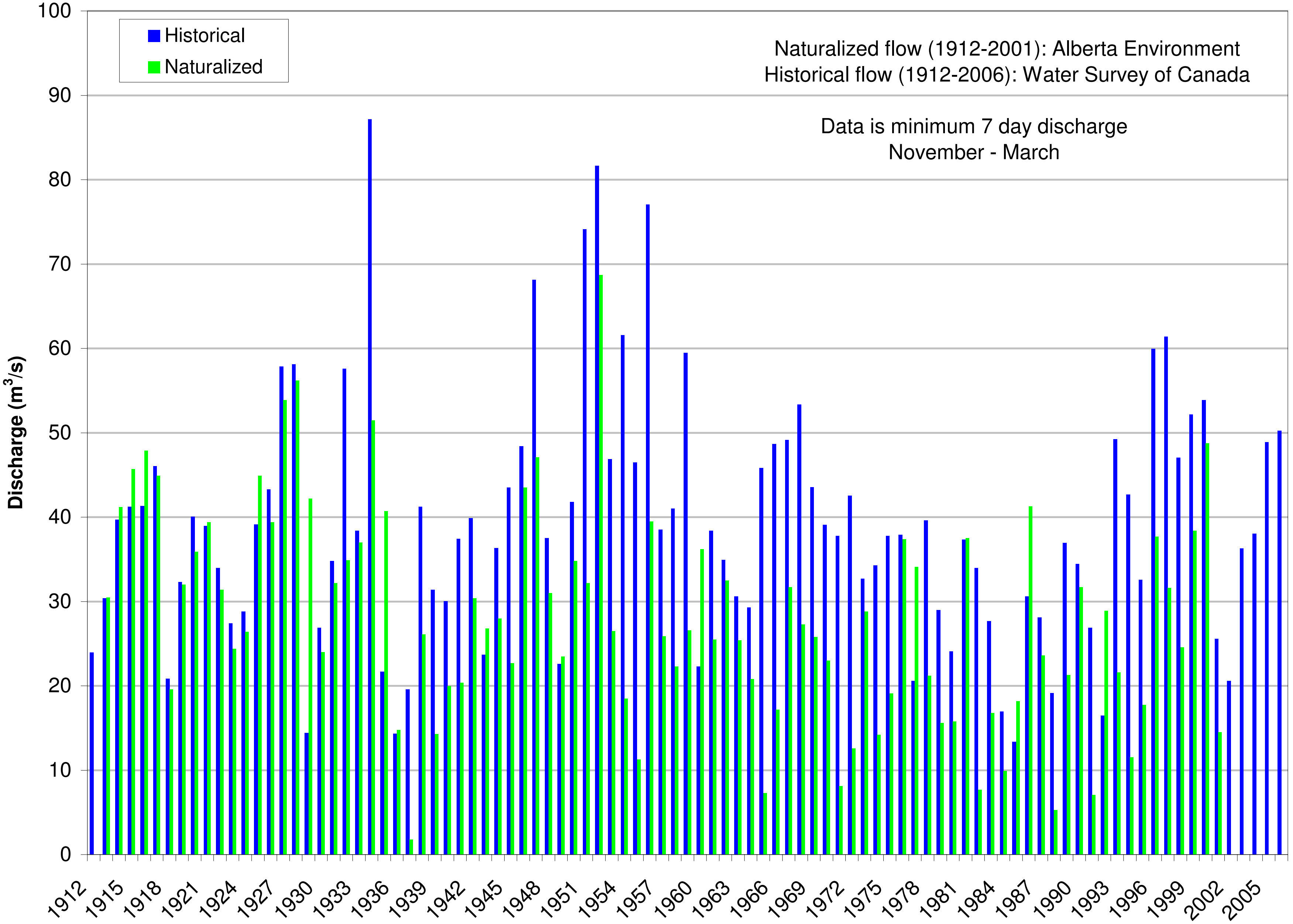


Figure 8.1: Annual Volumes for Interprovincial Apportionment

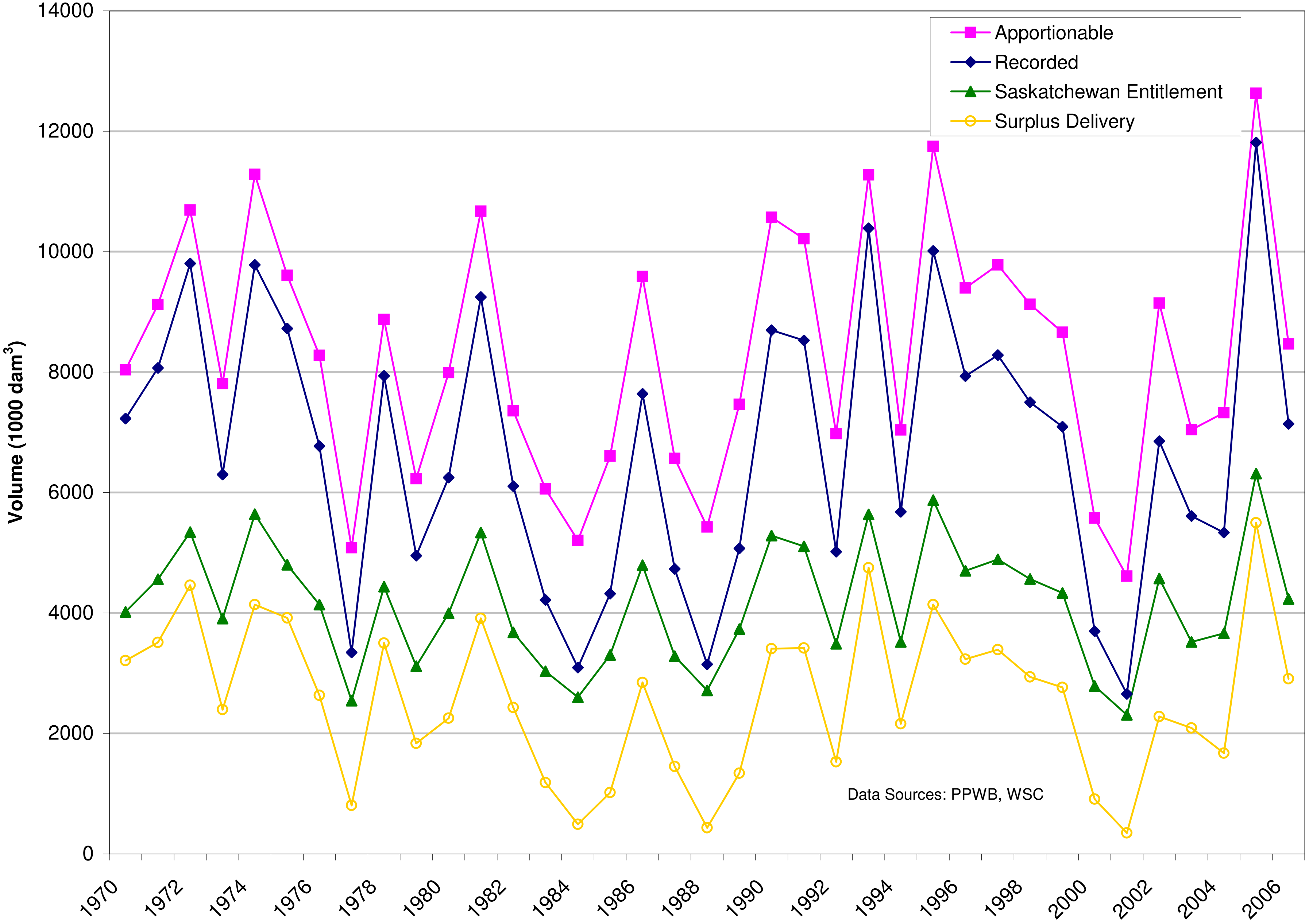
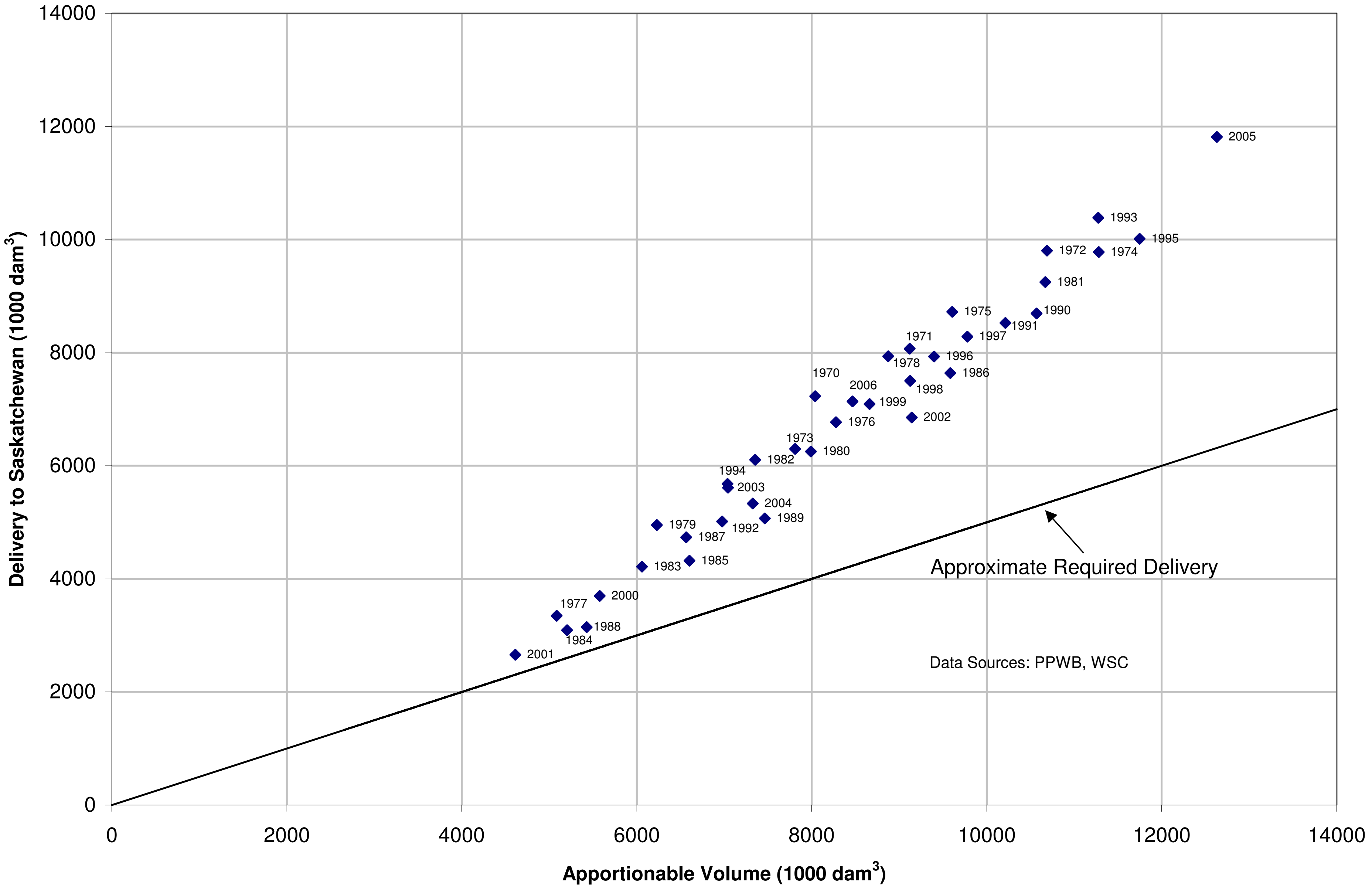
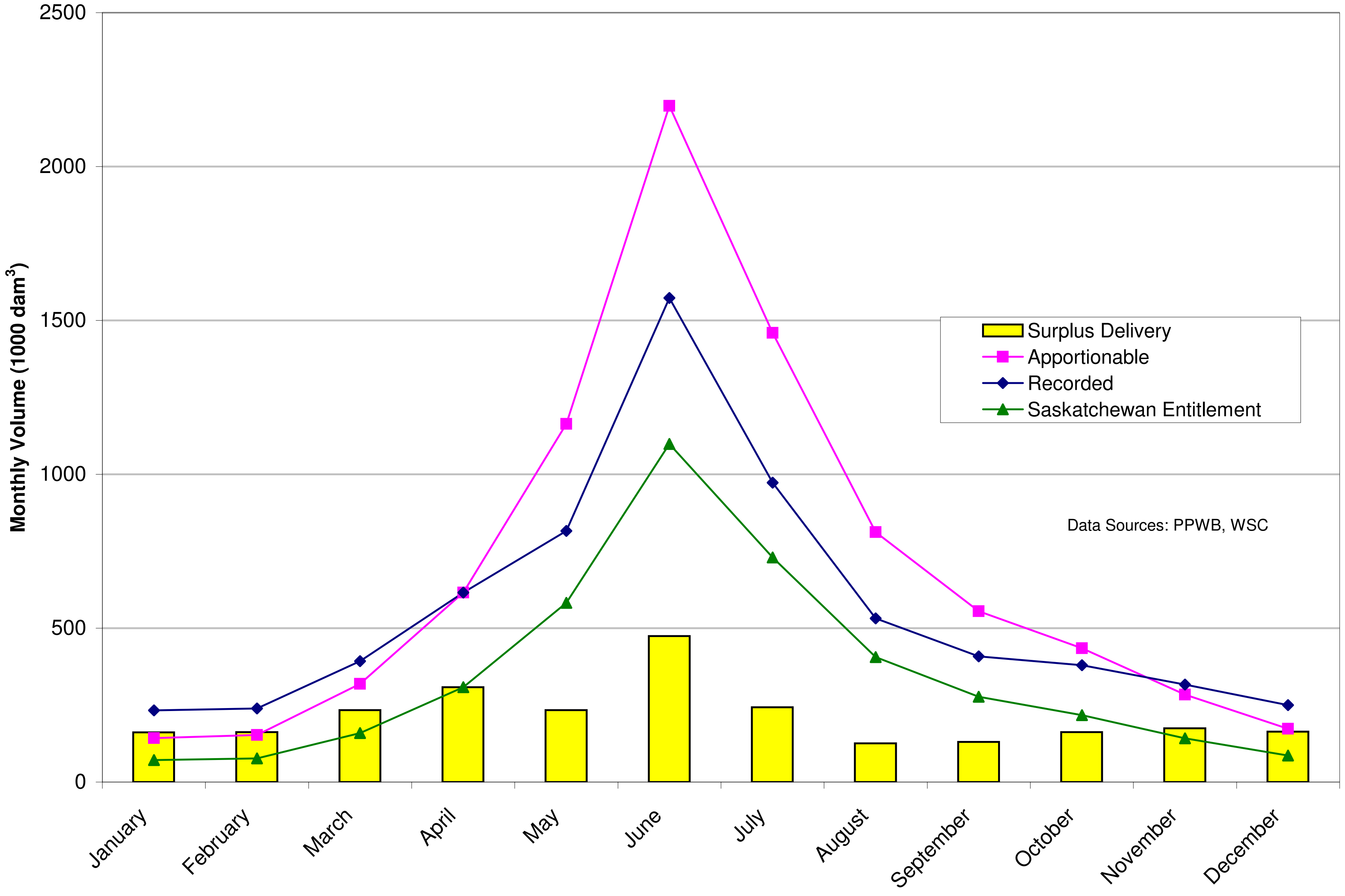


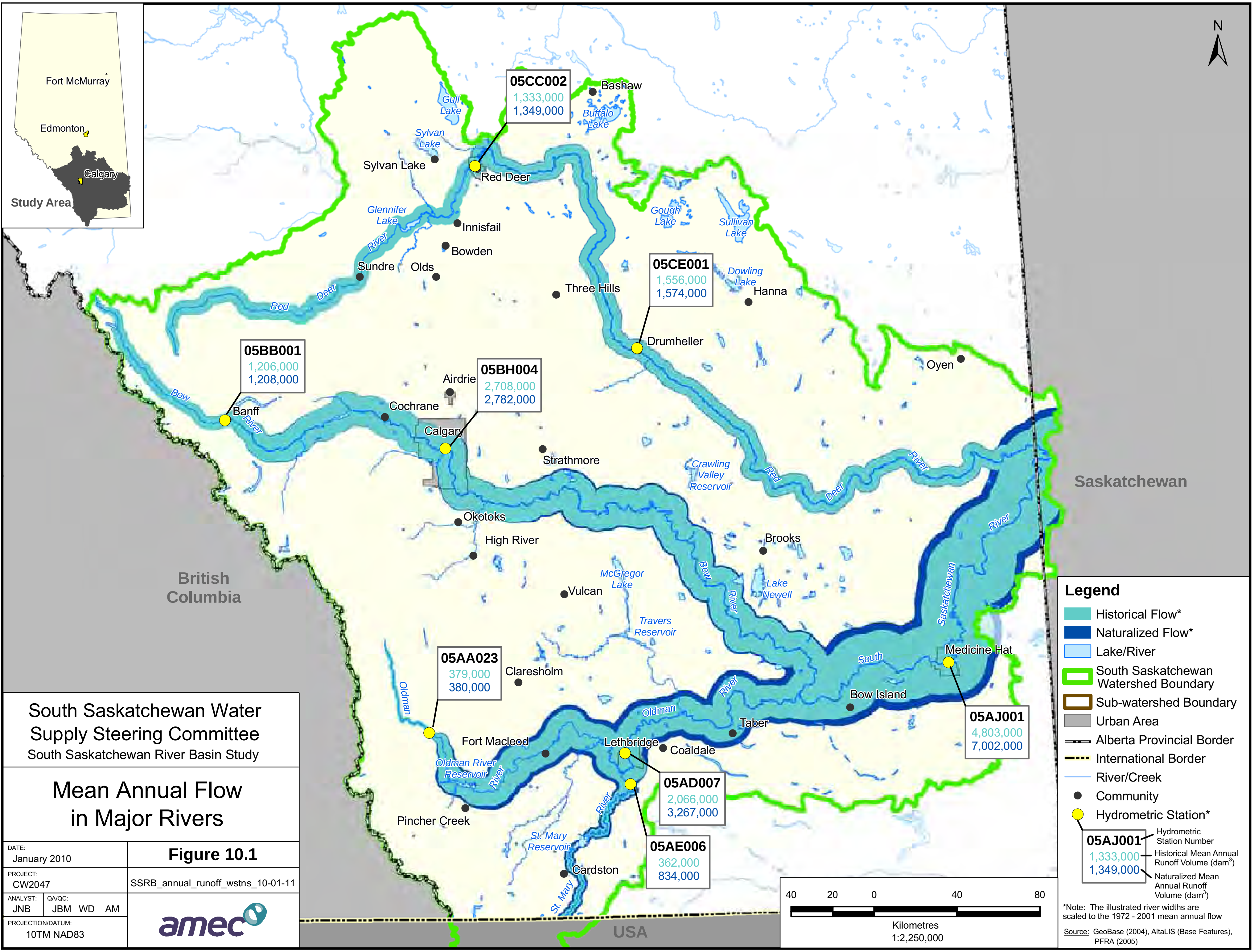
Figure 8.2: Annual Water Delivery to Saskatchewan 1970-2006



Data Sources: PPWB, WSC

Figure 8.3: Monthly Apportionment of South Saskatchewan River Flow 1970-2006





*Note: The illustrated river widths are scaled to the 1972 - 2001 mean annual flow

Source: GeoBase (2004), AltaLIS (Base Features), PFRA (2005)

South Saskatchewan Water Supply Steering Committee
South Saskatchewan River Basin Study

Mean Annual Flow in Major Rivers

DATE: January 2010

Figure 10.1

PROJECT: CW2047

SSRB_annual_runoff_wstns_10-01-11

ANALYST: JNB

QA/QC: JBM WD AM

PROJECTION/DATUM: 10TM NAD83

amec

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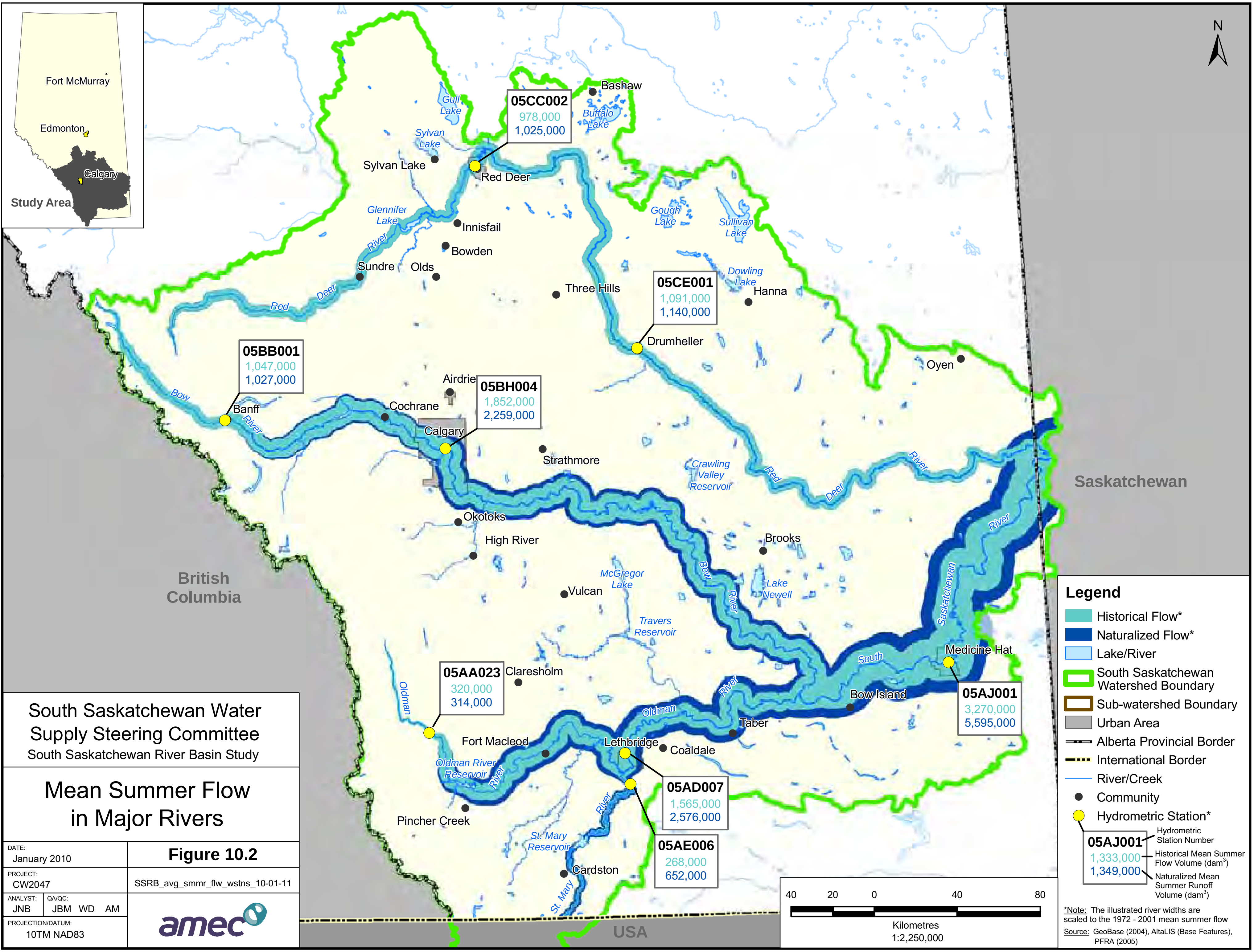

*Note: The illustrated river widths are scaled to the 1972 - 2001 mean summer flow

Source: GeoBase (2004), AltaLIS (Base Features), PFRA (2005)

South Saskatchewan Water
Supply Steering Committee
South Saskatchewan River Basin Study

Mean Summer Flow
in Major Rivers

DATE:
January 2010

Figure 10.2

PROJECT:
CW2047

SSRB_avg_smmr_flw_wstns_10-01-11

ANALYST: JNB
QA/QC: JBM WD AM

PROJECTION/DATUM:
10TM NAD83

amec

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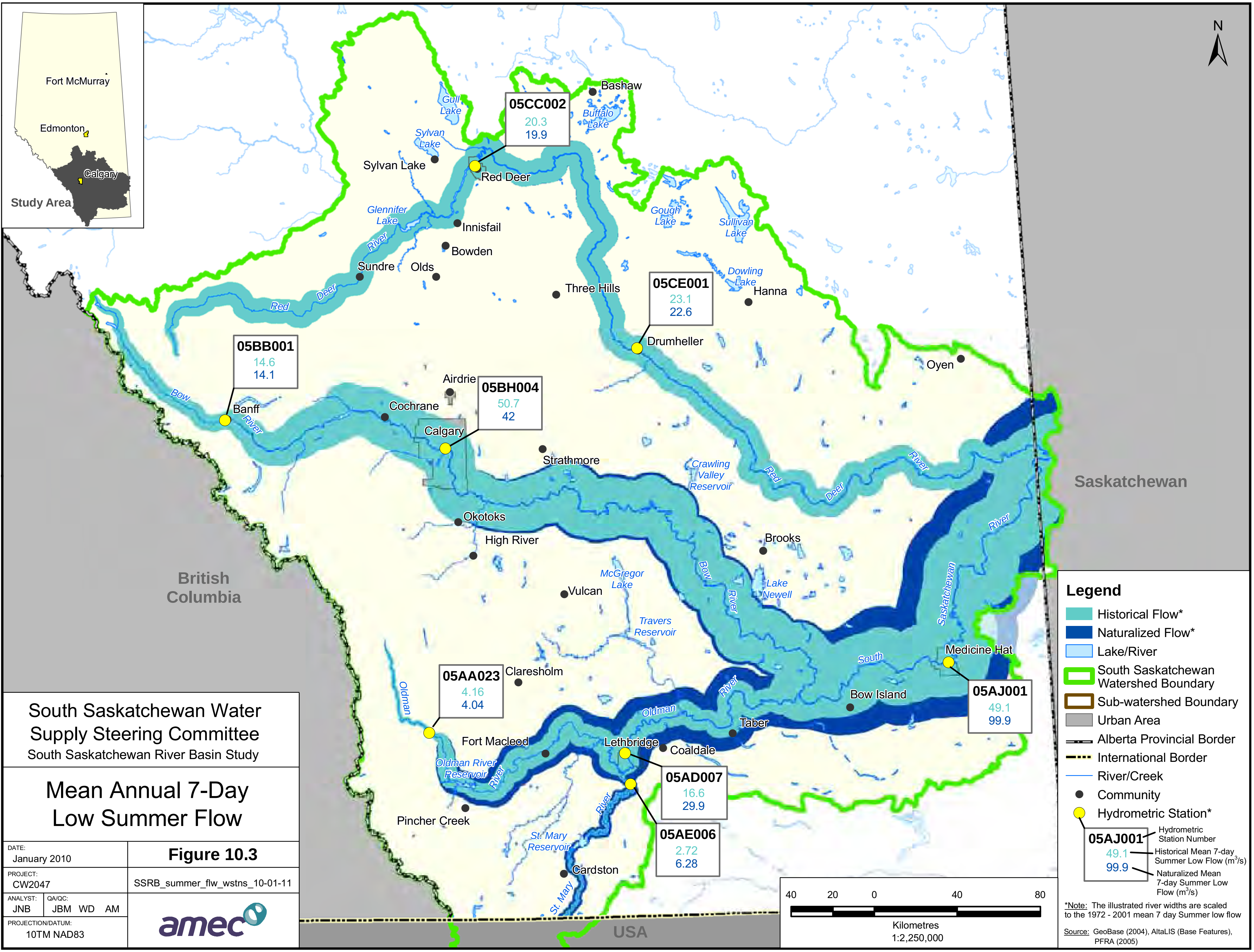

*Note: The illustrated river widths are scaled to the 1972 - 2001 mean 7 day Summer low flow

Source: GeoBase (2004), AltaLIS (Base Features), PFRA (2005)

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South Saskatchewan Water Supply Steering Committee

South Saskatchewan River Basin Study

Mean Annual 7-Day Low Summer Flow

DATE: January 2010

Figure 10.3

PROJECT: CW2047

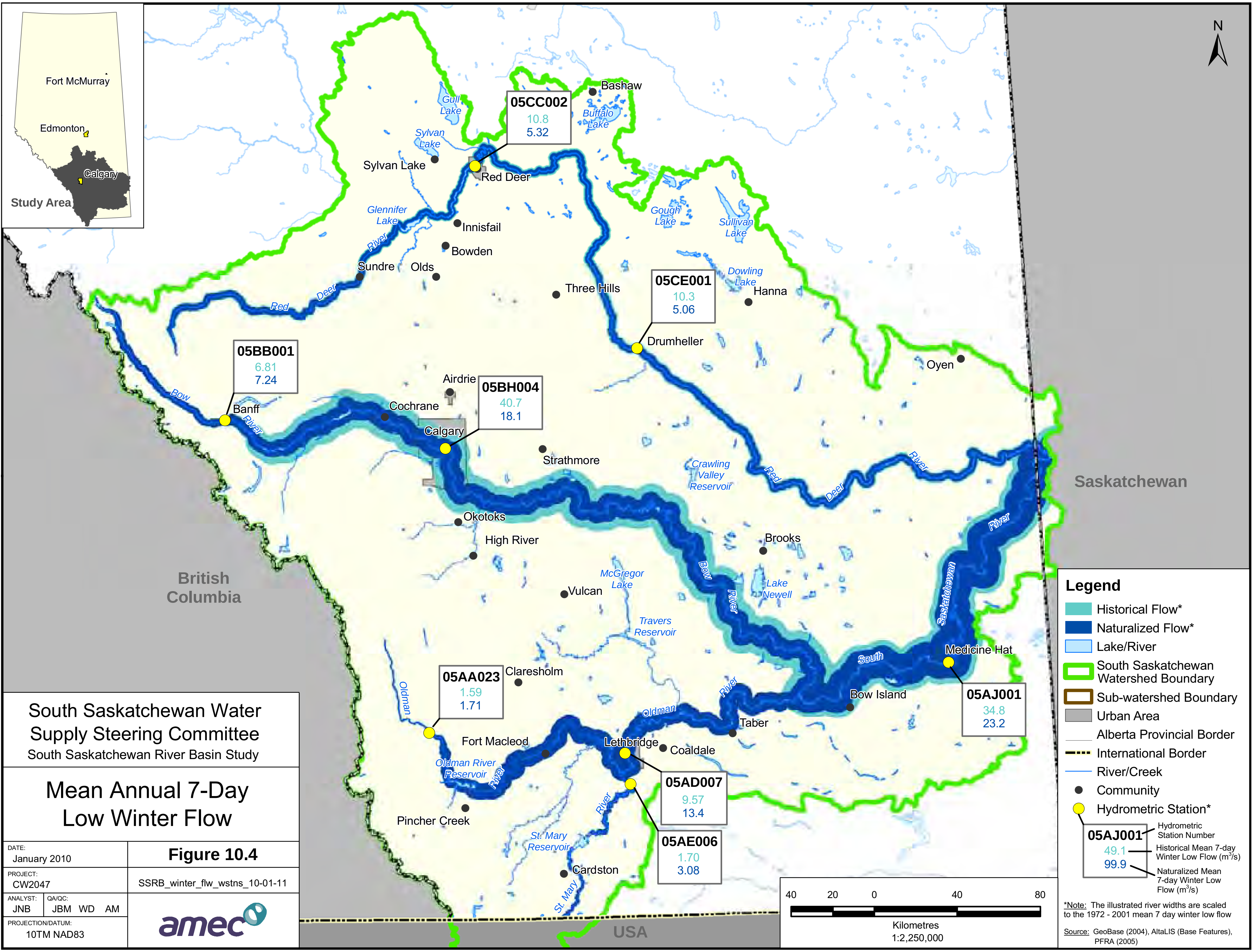
SSRB_summer_flw_wstns_10-01-11

ANALYST: JNB

QA/QC: JBM WD AM

PROJECTION/DATUM: 10TM NAD83

amec



*Note: The illustrated river widths are scaled to the 1972 - 2001 mean 7 day winter low flow

Source: GeoBase (2004), AltaLIS (Base Features), PFRA (2005)

South Saskatchewan Water Supply Steering Committee
South Saskatchewan River Basin Study

Mean Annual 7-Day Low Winter Flow

DATE: January 2010	Figure 10.4
PROJECT: CW2047	SSRB_winter_flw_wstns_10-01-11
ANALYST: JNB QA/QC: JBM WD AM	amec
PROJECTION/DATUM: 10TM NAD83	

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Technical Memorandum No. 2A – Municipal and Rural Domestic Water Demand

May 2008

South Saskatchewan River Basin
Water Supply Study

Technical Memorandum No. 2A

May 2008

Municipal and Rural Domestic Water Demand

Prepared for: South Saskatchewan Water Supply Steering Committee

Prepared by: AMEC Earth and Environmental

Date: May 21, 2008

Issues

- What are the current and 2030 projected populations of municipalities in the South Saskatchewan River Basin (SSRB)?
- What are the current municipal and rural domestic water demands within the basin?
- How much treated wastewater is returned to source streams?
- What is the potential water demand in 2030 based on projected urban and rural population growth with the basin?

1.0 INTRODUCTION

The water management plan for the South Saskatchewan River Basin (SSRB) was approved by the Alberta Government in August 2006. This plan led to establishment of the basin's Water Conservation Objectives (WCOs) in January 2007, and restricted the use of all unallocated water in the Bow, Oldman and South Saskatchewan Sub-basins in August 2007 (Regulation 171/2007). The plan and subsequent decisions have heightened competition for water in the SSRB. Water users throughout the basin are concerned about the security of supply and economic growth now and in the future.

The SSRB Water Supply Steering Committee commissioned a science-based study with objectives as follows:

- assess current and future water supply and demand in the SSRB;
- identify constraints to water supply and economic growth; and,
- identify, analyze and evaluate structural and non-structural water management alternatives to address constraints and issues.

This Technical Memorandum was undertaken to develop a municipal and rural domestic water demand database to support simulation modelling in the SSRB. Simulation modelling will determine performance of the basin's main-stem streams (Red Deer, Bow, Oldman and South Saskatchewan Rivers) in meeting water demands, particularly during low flow and drought conditions. The 2007 Water for Life report (AMEC, 2007) was used as a reference for the database. Additional information was acquired regarding actual water demands in the sub-basins. This study focuses on surface water demands that are, or could be in the future, supplied from mainstem streams within the SSRB. Water uses that do not directly impact mainstem streams are not included in this study. These situations include groundwater withdrawals that are not directly connected to the streams and return flows which do not discharge to the main-stems.

2.0 ANALYSIS

2.1 Population

Changes in municipal and rural populations have impacts on water demands in an area. Population and per capita water uses are key factors in determining municipal and rural domestic water needs. As the population increases in municipalities, it is important for decision makers to be aware of how that will affect water demands in order to plan for the provision of adequate, clean water supplies. In addition to the changes in demands, changes in water sources, typically from groundwater to surface water, may be necessary as populations grow and current sources become limited. For this study, projections were made to the Year 2030 for planning purposes (Appendix A tables).

Population changes are typically based on trends in fertility, mortality and migration rates to the subject area over time. Population projections require a record of recent populations and the rate of change of the populations in recent years in order to gain an understanding of trends and patterns, which can then be applied to obtain a picture of future growth. The current (2006) population and populations for 1996 and 2001 for urban centers in the study area were obtained from 2006 StatsCan census data (Statistics Canada, 2008), the Alberta Municipal Affairs Community Profiles (Alberta Municipal Affairs, 2007), and communication with the individual communities (Appendix B tables). Populations for 1996, 2001 and 2006 were used to determine annual community growth rates (Appendix A tables).

Overall sub-basin population projections were based on the Alberta Health Region (AHR) Report (AHR, 2007). A separate estimate was based on projected growth rates for individual municipalities determined from census data, Calgary Regional Partnership (CRP) Technical Memorandum 3.1 from a recent study conducted for the CRP (CH2MHill, 2007), and by individual communities as components of Municipal Development Plans (MDPs) or other planning documents, as available. Based on these three sources, a reasonable growth rate was selected to project the 2006 population to the Year 2030 based on the following selection criteria, in order of priority:

- If the community or CRP TM 3.1 growth rates were similar to the 10-year census growth rate, either the community or the CRP TM 3.1 rate was used.
- If either the 5- or 10-year annual growth rate derived from census data was negative, the growth rate was set to 0%.
- The growth rate for summer villages was set to 2.0%. Almost all of the summer villages were fully developed, but the number of permanent residents was growing in most.
- If no community or CRP TM 3.1 growth rates were available, the 10-year census growth rate was used.

Growth rate selections which do not fit within these criteria are listed in **Table 1** with the reasons for the applied growth rate for the population projection to 2030.

TABLE 1
Instances of Exceptions to the Growth Rate (GR) Selection Criteria

Municipality	Type	Annual GR	Selected GR	Explanation
		96-'06	06 - '30	
Red Deer Basin				
Cremona	V	2.00%	2.00%	Cremona MDP GR of 1.03% not used
Duchess	V	3.50%	3.19%	01-'06 annual growth rate used
Burnstick Lake	SV	26.81%	1.00%	Village at capacity. Growth in permanent residents only.
Bow River Basin				
Banff	T	3.64%	3.64%	GR based on 10-year federal and municipal census numbers
Okotoks	T	7.23%	4.80%	Population capped at 30000, GR reflects this cap.
Tsuu T'ina Nation (Sarcee 145)	R		4.90%	2006 pop. unknown, 1996-2001 Annual Growth Rate used
Oldman River Basin				
No Exceptions				
South Sask River sub-Basin				
No Exceptions				

Notes: V = Village; SV = Summer Village; T = Town; R = First Nation Reserve.

Population growth is dependent on sub-basin characteristics within the SSRB. Sub-basins with large urban centres and a high number of towns and villages have larger overall populations and growth rates than basins with primarily agricultural land and fewer urban centres. The highest growth in urban, rural and reserve populations was predicted for the Bow River Sub-basin, followed by the Red Deer River Sub-basin (**Table 2**). Higher average population growth is projected for the four urban municipalities in the South Saskatchewan River sub-basin than for those in the Oldman River Sub-basin; however, 0.23% annual rural growth is expected in the South Saskatchewan River Sub-basin, as compared to 0.40% growth in the Oldman River Sub-basin.

TABLE 2
Urban, Rural and Reserve Populations in 2006 and Projections to 2030

Subbasin		Projections Based on Municipal Growth Rates			Based on AHR GR to 2030
		2006 Population	**Growth Rate**	**2030 Population**	
Red Deer River Subbasin	**Urban**	172,598	2.76%	331,912	234,539
	Rural	83,508	1.59%	121,993	113,476
	TOTAL	**256,106**		**453,905**	**348,015**
Bow River Subbasin	**Urban**	1,107,733	2.58%	1,720,748	1,623,427
	Rural	43,985	1.04%	85,687	63,622
	Reserve	5,666	1.70%	13,315	11,194
	TOTAL	**1,157,384**		**1,819,751**	**1,698,243**
Oldman River Subbasin	**Urban**	126,207	0.77%	175,838	151,338
	Rural	35,699	0.40%	41,833	44,395
	Reserve	5,477	0.00%	5,477	6,475
	TOTAL	**167,383**		**223,148**	**202,207**
South Sask. Subbasin	**Urban**	64,407	1.18%	87,904	86,779
	Rural	7,130	0.23%	9,331	9,578
	TOTAL	**71,537**		**97,235**	**96,356**

Notes: AHR = Alberta Health Regions; GR = Growth Rates; Reseerve = First Nations Reserve

The total populations for the Bow, Oldman and South Saskatchewan River Sub-basins based on census data and municipal planning studies are within 10% of those projected using the Alberta Health Region growth rates. The degree of similarity validates the methods used for projecting the populations to the Year 2030. The dissimilarity observed in the Red Deer River Sub-basin is primarily due to recent high growth rates along the Highway 2 corridor and methodology used for some municipalities in projections for the future. This methodology is discussed in the Red Deer River Basin Municipal Water Needs Study, TM No. 1 (Associated Engineering, 2007).

Recognizing that municipal population projections are intended for land and infrastructure planning, high-side projections may be logical and justified considering the consequences of under-estimating populations and inadequate preparations for growth. It was decided to accept the municipal growth rate projections to 2030 in all four sub-basins for the purposes of this study.

2.2 Distribution of Population

The SSRB is urbanized with about 88.8% of the population living in an urban center (**Figure 1**). Approximately 8.9% of the population lives in rural settings and an additional 1.6% were counted as farmers in the 2006 census. The population living on First Nations Reserves make up the remaining 0.7%.

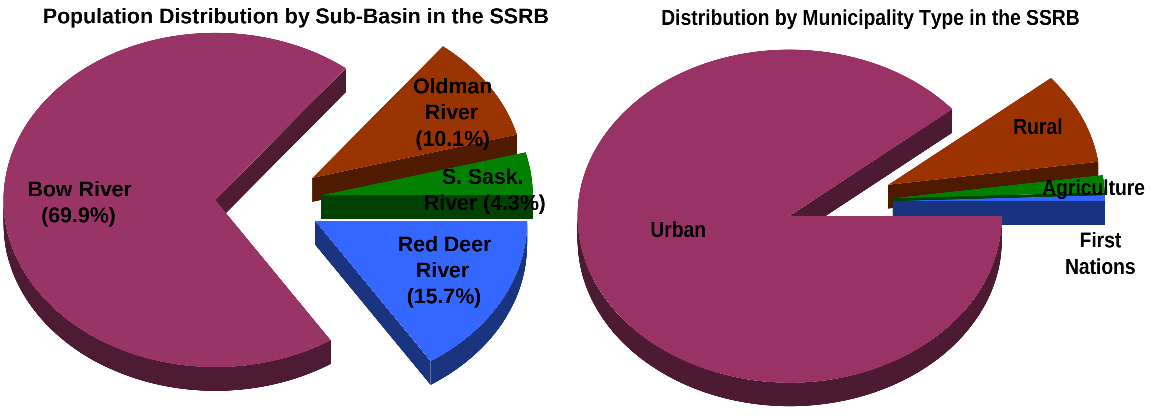

Figure 1 Population Distribution by Sub-basin and by Land Use

The Red Deer River Sub-basin has the lowest ratio of urbanized population of the sub-basins in the SSRB followed by the Oldman River Sub-basin (**Table 3**). The Red Deer and Oldman River Sub-basins also have the highest percentage of rural and farming populations. The population in the Bow River Sub-basin is highly urbanized and has the lowest percentage of rural and farm residents, largely because of Calgary's dominant population. The South Saskatchewan River Sub-basin is also highly urbanized with much lower percentages of rural and farming populations than the Red Deer or Oldman River Sub-basins. The Oldman River Sub-basin has the highest ratio of individuals living on First Nations reserves in the SSRB and the Red Deer and South Saskatchewan River Sub-basins do not have any reserve land.

TABLE 3
Population Distribution by Sub-basin in the SSRB

	Red Deer River	Bow River	Oldman River	S. Sask. River
Urban	66.5%	95.7%	75.4%	90.1%
Rural	27.3%	3.5%	18.0%	8.5%
Agriculture	6.2%	0.3%	3.6%	1.4%
First Nations	0.0%	0.5%	3.0%	0.0%

2.3 Municipal Water Use

Water withdrawals, including both surface- and groundwater sources for 2006 for communities in the basin, were obtained from the communities themselves or from Alberta Environment Water Use Reports. The data includes all domestic, commercial, institutional and industrial uses within the communities (Appendix tables). The 2006 average per capita withdrawals were computed based on the withdrawal volumes and populations. The average 2006 withdrawal for all communities in the SSRB was computed to be 493 litres per capita-day (L/c-d). Note that the variations in per capita use (**Table 4**) is not necessarily an accurate measure of efficiency because of the differences among communities in the non-household uses such as industrial, commercial, institutional and recreational uses, as well as unrecorded amounts provided for domestic use outside the urban area. An indication of the magnitude of non-residential uses in Alberta and Canada is noted in **Table 4**. The 2006 average per capita withdrawal for the Red Deer River Sub-basin is considerably less than the 2001 overall water-use average for Alberta and Canada published by Environment Canada in 2004 (**Table 4**). The Bow and the Oldman River Sub-basins are between Alberta and Canada per capita withdrawals and the South Saskatchewan River Sub-basin is somewhat higher than both Alberta and Canada average per capita withdrawals. These values are shown in **Table 4** below.

Municipal use: Water use by Cities, Towns, Villages and Summer Villages supplied by a municipal distribution system.

Rural domestic use: Household and outside watering uses occurring outside urban municipal boundaries, usually supplied by individual systems or water co-ops. Groundwater is a primary source for rural domestic use.

TABLE 4
Municipal Water Withdrawal Rates Per Capita

SSRB Sub-basin (2006)	Average Withdrawal (L/c-d)	Residential (%)	Commercial and Industrial (%)	System Losses (%)
Red Deer River	426			
Bow River	531			
Oldman River	562			
South Saskatchewan River	670			
Alberta (2001)	519	56	35	9
Canada (2001)	622	56	31	13

Note: Alberta and Canada average withdrawal rates are based on a sample of communities.

Alberta Environment and the 13 irrigation districts within the SSRB own and operate irrigation headworks and conveyance systems to carry water to irrigators and other users in southern Alberta. Communities licenced to receive water through the works of these systems are listed in **Table 5**. The irrigation districts often cross sub-basin boundaries. In the Appendix tables, communities are listed in the basin of the source stream.

2.4 Monthly Distribution of Water Demand

Monthly distributions of water demands reflect the climate of southern Alberta. Demands are lowest during the winter and begin to climb following the snow melt. The increased summer water demands are due to outside water uses such as landscape watering. The largest demands typically occur in July and August. June is the highest rainfall month in the SSRB and September generally brings lower temperatures and a reduced need for outside watering. The declining water demand continues into the winter months. These patterns of water urban water use are visible in **Figure 2**, which plots the monthly percent of annual water use for several communities in the SSRB, as well as the average distribution for all communities in the SSRB for which monthly water use is available.

TABLE 5
Communities Receiving Water from Irrigation Infrastructure

Irrigation District	Municipality
Bow River	Village of Champion
	Village of Lomond
	Village of Milo
	Village of Vauxhall
Western	Town of Chestermere
	Town of Strathmore
	Village of Standard
Eastern	City of Brooks
	Town of Bassano
	Village of Duchess
	Village of Rosemary
	Village of Tilley
Taber	Town of Taber
	Village of Barnwell
Lethbridge Northern	Town of Picture Butte
	Village of Barons
	Village of Nobleford
St Mary Project	Town of Bow Island
	Town of Cardston
	Town of Raymond
	Village of Stirling
	Village of Warner

2.5 Return Flow

All municipal and rural domestic water users return flow to the hydrologic cycle in one way or another. Return flow occurs in a number of ways such as direct discharges to the source stream or one of its tributaries, return to groundwater via a septic field or seepage from a holding pond, or return to atmospheric moisture via evaporation or transpiration. For purposes of this study, the return flow of interest is that which is available for downstream reuse in the Red Deer River, the Bow River, the Oldman River or the South Saskatchewan River. Communities that have significant return flows in this category are summarized by sub-basin in **Table 6** and include return flows to surface water from both surface- and ground-water withdrawals. Almost all other communities in the basin have lagoon wastewater treatment systems that either do not discharge, or discharge once or twice per year to locations on tributaries and intermittent streams that are distant from the main-stem streams. Most of the treated wastewater would be consumed in evaporation, transpiration, seepage and stream priming losses prior to reaching the mainstem rivers.

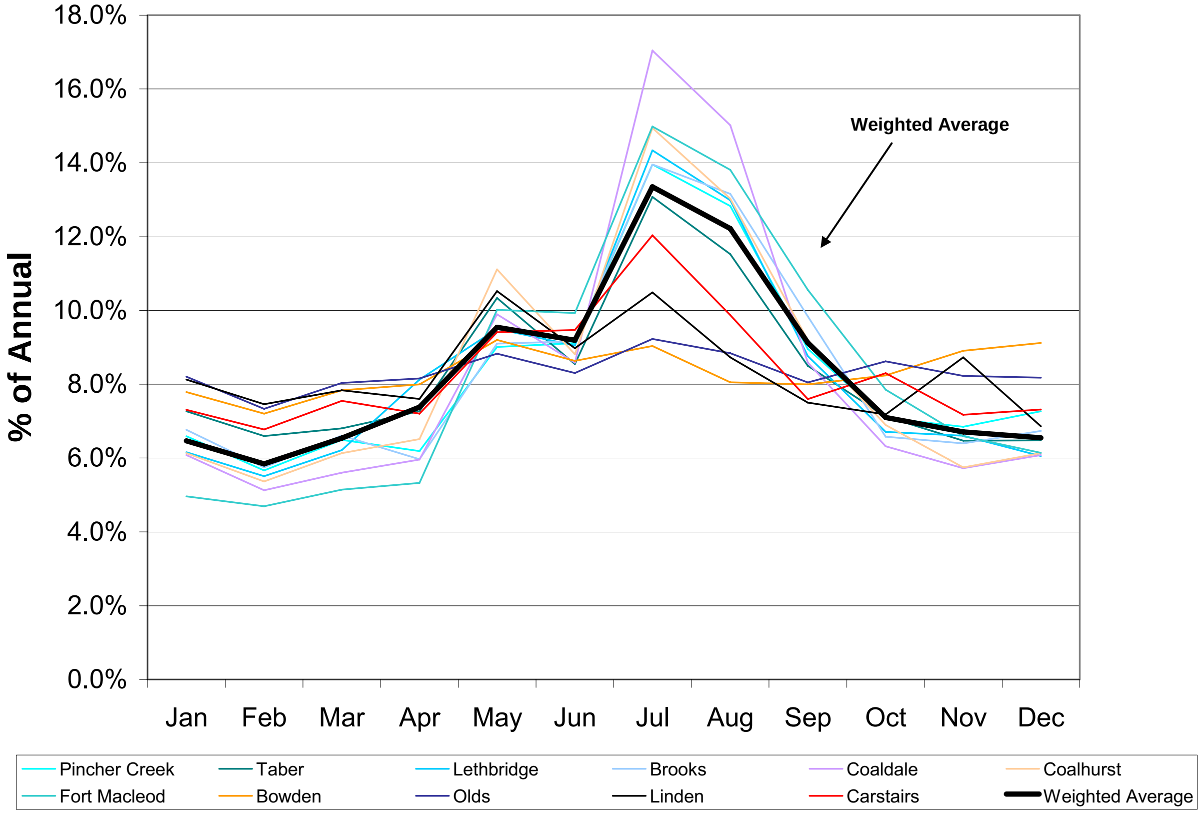

Figure 2 Monthly Distribution of Raw Water Use as a % of Annual Use for Several Communities in the South Saskatchewan River Basin

TABLE 6
Communities with Significant Return Flows to Surface Water

Red Deer River Basin	Bow River Basin	Oldman River Basin	SS River Sub-Basin
Surface Water Return to Surface Water			
Sundre	Calgary	Lethbridge	Medicine Hat
Innisfail	Banff	Fort Macleod	Redcliff
Bowden	Canmore	Coalhurst	
Olds	Cochrane	Coaldale	
Red Deer	Airdrie	Taber	
Blackfalds	Crossfield	Picture Butte	
Drumheller	Chestermere	Cardston	
	Turner Valley	Pincher Creek	
	Black Diamond	Nanton	
	Okotoks	Granum	
	Longview		
Ground Water Return to Surface Water			
Eckville	Arrowwood	Crowsnest Pass	
Penhold			
Bentley			
Rimbey			

The quantity of return flow can vary substantially from community to community. Some communities with high water tables return more water than they withdraw due to groundwater seepage into their sewerage systems. Others have unrecorded amounts of treated wastewater that is used for waterfowl or irrigation projects. Wastewater lagoons have evaporation and seepage losses that reduce the quantity of flow that is returned to the source stream. For planning purposes, an average of 80% return flow is commonly used for municipal systems. For this study, 80% return flow has been assumed for municipalities with continuous discharge, and 70% for municipalities with lagoons that discharge once or twice per year.

Estimated return flows to the Red Deer, Bow, Oldman and South Saskatchewan Rivers are summarized in the Appendix tables.

2.6 Rural Domestic Use

The percentage of population of each of the four sub-basins residing in rural areas (rural residents and hamlets) varies between sub-basins. Rural area populations comprise approximately:

- 27% of the population of the Red Deer River Sub-basin;
- 18% of the Oldman River Sub-basin;

- 8.5% of the South Saskatchewan River Sub-basin; and,
- 3.5% of the Bow River Sub-basin.

Regional projects have been developed to supply water to both rural and urban users and occasionally across sub-basin boundaries. Communities receiving water from regional projects are listed in the basin of the source stream (Appendix Tables).

The primary source of water for rural domestic users and hamlets is wells. However, rural water co-ops supplying surface water to rural residents have become popular in areas where groundwater is limiting in quantity and quality. Several water cooperatives are operating in each of the sub-basins. Alberta Environment's water licence database lists the number of surface water co-ops within each sub-basin as follows:

- 9 in the Red Deer River Sub-basin,
- 29 in the Bow River Sub-basin,
- 21 in the Oldman River Sub-basin, and
- 6 in the South Saskatchewan River Sub-basin.

Rural domestic use includes household use and lawn and garden watering. There are few records of rural domestic water use in the study area. A per capita use of 350 L/c-d is often used for design of rural water co-ops or regional systems serving rural users and hamlets. In this study, an average withdrawal of 350 L/c-d was assumed for all villages and hamlets with unreported water-use volumes (Appendix tables).

2.7 Future Municipal and Rural Domestic Water Demands

Future water demands for the Year 2030 were estimated primarily based upon population projections and current per capita consumption. The following assumptions were used:

- Continuation of the current trend to alleviate water quantity and quality concerns by converting from groundwater to surface water sources for both urban and rural users was assumed.
- It was assumed that 15% to 30% of both urban and rural users currently supplied from groundwater would convert to surface sources by 2030. In the Red Deer River Sub-basin, east of Highway 2, 30% of the groundwater sources were assumed to have changed to surface water sources by 2030. In all other areas in the SSRB, 15% of the groundwater sources were assumed to have switched to surface water sources by 2030.
- It was assumed the future surface sources would be major rivers (Red Deer, Bow, Oldman and South Saskatchewan) or a major tributary, and there would be insignificant return flow to the rivers.
- Future water demand projections were based on 2030 population projections and current per capita consumption. Water conservation could significantly reduce future demands.

Projected water demands for the Year 2030 are summarized in the Appendix B tables.

3.0 KEY FINDINGS AND DISCUSSION OF RESULTS (with Reference to Tables in Appendix B)

3.1 Red Deer River Sub-basin: Summary of Findings

a) Current licensed surface and groundwater allocations for urban and rural municipalities total 69 375 dam^3 (AMEC, 2007).

b) Current (2006) annual urban surface water (SW) and ground water (GW) withdrawals, return flows and net depletions of Red Deer River flows are estimated to be as follows:

SW Withdrawals	29 480 dam^3
SW Return Flows	17 387 dam^3
Net SW Depletion	12 093 dam^3
GW Withdrawals	2 883 dam^3
Rural Withdrawals (GW/SW)	15 084 dam^3

The SW withdrawals include regional projects, two of which that have been applied for and are under construction; the Highway 12/21 and Shirley McClellan Regional Projects. First Nations reserves in the Hobema area are included in the North Red Deer Regional Project. Their water use is included in SW Withdrawals. There are eight communities that have significant return flows to the Red Deer River, one of which is sourced from ground water (Penhold). Three other communities are sourced from groundwater and return to a tributary of the Red Deer River, representing a transfer from groundwater to surface water (**Table 6**).

c) Year 2030 annual urban surface water withdrawals, return flows and net depletions of Red Deer River flows are projected to be as follows:

SW Withdrawals	59 050 dam^3
SW Return Flows	32 352 dam^3
Net SW Depletion	26 698 dam^3
GW Withdrawals	5 296 dam^3
Rural Withdrawals (GW/SW)	25 496 dam^3
GW/SW Conversion	5 613 dam^3

This demand projection assumes completion of all identified regional projects plus a conversion to surface sources for 15 to 30% of current groundwater demands in urban and rural municipalities.

3.2 Bow River Sub-basin: Summary of Findings and Discussion of Results

a) Current licensed allocations of surface and ground water for urban and rural municipalities total 502 880 dam^3 (AMEC, 2007).

b) Current (2006) annual urban surface water withdrawals, return flows and net depletions of Bow River flows are estimated to be as follows:

SW Withdrawals	199 277 dam^3
SW Return Flows	155 575 dam^3
Net SW Depletion	43 702 dam^3
GW Withdrawals	68 dam^3
Rural Withdrawals (GW/SW)	9 554 dam^3

There are 12 communities that have significant return flows to the Bow River. One community (Arrowwood) that is sourced from groundwater, returns water to the Bow River and represents a transfer from groundwater to surface water. Five communities in the Bow River Sub-basin (High River, Black Diamond, Turner Valley, Okotoks and Longview), take water from wells that are hydraulically connected to streams and Alberta Environment considers surface water to be the source for these communities.

c) Year 2030 annual urban surface water withdrawals, return flows and net depletions of Bow River flows are projected to be as follows:

SW Withdrawals	307 391 dam^3
SW Return Flows	238 487 dam^3
SW Net Depletion	68 901 dam^3
GW Withdrawals	108 dam^3
Rural Withdrawals (GW/SW)	8 774 dam^3
GW/SW Conversion	1 567 dam^3

This demand projection assumes a conversion to surface sources for 15% of current groundwater demands for urban and rural municipalities.

3.3 Oldman River Sub-basin: Summary of Findings and Discussion of Results

a) Current licensed allocations of surface and ground water for urban and rural municipalities total 65 748 dam^3 (AMEC, 2007).

b) Current (2006) annual municipal, rural, reserve and regional projects surface water withdrawals, return flows and net depletions of the Oldman River flows are estimated to be as follows:

SW Withdrawals	33 256 dam^3
SW Return Flows	24 465 dam^3
SW Net Depletion	8 791 dam^3
GW Withdrawals	70 dam^3
Rural Withdrawals (GW/SW)	8 531 dam^3

There are six communities that have significant return flows to the Oldman River and five that return flow to a tributary or lake which subsequently contributes to the Oldman River. One community (Crowsnest Pass) that is sourced from groundwater, returns water to a tributary of the Oldman River and represents a transfer from groundwater to surface water. The municipality of Crowsnest Pass obtains water both from wells along the river and surface water sources, and is considered by Alberta Environment to be supplied by surface water sources.

c) Year 2030 annual municipal, rural, reserve and regional projects surface water withdrawals, return flows and net depletions of Oldman River flows are projected to be as follows:

SW Withdrawals	47 052 dam^3
SW Return Flows	34 273 dam^3
SW Net Depletion	11 862 dam^3
GW Withdrawals	60 dam^3
Rural Withdrawals (GW/SW)	4 543 dam^3
GW/SW Conversion	917 dam^3

This demand projection assumes a conversion to surface sources for 15% of current groundwater demands for urban and rural municipalities.

3.4 South Saskatchewan River Sub-basin: Summary of Findings and Discussion of Results

a) Current licensed allocations of surface and groundwater for rural and urban municipalities total 169 612 dam^3 (AMEC, 2007).

b) Current (2006) annual municipal and rural surface water withdrawals, return flows and net depletions of the South Saskatchewan River Sub-basin flows are estimated to be as follows:

SW Withdrawals	17 310 dam^3
SW Return Flows	13 848 dam^3
SW Net Depletion	3 462 dam^3
GW Withdrawals	67 dam^3
Rural Withdrawals (GW/SW)	911 dam^3

There are two communities that have significant return flows to the South Saskatchewan River.

c) Year 2030 annual municipal and rural surface water withdrawals, return flows and net depletions of South Saskatchewan River Sub-basin flows are projected to be as follows:

SW Withdrawals	24 045 dam^3
SW Return Flows	19 088 dam^3
SW Net Depletion	4 957 dam^3
GW Withdrawals	57 dam^3
Rural Withdrawals (GW/SW)	990 dam^3
GW/SW Conversion	185 dam^3

This demand projection assumes a conversion to surface sources for 15% of current groundwater demands for urban and rural municipalities.

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APPENDIX A

POPULATION TABLES

Appendix A - Table 1: Current (2006) and Projected (2030) Population in the Red Deer River Basin

Red Deer River Basin	Type	% in Sub-basin	Population (within Sub-basin)			Annual Growth Rate		Selected GR	Population Projections
			1996	2001	2006	01-'06	96-'06	06 - '30	2030
URBAN									
City of Red Deer	C	100%	60,075	67,829	82,971	4.11%	3.28%	2.43%	151,182
City of Brooks	C	100%	10,093	11,604	12,498	1.50%	2.16%	2.16%	21,325
Town of Drumheller	T	100%	7,883	7,785	7,932	0.37%	0.06%	1.50%	11,509
Town of Sundre	T	100%	2,038	2,277	2,518	2.03%	2.14%	2.14%	4,273
Town of Bowden	T	100%	1,014	1,174	1,205	0.52%	1.74%	2.97%	2,505
Town of Olds	T	100%	5,815	6,607	7,248	1.87%	2.23%	2.97%	15,066
Town of Eckville	T	100%	901	1,019	951	-1.37%	0.54%	0.54%	1,088
Town of Innisfail	T	100%	6,116	6,943	7,438	1.39%	1.98%	2.00%	12,203
Town of Penhold	T	100%	1,625	1,729	1,961	2.55%	1.90%	1.90%	3,137
Town of Sylvan Lake	T	100%	5,194	7,503	10,208	6.35%	6.99%	5.00%	34,568
Town of Blackfalds	T	100%	2,075	3,116	4,741	8.76%	8.61%	6.99%	25,671
Town of Rimbey	T	100%	2,142	2,154	2,252	0.89%	0.50%	0.50%	2,552
Town of Bashaw	T	100%	774	825	825	0.00%	0.64%	0.64%	968
Town of Carstairs	T	100%	1,909	2,254	2,656	3.34%	3.36%	3.36%	6,064
Town of Didsbury	T	100%	3,553	3,932	4,275	1.69%	1.87%	1.87%	6,789
Town of Hanna	T	100%	3,001	2,986	2,986	0.00%	-0.05%	0.00%	2,986
Town of Irricana	T	100%	828	1,043	1,243	3.57%	4.15%	3.74%	3,114
Town of Three Hills	T	100%	3,022	2,902	3,554	4.14%	1.63%	1.63%	5,331
Town of Trochu	T	100%	958	1,033	1,033	0.00%	0.76%	0.76%	1,247
Town of Bassano	T	100%	1,272	1,320	1,345	0.38%	0.56%	0.56%	1,546
Town of Oyen	T	100%	1,009	1,020	1,099	1.50%	0.86%	0.86%	1,361
Village of Caroline	VL	100%	472	556	515	-1.52%	0.88%	0.88%	640
Village of Cremona	VL	100%	380	415	463	2.21%	2.00%	2.00%	759
Village of Bentley	VL	100%	998	1,040	1,094	1.02%	0.92%	0.92%	1,376
Village of Alix	VL	100%	765	825	851	0.62%	1.07%	1.07%	1,111
Village of Clive	VL	100%	517	591	591	0.00%	1.35%	1.35%	826
Village of Delburne	VL	100%	641	719	765	1.25%	1.78%	1.78%	1,190
Village of Acme	VL	100%	600	648	656	0.25%	0.90%	0.90%	820
Village of Beiseker	VL	100%	708	838	828	-0.24%	1.58%	1.58%	1,225
Village of Big Valley	VL	100%	308	340	351	0.64%	1.32%	1.32%	487
Village of Carbon	VL	100%	450	530	570	1.47%	2.39%	2.39%	1,029
Village of Delia	VL	100%	208	215	207	-0.76%	-0.05%	0.00%	207
Village of Elnora	VL	100%	247	290	281	-0.63%	1.30%	1.30%	388
Village of Linden	VL	100%	565	636	660	0.74%	1.57%	1.57%	973
Village of Morrin	VL	100%	275	252	253	0.08%	-0.83%	0.00%	253
Village of Munson	VL	100%	201	222	222	0.00%	1.00%	1.00%	285
Village of Rockyford	VL	100%	346	375	375	0.00%	0.81%	0.81%	459
Village of Cereal	VL	100%	211	187	160	-3.07%	-2.73%	0.00%	160
Village of Duchess	VL	100%	693	836	978	3.19%	3.50%	3.19%	2,143
Village of Empress	VL	100%	186	171	136	-4.48%	-3.08%	0.00%	136
Village of Rosemary	VL	100%	332	366	388	1.17%	1.57%	1.57%	573
Village of Burnstick Lake	SV	100%	4	10	43	33.87%	26.81%	1.00%	55
Village of Birchcliff	SV	100%	102	105	125	3.55%	2.05%	2.05%	208
Village of Half Moon Bay	SV	100%	53	37	32	-2.86%	-4.92%	0.00%	32
Village of Jarvis Bay	SV	100%	83	124	183	8.10%	8.23%	2.00%	300
Village of Norglenwold	SV	100%	281	267	270	0.22%	-0.40%	0.00%	270
Village of Gull Lake	SV	100%	149	143	204	7.36%	3.19%	3.19%	447
Village of Parkland Beach	SV	100%	97	97	135	6.83%	3.36%	2.00%	221
Village of Sunbreaker Cove	SV	100%	86	86	137	9.76%	4.77%	2.00%	225
Village of Rochon Sands	SV	100%	86	58	66	2.62%	-2.61%	0.00%	223
Village of White Sands	SV	100%	49	73	120	10.45%	9.37%	2.00%	406
RURAL									
Acadia No. 34	MD	95%	506	486	518	1.26%	0.22%	0.22%	547
Bighorn No. 8	MD	47%	588	610	594	-0.53%	0.10%	0.09%	610
Camrose No. 22	RC	7%	532	509	501	-0.33%	-0.59%	0.00%	501
Clearwater No. 99	MD	20%	2,238	2,301	2,365	0.55%	0.55%	0.55%	2,716
Cypress No. 1	MD	2%	114	122	135	1.94%	1.70%	1.70%	205
Kneehill No. 48	MD	100%	5,064	5,319	5,218	-0.38%	0.30%	0.30%	5,624
Lacombe No. 14	RC	88%	8,953	9,303	9,197	-0.23%	0.27%	0.27%	9,836
Mountain View No. 17	RC	100%	11,245	12,124	12,391	0.44%	0.98%	1.66%	18,379
Newell No. 4	RC	55%	3,525	3,925	3,774	-0.78%	0.69%	0.37%	4,524
Paintearth No. 18	RC	18%	417	395	383	-0.61%	-0.85%	0.00%	383
Ponoka No. 3	RC	47%	3,877	4,132	4,061	-0.35%	0.46%	0.46%	4,559
Red Deer No. 23	RC	99%	16,798	18,307	18,917	0.66%	1.19%	1.19%	25,457
Rocky View No. 44	MD	37%	8,348	11,072	12,643	2.69%	4.24%	3.74%	31,676
Special Area No. 2	SA	89%	2,248	2,075	1,846	-2.31%	-1.95%	0.00%	1,846
Special Area No. 3	SA	53%	844	779	671	-2.93%	-2.27%	0.00%	671
Starland No. 47	MD	100%	2,075	2,210	2,371	1.42%	1.34%	1.34%	3,309
Stettler No. 6	RC	64%	3,350	3,428	3,338	-0.53%	-0.03%	0.00%	3,338
Wetaskiwin No. 10	RC	4%	461	428	421	-0.30%	-0.89%	0.03%	423
Wheatland No. 16	RC	51%	3,458	4,023	4,164	0.69%	1.87%	2.32%	7,389

Abbreviations:

C = City
T = Town
VL = Village
SV = Summer Village
RC = (Rural) County
MD = Municipal District
SA = Special Area
GR = Annual Growth Rate

Appendix A - Table 2: Current (2006) and Projected (2030) Population in the Bow River Basin

Bow River Basin	Type	% in Sub-basin	Population (within Sub-basin)			Annual Growth Rate		Selected GR	Population Projections
			1996	2001	2006	01-'06	96-'06	06-'30	2030
URBAN									
City of Calgary	C	100%	768,082	879,003	988,193	2.37%	2.55%	1.40%	1,379,598
City of Airdrie	C	100%	15,946	20,407	28,927	7.23%	6.14%	5.10%	95,470
Town of Banff	T	100%	6,098	7,135	8,721	4.10%	3.64%	3.64%	10,000
Town of Black Diamond	T	100%	1,811	1,866	1,900	0.36%	0.48%	0.48%	2,132
Town of Canmore	T	100%	8,354	10,792	12,039	2.21%	3.72%	3.72%	28,937
Town of Chestermere	T	100%	1,911	3,856	9,564	19.92%	17.47%	5.50%	34,570
Town of Cochrane	T	100%	7,424	12,041	13,760	2.70%	6.36%	6.36%	60,502
Town of Crossfield	T	100%	1,899	2,399	2,648	1.99%	3.38%	1.60%	3,876
Town of High River	T	100%	7,359	9,383	10,716	2.69%	3.83%	2.60%	19,841
Town of Okotoks	T	100%	8,528	11,689	17,145	7.96%	7.23%	4.80%	30,000
Town of Strathmore	T	100%	5,314	7,621	10,225	6.05%	6.76%	6.76%	49,186
Town of Turner Valley	T	100%	1,527	1,608	1,908	3.48%	2.25%	3.20%	4,063
Town of Vulcan	T	15%	234	264	291	1.94%	2.22%	2.22%	493
Village of Arrowwood	VL	100%	163	196	221	2.43%	3.09%	3.09%	459
Village of Hussar	VL	100%	157	181	187	0.65%	1.76%	1.76%	285
Village of Longview	VL	100%	303	300	300	0.00%	-0.10%	0.00%	300
Village of Milo	VL	100%	117	115	100	-2.76%	-1.56%	0.00%	100
Village of Standard	VL	100%	366	389	380	-0.47%	0.38%	0.00%	380
Village of Tilley	VL	100%	368	422	381	-2.02%	0.35%	0.00%	381
Village of Ghost Lake	SV	100%	63	69	78	2.48%	2.16%	2.16%	130
Village of Waiparous	SV	100%	47	55	49	-2.28%	0.42%	0.00%	49
RURAL									
Newell No 4	RC	45%	2,889	3,212	3,088	-0.78%	0.67%	1.25%	4,160
MD of Cypress No 1	MD	8%	455	489	538	1.94%	1.70%	1.25%	725
Improvement District No 9	ID	100%	1,305	1,497	938	-8.93%	-3.25%	0.00%	938
Kananaskis Improvement District	ID	100%	665	462	429	-1.47%	-4.29%	0.00%	429
Bighorn No 8	MD	51%	647	662	645	-0.53%	-0.04%	0.00%	645
Foothills No 31	MD	75%	10,748	12,452	14,802	3.52%	3.25%	2.90%	29,396
MD of Ranchland No 66	MD	2%	2	2	2	-2.18%	-2.25%	0.00%	2
Rocky View No 44	MD	50%	11,663	14,963	17,086	2.69%	3.89%	3.70%	40,862
Taber	MD	19%	1,134	1,142	1,193	0.88%	0.51%	0.70%	1,411
Vulcan County No 2	RC	34%	1,295	1,285	1,264	-0.32%	-0.24%	0.00%	1,264
Wheatland County No 16	RC	49%	3,438	3,866	4,000	0.69%	1.53%	1.60%	5,855
FIRST NATIONS									
Siksika Nation (146)	R	100%	2,678	2,767	2,767	0.00%	0.33%	0.33%	2,993
Tsuu Tiina Nation (Sarcee 145)	R	100%	1,509	1,982				4.90%	6,248
Stoney Band (142, 143, 144)	R	100%	2,157	2,173	2,529	3.08%	1.60%	1.60%	3,705
Eden Valley No 216	R	100%	432	509	370	-6.18%	-1.54%	0.00%	370

Abbreviations:

C = City
T = Town
R = Indian Reserve
VL = Village
SV = Summer Village
RC = (Rural) County
MD = Municipal District
ID = Improvement District
SA = Special Area
GR = Annual Growth Rate

Appendix A - Table 3: Current (2006) and Projected (2030) Population in the Oldman River Basin

Oldman River Basin	Type	% in Sub-basin	Population (within Sub-basin)			Annual Growth Rate		Selected GR	Population Projections
			1996	2001	2006	01-'06	96-'06	06-'30	2030
URBAN									
City of Lethbridge	C	100%	63,053	67,374	74,637	2.07%	1.70%	1.70%	111,879
Town of Taber	T	100%	7,214	7,671	7,591	-0.21%	0.51%	2.00%	12,210
Town of Coaldale	T	100%	5,770	6,008	6,177	0.56%	0.68%	0.68%	7,275
Town of Crowsnest Pass	T	100%	6,356	6,262	5,749	-1.69%	-1.00%	0.00%	5,749
Town of Pincher Creek	T	100%	3,659	3,666	3,625	-0.22%	-0.09%	0.00%	3,625
Town of Claresholm	T	100%	3,427	3,622	3,700	0.43%	0.77%	0.77%	4,447
Town of Fort Macleod	T	100%	3,034	2,990	3,072	0.54%	0.12%	0.12%	3,165
Town of Cardston	T	100%	3,417	3,475	3,452	-0.13%	0.10%	0.00%	3,452
Town of Magrath	T	100%	1,867	1,993	2,081	0.87%	1.09%	1.09%	2,700
Town of Nanton	T	100%	1,672	1,841	2,055	2.22%	2.08%	2.70%	3,895
Town of Picture Butte	T	100%	1,669	1,701	1,592	-1.32%	-0.47%	0.00%	1,592
Town of Coalhurst	T	100%	1,439	1,476	1,523	0.63%	0.57%	0.57%	1,745
Town of Vauxhall	T	100%	1,011	1,112	1,069	-0.79%	0.56%	0.00%	1,069
Town of Vulcan	T	85%	1,324	1,498	1,649	1.94%	2.22%	2.22%	2,791
Town of Stavely	T	100%	453	442	435	-0.32%	-0.40%	0.00%	435
Town of Granum	T	100%	337	392	415	1.15%	2.10%	2.10%	684
Town of Raymond	T	100%	3,056	3,200	3,205	0.03%	0.48%	0.80%	3,880
Village of Nobleford	VL	100%	558	610	689	2.47%	2.13%	2.13%	1,143
Village of Barnwell	VL	100%	553	548	613	2.27%	1.04%	1.04%	785
Village of Champion	VL	100%	362	355	364	0.50%	0.06%	0.06%	369
Village of Barons	VL	100%	285	284	276	-0.57%	-0.32%	0.00%	276
Village of Glenwood	VL	100%	295	258	280	1.65%	-0.52%	0.00%	280
Village of Carmangay	VL	100%	258	255	336	5.67%	2.68%	2.68%	633
Village of Cowley	VL	100%	273	225	219	-0.54%	-2.18%	0.00%	219
Village of Lomond	VL	100%	170	171	175	0.46%	0.29%	0.29%	188
Village of Stirling	VL	100%	874	877	921	0.98%	0.53%	0.53%	1,044
Village of Warner	VL	100%	421	379	307	-4.13%	-3.11%	0.00%	307
RURAL									
County of Lethbridge No 26	RC	96%	8,881	9,538	9,890	0.73%	1.08%	1.08%	12,804
County of Warner No 5	RC	50%	1,781	1,899	1,837	-0.66%	0.31%	0.00%	1,837
MD of Willow Creek No 26	MD	100%	5,106	5,412	5,337	-0.28%	0.44%	0.00%	5,337
MD of Foothills No 31	MD	25%	4,218	4,871	4,934	0.26%	1.58%	1.58%	7,189
MD of Taber No 14	MD	67%	4,000	4,028	4,208	0.88%	0.51%	0.51%	4,751
MD of Pincher Creek No 9	MD	100%	3,172	3,197	3,309	0.69%	0.42%	0.42%	3,662
Vulcan County	RC	55%	2,094	2,078	2,045	-0.32%	-0.24%	0.00%	2,045
MD of Cypress No 1	MD	2%	114	122	135	1.94%	1.70%	1.70%	202
Cardston County No 6	MD	63%	2,876	2,725	2,543	-1.37%	-1.22%	0.00%	2,543
40 Mile County No 8	RC	36%	1,163	1,236	1,229	-0.11%	0.56%	0.00%	1,229
Improvement District No 4	ID	100%	279	155	160	0.64%	-5.41%	0.00%	160
MD of Ranchland No 66	MD	85%	92	82	73	-2.18%	-2.25%	0.00%	73
FIRST NATIONS									
Blood Tribe 148	R	100%	4,326	3,857	4,177	1.61%	-0.35%	0.00%	4,177
Peigan Tribe 147 (Piikani (06))	R	100%	1,662	1,537	1,300	-3.29%	-2.43%	0.00%	1,300

Abbreviations:

C = City
T = Town
R = Indian Reserve
VL = Village
SV = Summer Village
RC = (Rural) County
MD = Municipal District
ID = Improvement District
SA = Special Area
GR = Annual Growth Rate

Appendix A - Table 4: Current (2006) and Projected (2030) Population in the South Saskatchewan River Sub-Basin

South Saskatchewan River Sub-basin	Type	% in Sub-basin	Population (within Sub-basin)			Annual Growth Rate		Selected GR	Population Projections
			1996	2001	2006	01-'06	96-'06	06-'30	2030
URBAN									
City of Medicine Hat	C	100%	46,783	51,249	56,997	2.149%	1.994%	1.200%	75,890
Town of Redcliff	T	100%	4,104	4,372	5,096	3.112%	2.189%	2.500%	9,217
Town of Bow Island	T	100%	1,668	1,704	1,790	0.990%	0.708%	1.000%	2,273
Village of Foremost	VL	100%	556	531	524	-0.265%	-0.591%	0.000%	524
RURAL									
Cypress County	MD	65%	4,024	4,330	4,374	0.201%	0.837%	0.837%	5,343
Forty Mile County No 8	RC	49%	1,869	1,946	1,673	-2.976%	-1.101%	0.000%	1,673
MD of Taber	MD	13%	1,103	1,119	816	-6.104%	-2.965%	0.000%	816
Warner County No 5	RC	5%	178	190	184	-0.662%	0.313%	0.313%	198
Special Area No 2	SA	4%	101	93	83	-2.309%	-1.972%	0.000%	83

Abbreviations:

C = City
T = Town
R = Indian Reserve
VL = Village
SV = Summer Village
RC = (Rural) County
MD = Municipal District
ID = Improvement District
SA = Special Area
GR = Annual Growth Rate

APPENDIX B

MUNICIPAL AND DOMESTIC WATER USE TABLES

Appendix B - Table 1: Municipal Domestic Current Water Use and Projections to 2030 in the Red Deer River Basin

Municipality	Type	% in Sub-basin	Population		Water Source RF Recipient	Current Use (2006)		2030 Demand dam³
			2006	2030		L/c-d	dam³	
City of Red Deer	C	100%	82,971	151,182 80% RF	Red Deer R Red Deer R Net Diversion	532	16,124 12,900 3,225	29,380 23,504 5,876
City of Brooks	C	100%	12,498	21,325	Bow R			
Town of Drumheller	T	100%	7,932	11,509 80% RF	Red Deer R Red Deer R Net Diversion	724	2,095 1,676 419	3,040 2,432 608
Town of Sundre	T	100%	2,518	4,273 80% RF	Red Deer R Red Deer R Net Diversion	554	509 407 102	863 691 173
Mountain View Regional							4,646	8,565
Town of Innisfail	T	100%	7,438	12,203 80% RF	Red Deer R Red Deer R Net Diversion	454	1,231 985 246	2,020 1,616 404
Town of Bowden	T	100%	1,205	2,505 80% RF	Red Deer R Red Deer R Net Diversion	340	150 120 30	311 249 62
Town of Olds	T	100%	7,248	15,066 80% RF	Red Deer R Red Deer R Net Diversion	450	1,190 952 238	2,474 1,980 495
Town of Didsbury	T	100%	4,275	6,789	Red Deer R	352	550	873
Town of Carstairs	T	100%	2,656	6,064	Red Deer R	311	301	688
Town of Crossfield	T	0%	2,648	3,876	Red Deer R	361	349	511
North Red Deer Regional							3,679	7,668
Town of Blackfalds	T	100%	4,741	25,671 80% RF	Red Deer R Red Deer R Net Diversion	251	434 347 87	2,350 1,880 470
Town of Lacombe	T	0%	10,850	16,694	Red Deer R	327	1,295	1,993
Town of Ponoka	T	0%	6,330	9,184	Red Deer R	370	855	1,240
Town of Eckville	T	100%	951	1,088 80% RF	GW Med R GW/SW Transfer	449	156 125 -125	178 143 -143
Town of Penhold	T	100%	1,961	3,137 80% RF	GW Red Deer R GW/SW Transfer	292	209 167 -167	334 267 -267
Town of Sylvan Lake	T	100%	10,208	34,568	GW	328	1,223	4,142
Town of Rimbey	T	100%	2,252	2,552 80% RF	GW Blindman R GW/SW Transfer	462	380 304 -304	430 344 -344
Highway 12/21 Regional							1,118	1,564
Town of Bashaw (future)	T	100%	825	968	GW	382	115	135
Village of Alix	VL	100%	851	1,111	Red Deer R	432	134	175
Village of Clive (future)	VL	100%	591	826	GW	267	58	81
Town of Stettler	T	0%	5,226	8,511	Red Deer R	591	1,128	1,837
Kneehills Regional							454	820
Town of Irricana	T	100%	1,243	3,114	Red Deer R	281	127	319
Village of Acme	VL	100%	656	820	Red Deer R	272	65	81
Village of Beiseker	VL	100%	828	1,225	Red Deer R	388	117	173
Village of Carbon	VL	100%	570	1,029	Red Deer R	257	53	97
Village of Linden	VL	100%	660	973	Red Deer R	211	51	75
Henry Kroeger Regional							850	903
Town of Hanna	T	100%	2,986	2,986	Red Deer R	381	416	416
Town of Oyen	T	100%	1,099	1,361	Red Deer R	537	215	267
Village of Delia	VL	100%	207	207	Red Deer R	583	44	44
Village of Youngstown	VL	100%	184	184	Red Deer R	616	41	41
Village of Cereal	VL	100%	160	160	Red Deer R	690	40	40
Town of Three Hills	T	100%	3,554	5,331	Red Deer R	565	733	1,099
Town of Trochu	T	100%	1,033	1,247	Red Deer R	565	213	257
Town of Bassano	T	100%	1,345	1,546	Bow R			
Village of Caroline	VL	100%	515	640 70% RF	GW Raven R GW/SW Transfer	492	93 65 -65	115 81 -81
Village of Cremona	VL	100%	463	759	GW	286	48	79
Village of Bentley	VL	100%	1,094	1,376 70% RF	GW Blindman R GW/SW Transfer	340	136 95 -95	171 120 -120
Village of Delburne	VL	100%	765	1,190	GW	370	103	161
Shirley McClellan Regional							1,979	5,117
Village of Big Valley (future)	VL	100%	351	487	GW	381	49	68
Village of Rochon Sands (Growth potential)	SV	100%	66	223	Red Deer R	450	11	37
Village of White Sands (Growth potential)	SV	100%	120	406	Red Deer R	450	20	67
Village of Elnora	VL	100%	281	388	GW	339	35	48
Village of Morrin	VL	100%	253	253	Red Deer R	416	38	38
Village of Munson	VL	100%	222	285	Red Deer R	575	47	60
Village of Rockyford	VL	100%	375	459	GW	610	84	102
Village of Duchess	VL	100%	978	2,143	Bow R			
Village of Empress	VL	100%	136	136	GW	350	17	17
Village of Rosemary	VL	100%	388	573	Bow R			
Village of Burnstick Lake	SV	100%	43	55	GW	450	7	9
Village of Birchcliff	SV	100%	125	208	Private Wells	436	20	33
Village of Half Moon Bay	SV	100%	32	32	Private Wells	464	5	5
Village of Jarvis Bay (Fully developed))	SV	100%	183	300	Private Wells	350	23	38
Village of Sunbreaker Cove	SV	100%	137	225	Private Wells	450	23	37
Village of Gull Lake	SV	100%	204	447	Private Wells	450	34	73
Village of Parkland Beach	SV	100%	135	221	GW	450	22	36
Village of Norglenwold (Limited growth)	SV	100%	270	270	Private Wells	450	44	44
Rural Domestic			80,398	119,269	GW	350	10,271	15,237
North Red Deer Regional								
First Nations	R	0%	10,308	21,583	Red Deer R	180	729	1,526
Basin Totals		**Urban SW Withdrawal**					28,751	51,911
		Urban SW Return Flow					17,387	32,352
		Urban SW Net Use					11,364	19,559
		Urban GW Withdrawal					2,883	5,296
		Rural Withdrawal (SW/GW)					15,084	25,496
		Reserve SW Withdrawal					729	1,526
		GW/SW Conversion						5,613

Appendix B - Table 2: Municipal Domestic Current Water Use and Projections to 2030 in the Bow River Basin

Municipality	Type	% in Sub-basin	Population		Water Source RF Recipient	Current Use (2006)		2030 Demand
			2006	2030		L/c-d	dam^3	dam^3
City of Calgary	C	100%	988,193	1,379,598	Bow/Elbow R	484	174,484	243,594
				80% RF	Bow R		139,587	194,875
					Net Diversion		34,897	48,719
City of Airdrie	C	100%	28,927	120,800	Bow R	347	3,665	15,303
				80% RF	Bow R		2,932	12,243
					Net Diversion		733	3,061
City of Brooks	C	0%	12,498	21,325	Bow R	713	3,253	5,551
Town of Banff	T	100%	8,721	10,000	Bow R	1,101	3,504	4,018
				80% RF	Bow R		2,803	3,214
					Net Diversion		701	804
Town of Bassano	T	0%	1,345	1,546	Bow R	1,035	508	584
Town of Black Diamond	T	100%	1,900	2,132	Sheep R	608	422	473
				80% RF	Sheep R		337	378
					Net Diversion		84	95
Town of Canmore	T	100%	12,039	28,937	Bow R	609	2,676	6,432
				80% RF	Bow R		2,141	5,145
					Net Diversion		535	1,286
Town of Chestermere	T	100%	9,564	34,570	Bow R	279	975	3,523
				80% RF	Calgary		780	2,818
					Net Diversion		195	705
Town of Cochrane	T	100%	13,760	60,502	Bow R	390	1,960	8,618
				80% RF	Calgary		1,568	6,895
					Net Diversion		392	1,724
Town of Crossfield	T	100%	2,648	3,876	Red Deer R			
				70% RF	Bow R		245	358
					Net Diversion		105	153
Town of High River	T	100%	10,716	19,841	Highwood R	719	2,811	5,205
				80% RF	Frank Lake (OMR)		2,249	4,164
					Net Diversion		562	1,041
Town of Nanton	T	0%	2,055	3,895	Mosquito Ck	424	318	603
				80% RF	Mosquito Ck		254	482
					Net Diversion		64	121
Town of Okotoks	T	100%	17,145	30,000	Sheep R	296	1,852	3,241
				80% RF	lagoon		1,482	2,593
					Net Diversion		370	648
Town of Strathmore	T	100%	10,225	49,186	Bow R	350	1,307	6,288
				80% RF	Irrigation, Bow R		1,046	5,030
					Net Diversion		261	1,258
Town of Stettler	T	100%	5226	8,511	Red Deer R			
Town of Turner Valley	T	100%	1,908	4,063	Sheep R	427	297	633
				80% RF	Sheep R		238	506
					Net Diversion		59	127
Town of Vauxhall	T	0%	1,069	1,069	Bow R	779	304	304
Town of Vulcan	T	0%	1,649	2,791	Highwood/Little Bow R	661	398	673
				80% RF	McGregor Lake		318	539
					Net Diversion		80	135
Village of Arrowwood	VL	100%	221	459	GW	512	41	86
				70% RF	lagoon to Bow R		29	60
					GW/SW Transfer		-29	-60
Village of Champion	VL	0%	364	369	Travers Res	745	99	100
Village of Carmangay	VL	0%	336	633	Little Bow R	404	49	93
Village of Duchess	VL	0%	978	2,143	Bow R	350	125	274
Village of Rosemary	VL	0%	388	573	Bow R	350	50	73
Village of Hussar	VL	100%	187	285	GW	398	27	41
Village of Longview	VL	100%	300	300	Highwood R	559	61	61
				80% RF	Highwood R		49	49
					Net Diversion		12	12
Village of Milo	VL	100%	100	100	McGregor Lake			
Village of Standard	VL	100%	380	380	Bow R, spring	670	93	93
Village of Tilley	VL	100%	381	381	Bow R	474	66	66
Summer Village of Ghost Lake	SV	100%	78	130	GW	350	N/A	N/A
Summer Village of Waiparous	SV	100%	49	49	GW	350	N/A	N/A
Rural Domestic		100%	74,786	80,801	GW	350	9,554	10,322
First Nations								
Siksika Nation (146)	R	100%	2,767	2,993	GW	350	353	382
Tsuu Tiina Nation (Sarcee 145)	R	100%	1,982	6,248	wells, Bow R (Calgary)	350	253	798
Stoney Band (142, 143, 144)	R	100%	2,529	3,705	GW	350	323	473
Eden Valley No 216	R	100%	370	370	GW	350	47	47
Sub-basin BRB Municipal Summary								
			Urban SW Withdrawal				199,277	305,805
			Urban SW Return Flow				155,813	238,993
			Urban SW Net Use				43,464	66,812
			Urban GW Withdrawal				68	108
			Rural Withdrawl (SW/GW)				9,554	8,774
			Reserve GW Withdrawl				977	1,446
			GW/SW Conversion					1,567

Appendix B Table 3: Municipal Domestic Current Water Use and Projections to 2030 in the Oldman River Basin

Municipality	Type	% in Sub-basin	Population		Water Source RF Recipient	Current Use (2006)		2030 Demand dam^3
			2006	2030		L/c-d	dam^3	
City of Lethbridge	C	100%	74,637	111,879	Oldman R	767	20,891	31,316
				80% RF	Oldman R		16,713	25,053
					Net Diversion		4,178	6,263
Town of Taber	T	100%	7,591	12,210	Chin L; TID	922	2,556	4,111
				80% RF	lagoon-OMR-irr		2,044	3,288
					Net Diversion		767	822
Town of Bow Island	T	0%	1,790	2,273	SMRID	666	435	552
Lethbridge Regional Water Services Commission								
Town of Coaldale	T	100%	6,177	7,275	Lethbridge	372	839	988
				80% RF	Oldman R		671	790
					Net Diversion		168	198
Town of Crowsnest Pass	T	100%	5,749	5,749	wells, Crowsnest R	1,149	2,411	2,411
				80% RF	Crowsnest R		1,929	1,929
					GW/SW Transfer		482	482
Town of Pincher Creek	T	100%	3,625	3,625	Pincher Ck, Castle R	734	971	971
				80% RF	lagoon/Pincher C		777	777
					Net Diversion		194	194
Town of Claresholm	T	100%	3,700	4,447	Pine Coulee	908	1,227	1,474
Town of Fort Macleod	T	100%	3,072	3,165	Oldman R	988	1,108	1,142
				80% RF	Oldman R		886	913
					Net Diversion		222	228
Town of Cardston	T	100%	3,452	3,452	St Mary R	829	1,044	1,044
				80% RF	St Mary R		835	835
					Net Diversion		209	209
Town of Magrath	T	100%	2,081	2,700	Jensen Res	595	452	586
Town of Nanton	T	100%	2,055	3,895	Mosquito Ck			
				80% RF	Mosquito Ck			
					Net Diversion			
Town of Picture Butte	T	100%	1,592	1,592	LNID	703	408	408
				80% RF	lagoon - OMR		327	327
					Net Diversion		82	82
Town of Coalhurst	T	100%	1,523	1,745	Oldman R	470	261	299
				80% RF	lagoon - OMR		209	239
					Net Diversion		52	60
Town of Vauxhall	T	100%	1,069	1,069	Bow R			
Town of Vulcan	T	100%	1,649	2,791	Highwood/Little Bow R			
				80% RF	McGregor Lake			
					Include with Bow R Basin			
Town of Stavely	T	100%	435	435	GW	439	70	70
Town of Granum	T	100%	415	684	Willow Ck	693	105	173
				70% RF	Willow Ck		74	121
					Net Diversion		32	52
Town of Raymond	T	100%	3,205	3,880	Ridge Res	719	841	1,018
Village of Nobleford	VL	100%	689	1,143	LNID	0	0	0
Village of Barnwell	VL	100%	613	785	Chin L; TID	350	78	100
Village of Champion	VL	100%	364	369	Travers Res			
Village of Barons	VL	100%	276	276	LNID	23	2	2
Village of Glenwood	VL	100%	280	280	GW	4	0	0
Village of Carmangay	VL	100%	336	633	Little Bow R			
Village of Cowley	VL	100%	219	219	Castle R	21	2	2
Village of Lomond	VL	100%	175	188	BRID (Little Bow)	23	1	2
Village of Milo	VL	0%	100	100	McGregor Lake	1,332	49	49
Village of Stirling	VL	100%	921	1,044	Ridge Res	1,114	374	425
Village of Warner	VL	100%	307	307	Ridge Res	350	39	39
Rural Domestic		100%	66,782	41,833	GW	350	8,531	5,344
First Nations								
Blood Tribe 148	R	100%	4,177	4,177	GW	350	534	534
Peigan Tribe 147 (Piikani)	R	100%	1,300	1,300	GW	350	166	166
Sub-basin ORB Municipal Summary			**Urban SW Withdrawal**				**33,256**	**46,135**
			Urban SW Return Flow				**24,465**	**34,273**
			Urban SW Net Use				**8,791**	**11,862**
			Urban GW Withdrawal				**70**	**60**
			Rural Withdrawl (SW/GW)				**8,531**	**4,543**
			Reserve GW Withdrawal				**700**	**595**
			GW/SW Conversion					**917**

Appendix B - Table 4: Municipal Domestic Current Water Use and Projections to 2030 in the South Saskatchewan River Sub-basin

Municipality	Type	% in Sub-basin	Population		Water Source RF Recipient	Current Use (2006)		2030 Demand dam^3
			2006	2030		L/c-d	dam^3	
City of Medicine Hat	C	100%	56,997	75,890	SS R	750	15,607	20,780
				80% RF	SS R		12,485	16,624
					Net Diversion		3,121	4,156
Town of Redcliff	T	100%	5,096	9,217	SS R	916	1,703	3,080
				80% RF	Medicine Hat		1,362	2,464
					Net Diversion		341	616
Town of Bow Island	T	100%	1,790	2,273	SMRID			
Village of Foremost	VL	100%	524	524	GW	350	67	67
Rural Domestic		100%	7,130	9,113	GW	350	911	1,164

Sub-basin SSRsB Municipal Summary			
	Urban SW Withdrawal	**17,310**	**23,871**
	Urban SW Return Flow	**13,848**	**19,088**
	Urban SW Net Use	**3,462**	**4,782**
	Urban GW Withdrawal	**67**	**57**
	Rural Withdrawl (SW/GW)	**911**	**990**
	GW/SW Conversion		**185**

Technical Memorandum No. 2B – NON-MUNICIPAL WATER USE

May 2008

South Saskatchewan River Basin
Water Supply Study

Technical Memorandum No. 2B

May 2008

Non-municipal Water Use

Prepared for: South Saskatchewan River Basin Water Supply Steering Committee

Prepared by: AMEC Earth and Environmental

Date: May 23, 2008

Issues

- What are the current non-municipal water uses in the South Saskatchewan River Basin?
- What non-municipal water demands are projected for Year 2030?
- What is the distribution of demands among the four sub-basins?

1.0 INTRODUCTION

The water management plan for the South Saskatchewan River Basin (SSRB) was approved by the Alberta Government in August 2006. This plan led to establishment of the basin's Water Conservation Objectives (WCOs) in January 2007, and restricted the use of all unallocated water in the Bow, Oldman and South Saskatchewan Sub-basins in August 2007 (Regulation 171/2007). The plan and subsequent decisions have heightened competition for water in the SSRB. Water users throughout the basin are concerned about the security of supply and economic growth now and in the future.

The SSRB Water Supply Steering Committee commissioned a science-based study with objectives as follows:

- assess current and future water supply and demand in the SSRB;
- identify constraints to water supply and economic growth; and,
- identify, analyze and evaluate structural and non-structural water management alternatives to address constraints and issues.

Current and projected future municipal and rural domestic water needs are dealt with in Technical Memorandum No. 2A (Volume 2 of this document). This memorandum deals with agricultural, commercial, petroleum sector, industrial and other water uses. All water users share the finite water supplies of the South Saskatchewan River Basin (SSRB). The magnitude and characteristics of all water uses influence the security of water supplies for individual users regardless of the purpose of the use. Simulation modelling to determine the magnitude and frequency of insufficient water supplies for users in the SSRB must consider the location, magnitude and seasonal distribution of all water uses. The main concern for existing and potential future users in the basin is the ability of the three main tributaries within the SSRB (Red Deer, Bow, and Oldman Rivers) and the South Saskatchewan River itself to support current and projected increases in demands within the basin and, at the same time, provide sufficient flow and water quality to protect the aquatic environment. With this concern in mind, this study will focus on those uses and return flows that have an impact on the mainstem streams in median or lower flow years, or in other words, uses within the effective drainage areas. Water uses outside the effective drainage areas would affect flows in the mainstem streams only in years when runoff exceeds median flows. In these years, water supply deficits are usually not an issue.

The recently completed SSRB planning program considered the impact of **licensed demand** (licenced allocation minus return flow) on water supply. Actual water uses are often substantially less than the licensed allocation and use. In this study, **actual surface water use** will be estimated. Surface water use represents about 98% of total water use in the SSRB (AMEC, 2007). Surface water demand to Year 2030 will be projected.

Water licences define purpose, location, maximum allocation, and maximum rate of diversion of projects in the study area. The irrigated area is defined for irrigation projects. The allocations provide an indication of the size of the projects. The licensed water allocation can be considered an upper limit of withdrawal from the source for the project. However, the entire allocation may not be withdrawn every year, depending on many factors such as weather conditions, water availability, crop rotations, and economic circumstances. A review of reported actual withdrawals submitted by licensees indicated that withdrawals are usually less than licensed withdrawals by varying degrees depending on user category (Hydroconsult, 1999). The licences also include **estimates** of consumptive use, losses and return flow. These are all non-enforceable quantities, but they provide an indication of the intent of the project when the licence application was made. In this document, the term "licensed water use" will refer to 'Consumptive Use plus Losses', or 'Withdrawal minus Return Flow' as determined from information on the licence; "actual water use" will refer to an 'Estimate of Average Annual Actual Water Use' by the project. In other words, "actual water use" is the estimated actual net impact on the source stream.

The task is to define "actual water use" using the licensing database to determine the location and relative size of the project, and to use Alberta Environment's Water Use Reporting System (WURS) and other relevant data to relate actual water use to licensed water use. The WURS is a relatively new database which contains actual water-use data from a small percentage of water users for a few years.

This analysis draws heavily on the water demand database prepared by Alberta Environment for use in the SSRB Planning Program and a recently released study of actual water uses throughout Alberta, completed under the Water for Life program (AMEC, 2007). Alberta Environment based their demands primarily on licensing information (withdrawal minus return flow), and projected future uses. The AMEC study estimated current and projected **actual water uses** for the entire province. This study updates and combines the two databases to provide estimated actual current and future demands distributed throughout the SSRB in a manner consistent with requirements for simulation modelling. An effort was made to improve on the 2007 study by removing licensing duplications, misfiled licence listings that are outside of the SSRB, and licences outside the effective drainage area, as they are discovered. Even so, the actual water uses determined in this study are not the definitive answer. Assumptions and approximations are necessary. Given that there are about 9400 surface water licences in the SSRB (not counting registrations), a thorough review of the database is beyond the scope of this study.

To summarize, the following terminology will be used in this study:

- **Water Allocation** – the maximum amount of water that can be diverted for uses set out in licences under the *Water Act.* The allocation is an enforceable quantity generally reflecting the maximum annual amount that the licensee intends to divert over the licensing period. It includes consumptive use, losses and return flows.
- **Water consumption, losses and return flows** – unenforceable estimated amounts defined in the licences. They reflect the intent of the applicant at the time the licence application is made. “Consumption“ is the amount of water used for the applicant’s project. It is not available for reuse. The term “losses“ refers to water that is diverted and lost due to evaporation, seepage or other means that is not beneficial to the applicant. The lost water is not available for immediate reuse, although it generally remains a component of the hydrologic cycle. “Return flow“ is water returned to the environment that is available for reuse. Typical return flows in the SSRB are treated wastewaters from municipalities or industries, irrigation operational surpluses or runoff from irrigated fields, and returns of industrial cooling waters.
- **Licensed Uses** – water use based on information provided in the licences. Licensed uses are equal to ‘Consumption plus Losses’ or ‘Allocation minus Return Flow’ (which will give the same value). Licenced uses are usually larger than actual use because the full allocation is not required in most years. However, they could be less than actual uses if return flows are less or losses are larger than the licenced amounts.
- **Actual Uses** – actual withdrawals minus return flows determined by direct monitoring of projects or a sample of projects in specific activity categories. If the sample is large enough to establish a relationship between actual use and licensed use, the relationship is applied to all licences in the category. Actual water use reflects the fact that licensees may not always withdraw their full entitlements, and return flow and losses may differ from the amounts recorded in licences. If no information on actual use is available, actual use is assumed to equal licensed use.

The AMEC (2007) study provided graphics on the distribution of active licensed water allocations for each of the four SSRB sub-basins (**Figure** 1). In the interest of efficient and effective study effort, this study will concentrate on efforts to determine the more significant uses in each basin as accurately as possible. These will include irrigation and municipal uses in all four sub-basins, industrial uses in the Red Deer and South Saskatchewan Sub-basins, petroleum uses in the Red Deer Sub-basin, and other uses in the Red Deer and Oldman Sub-basins.

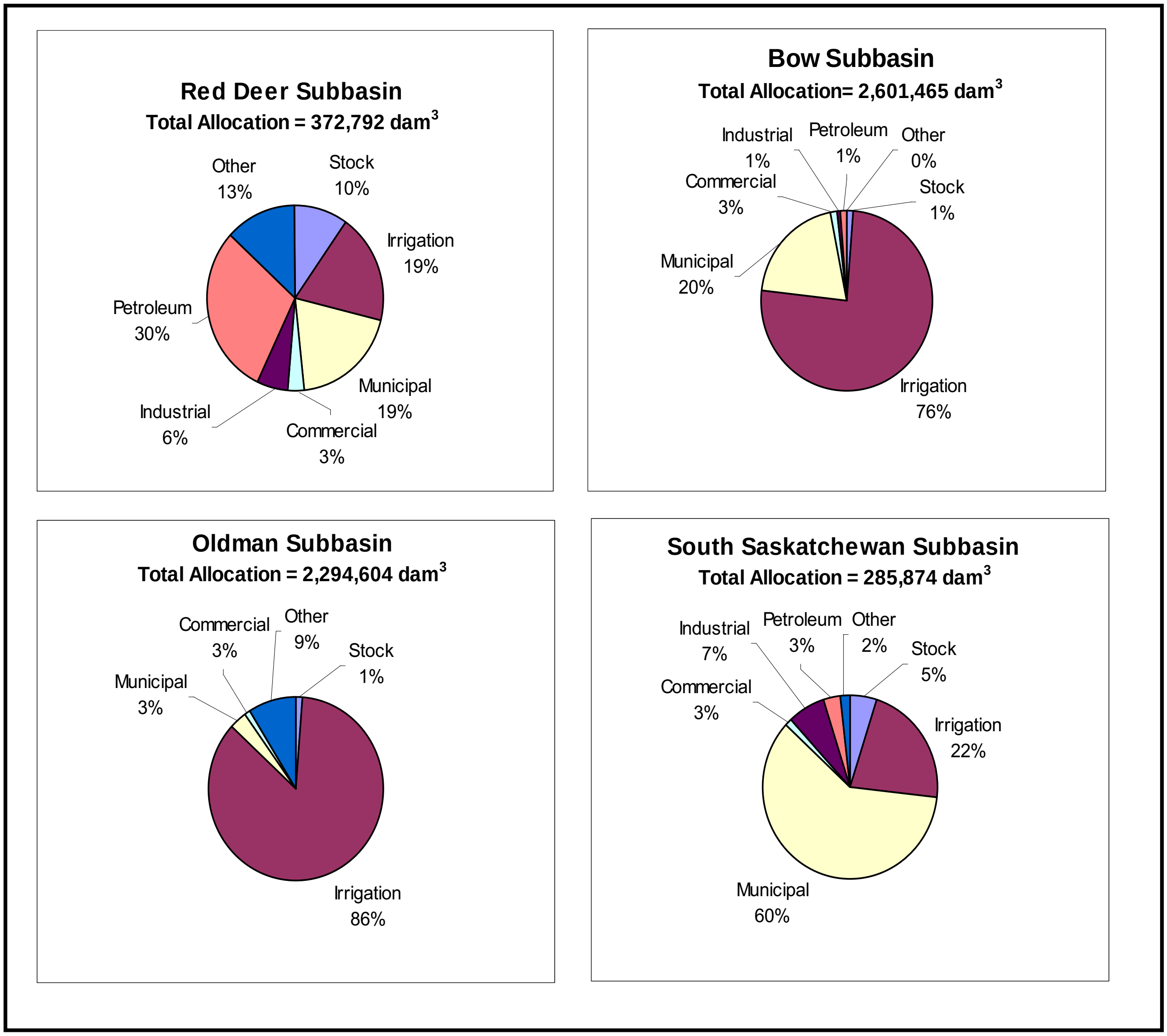
2.0 CURRENT WATER USE AND PROJECTED WATER DEMANDS

2.1 Agricultural Sector

The Agricultural sector includes irrigation, stock water, and feedlots.

2.1.1 Irrigation

Irrigation represents the largest demand in the SSRB (**Figure 1**), considering both the withdrawal or gross diversion from source streams and the actual consumptive use. About 83% of the



Adapted from AMEC, 2007.

Figure 1 **Distribution of Licensed Surface and Groundwater Allocations in the Sub-basins of the South Saskatchewan River Basin**

irrigation demand in the SSRB occurs within the **13 irrigation districts** in the basin. Irrigation has a highly variable temporal and spatial demand in southern Alberta, largely dependent on crop types, and growing season temperature and precipitation. For these reasons, simulation modelling for this purpose has been addressed in a more rigorous manner than for most other uses. Alberta Agriculture and Rural Development (ARD) has developed an Irrigation District Model (IDM) which is used to determine weekly irrigation crop demand, on-farm losses, irrigation district conveyance losses and return flows for various levels of technology changes and crop mixes. This variable weekly information is input into Alberta Environment's Water Resource Management Model (WRMM) for simulation modelling of supply and demand in the SSRB.

For the purposes of this Technical Memorandum, the average irrigated areas and gross diversions to irrigation districts for the past 4 years (2004–2007) are assumed to be representative of the current level of demand (**Table 1**). The gross diversions include a relatively small amount of water that is supplied to non-irrigation users through the works of the irrigation districts. Other users supplied by these withdrawals include industries, municipalities, domestic and stockwater users, recreation and wildlife projects. The irrigation district mean annual withdrawals from the source streams and return flows over the past 4 years were as follows.

	Gross Diversion (GD, dam^3)	**Approximate Return Flow (% of GD)**	**Estimated Actual Use (dam^3)**
Bow River	852 959	25%	639 719
Oldman River	218 291	18%	178 999
Waterton, Belly and St. Mary Rivers (Oldman Sub-basin)	631 595	11%	562 120
Ross Creek (South Sask Sub-basin)	405	N/A	N/A
Total	1 703 250	19%	1 380 838

Source: Ropin' the Web
http://www.agric.gov.ab.ca/app21/infopage?cat1=Soil%2FWater%2FAir&cat2=Irrigation

Return flows from irrigation districts are a function of several characteristic variables, such as the amount of gravity flood irrigation within the district, the proportion of the conveyance system converted from canals to pipelines, and district density (irrigated area/km of conveyance). During the past decade, the irrigation districts and ARD have made a concerted effort to improve monitoring of return flows, and to understand factors affecting it and ways to reduce it. Definitive return flow data is not yet available for all districts, but sufficient monitoring has taken place to provide rough approximations, which are listed above. A portion of the return flows from 6 of the 13 districts are returned to streams other than the source streams.

TABLE 1
Irrigation District Irrigated Areas and Gross Diversions for 2004 to 2007

District	Actual Irrigated Area (ha)					Gross Diversion (dam^3)					Ave. Unit Gross Demand (mm)
	2004	2005	2006	2007	Ave Area	2004	2005	2006	2007	Ave Div	
Bow River Subbasin											
BRID	82,189	83,584	84,364	81,492	82,907	280,012	258,198	262,656	310,465	277,833	335
EID	114,828	114,278	113,665	115,149	114,480	515,272	392,593	413,840	515,840	459,386	401
WID	22,132	22,747	17,464	16,484	19,707	140,741	148,148	90,123	83,951	115,741	587
Totals	219,149	220,609	215,493	213,126	217,094	936,025	798,938	766,619	910,256	852,959	393
Oldman River Subbasin											
AID	966	956	956	956	958	4,247	4,938	4,544	3,994	4,431	462
LID	1,928	1,928	1,928	1,928	1,928	6,698	7,707	6,594	7,815	7,203	373
LNID	71,015	70,934	70,925	70,718	70,898	196,649	165,541	220,370	290,605	218,291	308
MID	5,866	5,281	5,357	5,942	5,611	15,298	10,937	17,425	22,517	16,544	295
MVID	1,421	1,421	1,421	1,421	1,421	3,284	2,552	4,922	4,444	3,801	267
RID	15,571	14,822	16,662	17,236	16,073	34,844	33,390	45,740	42,584	39,140	243
SMRID	142,949	140,322	135,736	140,055	139,766	404,691	378,148	437,654	518,025	434,630	311
TID	30,881	31,385	31,079	31,202	31,137	79,505	89,490	101,788	124,572	98,839	317
UID	8,800	8,413	9,219	8,915	8,837	26,667	16,935	25,173	39,260	27,009	306
Totals	279,398	275,463	273,284	278,372	276,629	771,883	709,638	864,210	1,053,816	849,887	307
South Saskatchewan River Subbasin											
RCID*	324	324	0		324	0	482	0		494	381
Basin Totals	498,870	496,396	488,777	491,741	494,047	1,707,907	1,510,046	1,630,828	1,964,072	1,703,340	345

Source: Alberta Agriculture and Rural Development's Website "Ropin' the Web"
(http://www.agric.gov.ab.ca/app21/infopage?cat1=Soil%2FWater%2FAir&cat2=Irrigation).

* RCID is a small irrigation district with a water supply that is often insufficient. It is treated differently from other districts in the above table.

Private irrigation projects have been developed throughout the SSRB. These projects are also modelled in the WRMM using variable demands produced by ARD. The number of projects, area irrigated, and the approximate average annual demand within each sub-basin are summarized in **Table 2**.

Note that projects along Mosquito Creek and the Little Bow River (Oldman River Sub-basin) are supplied from two sources: the natural flow of Mosquito Creek and the Little Bow River, and diversions from the Highwood River. During low flow years there is little or no natural flow in the Little Bow River or Mosquito Creek and a high percentage of the demand is supplied from the Highwood River. For the purposes of this analysis, it is assumed that the projects along Mosquito Creek and the Little Bow River are supplied from the Highwood River (Bow River Sub-basin). In simulation modelling, the Mosquito Creek and Little Bow projects are supplied from natural flow whenever it is available. They draw on Highwood River water only when local supplies are unavailable.

There is little or no return flow from the private irrigation projects.

With regard to future irrigation expansion, including field crops, gardens, parks and golf courses, annual growth rates for private irrigation over the past 20 years has been very low at about 0.3% (AMEC, 2007). Projections for the Red Deer River Sub-basin have been made based upon water licence applications for the Special Areas Water Supply Project (SAWSP) and the Acadia Project, and historical trends for private individual agricultural and recreation projects. The SAWSP project would divert 2.5 m^3/s from the Red Deer River west of Stettler for multi-purpose use, including about 3 240 ha (8,000 acres) of sprinkler irrigation. The Acadia project near the Alberta/Saskatchewan border would irrigate about 10 930 ha. Private irrigation projects are most likely to be developed along valley lands in the lower reaches of the Red Deer River where the growing season moisture deficit is high and soils are irrigable (Acres, 1988). Park and golf course irrigation is expected to increase at approximately the same rate as population. Future expansion in the Red Deer River Sub-basin to Year 2030 is projected as summarized in **Table 3**.

TABLE 2
Private Irrigation Projects in the SSRB

	No. of Projects	Area Irrigated (ha)	Average Annual Demand (dam^3)
Red Deer River Sub-basin	488	13 972	48 900
Bow River Sub-basin*	370	23 528	72 750
Oldman River Sub-basin	477	41 834	129 270
South Saskatchewan River Sub-basin	353	10 549	42 200
Total	1,688	89 883	293 120

* Projects along the Little Bow River and Mosquito Creek are included in the Bow River Sub-basin totals, although these projects are partially supplied from the Little Bow River and Mosquito Creek (Oldman River Sub-basin). The irrigated area listed includes 8 097 ha associated with the Highwood/Little Bow Project.

Sources: Associated Engineering, 2008; Ropin' the Web; Alberta Environment Licensing Listings, and personal communication with Donna McCall, Alberta Environment.

TABLE 3
Current and Projected Future Irrigation in the Red Deer River Sub-basin

	Current	Projection to 2030
Current Irrigated Area (ha)	13 972	13 972
Expansion		
SAWSP (ha)		3 237
Acadia (ha)		10 926
Other Projects (crop irrigation, gardens, parks, golf) (ha)		2 100
Total Irrigated Area (ha)	13 972	30 236
Average Annual Demand (dam^3)	48 000	112 800

Source: Associated Engineering, 2008.

Future average demands for irrigation are based on approximate irrigation water applications for the locations where projects are likely to be developed.

The Bow, Oldman and South Saskatchewan Sub-basins are closed to new allocations. However, the Irrigation Districts Act allows districts to increase their irrigated area provided that expansion is approved by District Members. With efficiency improvements and more effective water use, districts could expand to more fully utilize their existing water right allocations.

The irrigation district expansion limits defined for the Bow River Sub-basin in the *1991 South Saskatchewan Basin Water Allocation Regulation* (now repealed) were 10.2% higher than the average irrigated area in the districts during 2004 to 2007 (217 094 ha). The guidelines for the Oldman River Sub-basin irrigation districts were 8.5% higher than the average irrigated area over years 2004 to 2007 (276 629 ha). The Irrigation Water Management Study Committee (2002) indicated that a 10 to 20% expansion beyond the expansion limit would be sustainable in the Bow River Sub-basin with improvements in water-use efficiency, reduced return flows and higher crop water applications. Similarly, the Committee stated that a 10% expansion in the Oldman River Sub-basin could be considered. For the purposes of this study, two levels of expansion for district irrigation were considered. *Level 1* expansion would increase the irrigated areas to those of the 1991 Regulation that defined the limits of irrigation expansion (**Table 4**). *Level 2* expansion would be consistent with the findings of the Irrigation Water Management Study Committee (2002) that expansion 20% beyond the 1991 limits in the Bow River Sub-basin and 10% beyond the limits in the Oldman River Sub-basin would be worthy of further consideration.

Future gross diversion demands of 496 mm for the Bow Sub-basin districts and 360 mm for the Oldman Sub-basin districts are based on transitions to higher value crops, improved district and on-farm efficiencies and higher on-farm applications (Irrigation Water Management Study Committee 2002, **Table A-3**, Scenario S9). Corresponding Unit Net Use (Unit Gross Demands minus Return Flows) is estimated to be 391 mm for the Bow Sub-basin districts and 314 mm for the Oldman River districts.

With respect to private irrigation, AMEC (2007) indicated that the Bow, Oldman and South Saskatchewan Sub-basins had annual growth rates in of 1.7, 1.6 and 1.1% respectively over the past 20 years. With closure of the Bow, Oldman and South Saskatchewan Sub-basins, private irrigation expansion will be limited to applications on hand that are approved for licensing, expansion in the area of the Oldman River Reservoir in accord with the Oldman River Basin Water Allocation Order (Regulation 319/2003), and expansion for First Nation projects.

The Pine Coulee Project in the Oldman River Sub-basin has a target irrigation expansion area of 5263 ha. At an estimated irrigation application of about 300 mm, the total allocation for full development would be 15 789 dam^3. As of early 2008, licences for 8795 dam^3 have been issued. Additional water available for allocation from the project is about 7000 dam^3 or enough to add about 2330 ha of irrigation[1]. The Highwood/Little Bow Project has been fully allocated (8097 ha) and is included under current irrigation.

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[1] Alberta Environment’s Licence Viewer: http://ssrb.environment.alberta.ca/licence_viewer.html

TABLE 4
Level 1 and Level 2 Irrigation District Expansion Projections to Year 2030

District	Current Area (ha)	Level 1 Expansion		Level 2 Expansion		
		1991	% above Current	Based on IWMSC 2002	% above Level 1 Exp.	% above Current
Bow River Subbasins						
BRID	82,907	84,984	2.5%	101,981	20.0%	23.0%
EID	114,480	115,740	1.1%	138,888	20.0%	21.3%
WID	19,707	38,445	95.1%	46,134		134.1%
Totals	217,094	239,169	10.2%	287,003	20.0%	32.2%
Oldman River Subbasins						
AID	958	1,429	49.1%	1,572	10.0%	64.0%
LID	1,928	1,930	0.1%	2,123	10.0%	10.1%
LNID	70,898	71,632	1.0%	78,795	10.0%	11.1%
MID	5,611	7,406	32.0%	8,147	10.0%	45.2%
MVID	1,421	1,497	5.4%	1,647	10.0%	15.9%
RID	16,073	18,818	17.1%	20,700	10.0%	28.8%
SMRID	139,766	150,543	7.7%	165,597	10.0%	18.5%
TID	31,137	33,265	6.8%	36,592	10.0%	17.5%
UID	8,837	13,759	55.7%	15,135	10.0%	71.3%
Totals	276,629	300,279	8.5%	330,307	10.0%	19.4%
South Saskatchewan River Sub basin						
RCID	324	486	50.1%	486	0.0%	50.1%
SSRB Totals	494,047	539,934	9.3%	617,796	14.4%	25.0%

Notes:

1. The original Irrigation Expansion Limit of 111 289 ha for the EID was revised in the Irrigation Districts Act to 115 740 ha.
2. The LNID original area of 67 583 ha was increased to incorporate the 4049 ha Keho/ Barons South area, which is now incorporated into the LNID.
3. IWMSC 2002 refers to the Irrigation Water Management Steering Committee report, "Irrigation in the 21st Century" prepared in 2002. The irrigation expansion scenarios considered in this study are consistent with the findings of the IWMSC.

Other private applications received by Alberta Environment may or may not be approved for development depending on water supply performance, which is expected to be poor. For the purposes of this study, it is assumed that none of these additional applications will proceed to the development stage, either because of non-approval or voluntary withdrawal.

First Nations that have a firm or near-firm commitment are the Piikani and the Siksika for 43 200 dam^3 each. Most of the committed amount would be for irrigation water use[2].

In summary, existing average water use and future demand for irrigation in the SSRB is shown in **Table 5**.

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[2] Communication with Alberta Environment's modelling staff.

TABLE 5
Current Irrigation Water Use and Projected Demand Circa 2030 in the South Saskatchewan River Basin

Sub-basin	Licence Allocation (dam^3)	Current Water Use				Projected 2030 Demand with Level 1 Expansion within Irrigation Districts				Projected 2030 Demand with Level 2 Expansion within Irrigation Districts			
		Irrigated Area (ha)	Withdrawal (dam^3)	Return Flow (dam^3)	Water Use (dam^3)	Irrigated Area (ha)	Withdrawal (dam^3)	Return Flow (dam^3)	Net Water Demand (dam^3)	Irrigated Area (ha)	Withdrawal (dam^3)	Return Flow (dam^3)	Net Water Demand (dam^3)
Red Deer River Sub-basin													
Private Projects	67,400	13,972	48,900	-	48,900	16,072	56,250	-	56,250	16,072	56,250	-	56,250
SAWSP Project						3,240	12,900	-	12,900	3,237	12,900	-	12,900
Acadia Project						10,926	43,700	-	43,700	10,926	43,700	-	43,700
Sub-basin Total	**67,400**	**13,972**	**48,900**	**-**	**48,900**	**30,238**	**112,850**	**-**	**112,850**	**30,235**	**112,850**	**-**	**112,850**
Bow River Sub-basin													
Irrigation Districts	1,689,800	217,094	852,959	213,240	639,719	239,169	1,180,514	259,713	920,801	287,003	1,398,686	293,724	1,104,962
Private	71,300	27,806	108,480	-	108,480	27,806	108,480	-	108,480	27,806	108,480	-	108,480
Siksika Expansion						12,000	43,200		43,200	12,000	43,200		43,200
Sub-basin Total	**1,761,100**	**244,900**	**961,439**	**213,240**	**748,199**	**278,975**	**1,332,194**	**259,713**	**1,072,481**	**326,809**	**1,550,366**	**293,724**	**1,256,642**
Oldman River Sub-basin													
Irrigation Districts	1,756,700	276,629	849,887	152,980	696,907	300,279	1,096,368	153,491	942,876	330,307	1,192,143	154,979	1,037,164
Private	99,200	41,834	129,270	-	129,270	41,834	129,270	-	129,270	41,834	129,270	-	129,270
Willow Cr./Pine Coulee						2,330	7,000	-	7,000	2,330	7,000	-	7,000
Summerview Project						4,500	13,600		13,600	4,500	13,600		13,600
Piikani Expansion						6,192	18,600		18,600	6,192	18,600		18,600
Blood Expansion						3,036	9,100		9,100	3,036	9,100		9,100
Sub-basin Total	**1,855,900**	**318,463**	**979,157**	**152,980**	**826,177**	**358,171**	**1,273,938**	**153,491**	**1,120,446**	**388,199**	**1,369,713**	**154,979**	**1,214,734**
South Saskatchewan River Sub-basin													
Irrigation Districts	3,700	324	405		405	486	1,700		1,700	486	1,700		1,700
Private		10,549	42,200	-	42,200	10,549	42,200	-	42,200	10,549	42,200	-	42,200
Sub-basin Total	**3,700**	**10,873**	**42,605**	**-**	**42,605**	**11,035**	**43,900**	**-**	**43,900**	**11,035**	**43,900**	**-**	**43,900**
SSRB Total	**3,688,100**	**588,208**	**2,032,101**	**366,220**	**1,665,881**	**678,419**	**2,762,881**	**413,204**	**2,349,677**	**756,278**	**3,076,829**	**448,703**	**2,628,126**

Bow River Sub-basin private includes full development of the Highwood/Little Bow Project and existing irrigation on Siksika First Nations Reserve for both current and future scenarios.

Oldman River Sub-basin private includes existing development on Willow Creek/Pine Ciulee Project, and on Blood and Piikani First Nations Reserves.

2.1.2 Stock Water

Secure sources of good quality water are essential for the important livestock industry in the study area. Cow-calf operations and the feedlot industry have the largest livestock water requirement in the basin. Water supplies well distributed within grazing lands enable sound range management practices. Feedlots and winter-feeding areas must have ready access to secure water supplies.

Common sources of stock water in the study area are wells, dugouts, small stock water dams on intermittent streams, and the streams themselves. Well-managed use of riparian areas and controlled access to streams is important to maintain healthy streams and riparian vegetation.

The total number and allocations of current licences and registrations for stock watering purposes (surface- and ground-water) in the four sub-basins within the SSRB are as follows:

Sub-basin	Number	Allocations (dam^3)
Red Deer River	22,766	57 096
Bow River	6,194	17 243
Oldman River	9,587	25 870
South Saskatchewan River	4,035	13 297
Total	42,582	113 506

Source: AMEC, 2007.

There is no information on actual water uses for the livestock industry in Alberta Environment's water-use database. Based on procedures used in AMEC (2007), estimates of current actual and projected future actual water use are made for each of the four sub-basins based on the following steps:

1. Determine cattle populations in each basin based on 2001 census data.
2. Determine actual annual cattle water consumption based on cattle populations and daily water consumption data published by Alberta Agriculture and Rural Development (Alberta Agriculture and Rural Development 2001).
3. Determine total livestock water consumption based on the ratio of cattle consumption to total livestock consumption defined by AMEC (2007).
4. Determine surface water livestock consumption based on surface/total licensed consumption ratio.
5. Add surface water losses based on losses identified in the licensing database. Losses can be substantially higher than the estimated consumptive uses. The losses listed on the licences may not accurately reflect actual conditions. Some stock water projects may have been washed out and abandoned or replaced by another more secure source.

6. Estimate 2030 annual demands based on projected growth rates of the cattle industry defined by AMEC (2007) based on research conducted by Alberta Agriculture and Food, and the Natural Resources Conservation Board, the agency responsible for controlling expansion of the confined livestock industry. It is assumed that future livestock supplies will have the same surface water/groundwater ratio and the same ratio of losses to consumption.

Table 6 summarizes the results of the analysis for each of the four sub-basins.

The livestock demands are highest in the Red Deer River Sub-basin, but only slightly higher than the Oldman River Sub-basin. The Bow and South Saskatchewan Sub-basin livestock demands are currently about the same, but the Bow Sub-basin demands have a higher growth rate projection than the South Saskatchewan Sub-basin. Livestock demands are small in relation to irrigation demands in the Bow, Oldman and South Saskatchewan River Sub-basins, at less than 2.0%. They become slightly more significant in the Red Deer River Sub-basin at 3.7% of the irrigation demand.

2.2 Commercial Sector

The commercial sector includes aggregate washing, food processing, water hauling and other activities. Golf courses, gardening and parks are sometimes included under the commercial sector. They have a similar demand pattern to crop irrigation, and in this study, they were considered with crop irrigation under the Agricultural sector. Commercial activities account for 3.0% or less of total allocations in the four sub-basins.

There is no information in the WURS database on actual use for the three commercial activities. AMEC (2007) assumed that actual use was equal to licensed use. This assumption probably overstates actual use, but the commercial sector accounts for only a very small portion of total water use. For this study, AMEC’s water-use estimates minus the irrigation components were adopted for the Commercial sector.

AMEC (2007) used the forecast of Alberta’s average long-term economic growth rate of 2.2% to project the growth in all three categories of commercial activities. The same assumption was adopted for this study. Current and projected surface water use for the commercial sector is summarized in **Table 7**.

TABLE 6
Summary of Annual Livestock Water Use in the Red Deer, Bow, Oldman and South Saskatchewan River Sub-basins

Animal Type	Consumption (L/d)	Red Deer Sub-basin		Bow Sub-basin		Oldman Sub-basin		South Saskatchewan Sub-basin	
		Animal Population	Annual Demand (dam^3)	Animal Population	Annual Demand (dam^3)	Animal Population	Annual Demand (dam^3)	Animal Population	Annual Demand (dam^3)
Bulls	40	30,990	463	7,186	105	10,060	147	3,199	47
Milk Cows	135	26,674	1 327	3,224	159	15,660	772	1,474	73
Beef Cows	40	571,825	8 534	123,632	1 805	185,391	2 707	54,558	797
Heifers	25	235,700	2 345	82,097	749	387,650	3 537	30,647	280
Steers	25	262,037	2 607	151,944	1 386	313,264	2 858	22,657	207
Calves	14	555,219	2 762	160,052	818	286,386	1 464	55,817	285
Source for above: AMEC, 2007									
Total Annual Cattle Consumption (dam^3)			18 038		5 022		11 485		1 689
Adjustment for Other Species									
	Adjustment Factor		1.18		1.14		1.11		1.11
	Total Livestock Consumption (dam^3)		21 285		5 725		12 748		1 875
Adjustment for Surface Water Sources Only									
	Adjustment Factor		0.46		0.65		0.82		0.94
	Total Surface Water Livestock Consumption (dam^3)		9 791		3 721		10 453		1 762
Surface Water Losses (dam^3)			8 201		4 285		5 517		6 242
Total Current Surface Water Demand (dam^3)			**17 992**		**8 006**		**15 970**		**8 004**
Projected Annual Growth Rate			2.2%		2.2%		2.2%		1.2%
Projected 2030 Demands (dam^3)			**33 820**		**15 050**		**30 020**		**11 310**

Sources: StatsCanada; AMEC (2007).

TABLE 7
Current and Projected Commercial Water Use in the SSRB

	Sub-basin Withdrawals and Use[1] (dam^3)				SSRB Total (dam^3)
	Red Deer	**Bow**	**Oldman**	**South Sask**	
Allocations	1 719	7 502	8 493	743	18 457
Licensed Use	1 037	7 295	4 957	743	14 032
Estimated Use					
Current Actual Use	1 037	7 295	4 957	743	14 032
Projected 2030 Demand	1 748	12 299	8 358	1 253	23 658

[1] Excludes golf course, garden and park irrigation.

2.3 Petroleum Sector

The Petroleum sector includes gas and petrochemical plant processing, injection for secondary oil recovery and other petroleum activities. This water-use sector represents 30% of allocations in the Red Deer Sub-basin and 9% in the Oldman Sub-basin. It is of lesser significance in the Bow and South Saskatchewan Sub-basins at 1 and 3% of total allocations, respectively.

Analysis of Alberta Environment's water-use database indicate that gas and petrochemical plants are using about 58% of their licensed surface water use in the Red Deer Sub-basin, 25% in the Bow Sub-basin, 53% in the Oldman Sub-basin, and 67% in the South Saskatchewan Sub-basin (AMEC, 2007). A detailed review of water use for injection purposes in each of the four sub-basins was conducted in 2005 and indicated that actual surface water use for this purpose was 1.7% of licensed use in the Red Deer Sub-basin, 10.5% in the Bow Sub-basin, and 9.5% in the Oldman Sub-basin. There are no surface water allocations for injection purposes in the South Saskatchewan Sub-basin. These ratios are accepted for the purposes of this study.

There is no data on actual water use for other petroleum purposes. Actual water use was assumed to be equal to licensed water use for this activity.

AMEC (2007) projected that future water use for petrochemical plants and other petroleum activities would remain about the same over the next 20 years, but water use for injection purposes would decline at a rate consistent with the expected rate of decline of conventional crude in Alberta, which is about 5% per year. For the purposes of this study, future water use to 2030 was projected on the basis of AMEC's rationale.

Current and projected surface water use for the Petroleum sector is summarized in **Table 8**.

TABLE 8
Current and Projected Petroleum Water Use in the SSRB

Petroleum Activity	Red Deer		Bow		Oldman		South Saskatchewan	
	Licensed Use (dam^3)	Actual Use (dam^3)	Licensed Use (dam^3)	Actual Use (dam^3)	Licensed Use (dam^3)	Actual Use (dam^3)	Licensed Use (dam^3)	Actual Use (dam^3)
Gas/petrochemical	30 872	17 910	1 781	452	1 109	591	6 097	4 069
Injection	10 988	182	7 508	791	2 418	231	0	0
Other	16	16	1	1				
Total Current Actual Use		18 108		1 244		822		4 069
Projected 2030 Use		17 960		671		655		4 069

2.4 Industrial Sector

The Industrial sector includes water allocations for cooling, fertilizer plants, mining and other industrial activities. It is a relatively minor surface water use in the SSRB. Licensed water use is dominated by cooling in the Red Deer Sub-basin; fertilizer, cooling and other activities in the Bow Sub-basin; and, fertilizer in the South Saskatchewan Sub-basin (**Table 9**). There are no significant licensed surface water uses for industrial purposes in the Oldman Sub-basin.

TABLE 9
Current and Projected Industrial Water Use in the SSRB

Industrial Activity	Red Deer		Bow		Oldman		South Saskatchewan	
	Licensed Use (dam^3)	Actual Use (dam^3)	Licensed Use (dam^3)	Actual Use (dam^3)	Licensed Use (dam^3)	Actual Use (dam^3)	Licensed Use (dam^3)	Actual Use (dam^3)
Cooling	13 807	13 807	2 556	2 556	0			
Fertilizer			14 402	14 402	0		17 142	17 142
Mining			0	0	0			
Other	122	122	3 179	3 179	0		25	25
Total Current Actual Use				20 137		0		17 167
Projected 2030 Use		13 929		20 137		0		17 167

Cooling involves a small amount of consumption for forced evaporation and natural evaporation if a constructed cooling pond is involved, and high return flows. There is no information in Alberta Environment's WURS database on actual uses for cooling purposes. For purposes of this analysis, it is assumed that licensees are using the full amount of their licensed water use.

Water requirements for the fertilizer industry are primarily related to washing and cleaning activities. There is no information available on actual surface water uses for the fertilizer industry in the Bow or South Saskatchewan Sub-basins. For purposes of this analysis, it is assumed that licensees are using the full amount of their licensed water use.

AMEC (2007) projected that there would be no growth in water used for cooling or for fertilizer manufacture for the next 20 years. For the purposes of this study, it is projected that there will be no growth to 2030.

Current and projected water use for the Industrial sector is summarized in **Table 9**.

2.5 Other Sector

The Other sector includes water management projects, habitat enhancement projects and projects designated as "other" by the *Water Act* director. Water management includes water level stabilization projects and storage development for multi-purpose use. Flood control projects (dykes, channel improvements, etc) are sometimes included as water management projects, but apart from temporary reservoir storage during high flow periods or diversions to other streams (uncommon in Alberta), they are generally not considered to be water-use projects. Allocations for other purposes are significant in the Red Deer and Oldman Sub-basins (**Figure** 1). Licensed water uses (uses expected at the time of licensing) are listed in **Table 10**.

TABLE 10
Current and Projected Other Sector Water Use in the SSRB

Other Sector Specific Activity	Red Deer		Bow		Oldman		South Saskatchewan	
	Licensed Use (dam^3)	Actual Use (dam^3)	Licensed Use (dam^3)	Actual Use (dam^3)	Licensed Use (dam^3)	Actual Use (dam^3)	Licensed Use (dam^3)	Actual Use (dam^3)
Water Management	37 801	37 801	7 062	7 062	42 575	42 575	0	
Habitat	17 800	17 800	1 422	1 422	1 046	1 046	0	
Other Specified	15	15	3	3	8	8	0	
Total Current Actual Use		55 616		8 487		43 629		0
Projected 2030 Use		55 616		8 487		43 629		0

Within the Red Deer River Sub-basin, the water management category includes water level stabilization at Buffalo, Gull and Burnstick Lakes, and 26 Ducks Unlimited Canada projects, and evaporation losses on Glennifer Lake Reservoir. Habitat management projects are almost entirely Ducks Unlimited Canada projects. There is a lack of information on actual diversions and water use for this activity. AMEC has assumed that licensees are using their full entitlement of 30 000 dam^3, and that water use will remain constant for the forecast period. The AMEC assumptions have been adopted for the Red Deer and other sub-basins for purposes of this study. However, in this study projects outside of the effective drainage area have been excluded.

Within the Bow River Sub-basin, the water management category includes evaporation losses for the Women's Coulee, Little Bow and Clear Lake projects, and stabilization requirements for Frank Lake and several Ducks Unlimited Canada projects. Habitat projects are primarily Ducks Unlimited Canada projects.

The water management category in the Oldman Sub-basin includes evaporation losses from the St. Mary and Lethbridge Northern Headworks, evaporation from the Oldman River Reservoir, and stabilization of three Ducks Unlimited Canada projects.

There are no projects in the Other sector within the effective drainage area of the South Saskatchewan Sub-basin.

Estimates of current and 2030 water use for the Other sector are listed in **Table 10**.

3.0 POTENTIAL IMPACT OF CLIMATE CHANGE ON FUTURE WATER USES

In the foregoing analysis, current water uses are estimated and future water demands are projected based on continuation of historical climatic conditions. Future increases in water demand are primarily the result of population increases and new economic developments. Climate change will probably impact unit demands for water irrespective of increases in population and economic development. For instance, increased temperatures may increase demands for summer outside watering in municipalities to sustain lawns and gardens. Evaporation from open water surfaces may increase. Livestock requirements will increase with higher temperatures. These increases may be partially or entirely offset by increases in precipitation. Changes in water needs for non-irrigation purposes will likely be small in relation to changes in uses for irrigation since irrigation is the largest water-use sector in the SSRB. A relatively small change in the unit demand for irrigation could have a significant impact on the water balance in the basin because irrigation is already a very high fraction of existing demands. A dryer climate will increase the desire of current dry-land producers to incorporate irrigation into their farming operations. Also, warmer temperatures and a longer growing season would enhance crop choices and probably lead to changes in irrigation cropping patterns to higher value crops, but not necessarily higher water demanding crops. Double-cropping may be possible in some areas, which would undoubtedly increase irrigation demands.

A recent report prepared for the Prairie Adaptation Research Collaborative (PARC) summarized current knowledge of climate change impacts on Canada's Prairie Provinces (Henderson and Sauchyn, eds. 2008). The report shows a plot of temperature and precipitation changes for a period centered around the 2050s derived from seven Global Climate Models and seven emission scenarios. The plot shows that for the grassland region of the prairies there is considerable variation in the predicted temperature and precipitation changes (**Table 11**). The median projection shows a mean annual temperature increase of about 3.3°C and a mean annual precipitation increase of about 5%. The authors noted that much of the increase in both temperature and precipitation is weighted to the winter months.

TABLE 11
Precipitation and Temperature Changes for the Grassland Region of the Canadian Prairies Based on 26 Global Climate and Emission Scenario Simulations

	Temperature (°C)	Precipitation (%)
Maximum Change	5.7	+18
Median Change	3.3	+5
Minimum Change	1.8	-4

Based on scatter plots from Henderson and Sauchyn, eds. 2008.

Similarly, a study conducted for Alberta Agriculture and Food (Marv Anderson and Associates, 2007) considered the results of four Global Climate Model scenarios for the 2050s in southern Alberta. In each scenario, the average annual temperature increased by about 3°C and the number of degree-days in excess of 5°C increased by about 50%. The average annual precipitation decreased by about 10% in the driest scenario, and increased by about 15% in the wettest scenario, indicative of the uncertainty about precipitation. Anderson (2007) indicated that with this range of outcomes, the unit irrigation demands for cereals, oil seeds and pulse crops could amount to plus or minus about 6.0%, depending on the precipitation changes. This is a modest change in the irrigation demand that could either increase or decrease. Probably the more significant issues are changes in crop types, double-cropping, additional cuts on hay crops and other such matters. Unequivocally, with warmer temperatures and a longer growing season, the value of irrigation will increase which will increase the number of producers and the land area that would benefit from irrigation development (Anderson and Associates 2007).

The potential impact on irrigation crop demands will be discussed further in the Technical Memorandum on simulation modelling.

4.0 SUMMARY OF FINDINGS AND DISCUSSION OF RESULTS

1. A summary of estimated current and projected future surface water use for each sub-basin in the South Saskatchewan River Basin, and for each water-use sector, including the municipal sector (Technical Memorandum No. 2A), is provided in **Table 12**. Current actual surface water use in the SSRB is estimated to be about 1 979 000 dam^3. By the Year 2030, water demands are expected to increase by 37% to 2 712 000 dam^3.
2. Irrigation is the highest water-use sector in the South Saskatchewan River Basin with 84% of the total current water use (**Figure 2**). The distribution of water use by purpose is expected to be essentially unchanged during the next 25 years. Irrigation expansions in the SSRB include the Acadia and the Special Areas Water Supply Project in the Red Deer River Sub-basin; the Siksika First Nation Project, and an estimated 10% expansion in irrigation districts' irrigated area in the Bow River Sub-basin; and the Piikani First Nation, Oldman River Reservoir area and Pine Coulee Projects, and about 7% expansion in irrigation districts' irrigation area in the Oldman River Sub-basin.
3. The Oldman River Sub-basin has the highest percentage of current water use among the four sub-basins, followed by the Bow, Red Deer and South Saskatchewan Sub-basins. By 2030, the Bow Sub-basin increases it share from 39 to 43% (**Figure 3**). The Oldman's share decreases by 4%, while the Red Deer and South Saskatchewan remain about the same.
4. Potential climate change will probably impact unit demands for water irrespective of increases in economic development and population. Changes in water uses for non-irrigation purposes will likely be small in relation to changes in demands for irrigation since irrigation is the largest water-use sector in the SSRB. A relatively small change in the unit demand for irrigation could have a significant impact on the water balance in the basin because irrigation is already a high fraction of existing demands. Also, a dryer climate will increase the desire of current dry land producers to incorporate irrigation into their farming operations. Warmer temperatures and a longer growing season would enhance crop choices and would probably lead to changes in the irrigation cropping patterns to higher value crops, but not necessarily higher water demanding crops.

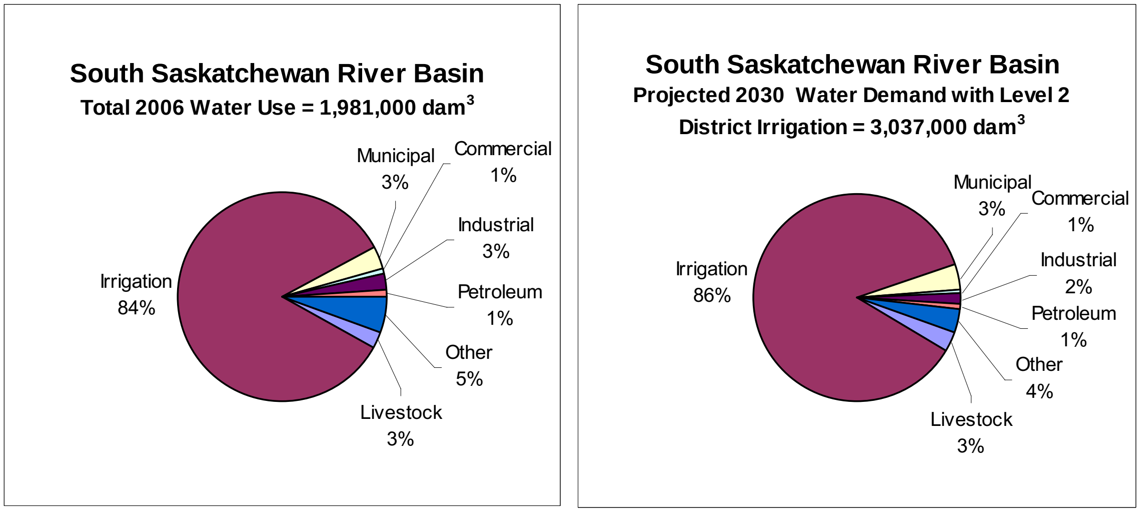
A study conducted for Alberta Agriculture and Food (Marv Anderson and Associates, 2007) considered the results of four climate scenarios representing potential climate circa the 2050s in southern Alberta. In each of the four scenarios, the average annual temperature increased by 3°C and the number of degree-days in excess of 5°C increased by about 50%. The average annual precipitation decreased by about 10% in the driest scenario, and increased by about 15% in the wettest scenario. Dr. Anderson (2007) indicated that with this range of outcomes, the unit irrigation demands for cereals, oil seeds and pulse crops could amount to plus or minus about 6.0%, depending on the precipitation changes.

TABLE 12
Summary of Current Surface Water Use and Projected Future Demands in the South Saskatchewan River Basin in Alberta

Water Use Sector	Estimates of Actual 2006 Use and Projected 2030 Demand in the Subbasins (dam^3)[1]										Total Demands in the South Saskatchewan River Basin (dam^3)		
	Red Deer		Bow			Oldman			South Saskatchewan				
	2006	2030	2006	2030 Level 1	2030 Level 2	2006	2030 Level 1	2030 Level 2	2006	2030	2006	2030 Level 1	2030 Level 2
Municipal													
-- Urban Withdrawal	29,480	59,050	199,277	307,391	307,391	33,256	47,052	47,053	17,310	24,056	279,323	437,549	437,549
-- Urban (Net) Use	12,093	26,698	43,702	68,901	68,901	8791	12,779	12,779	3462	4341	68,048	112,719	112,719
Agriculture													
-- Irrigation Withdrawal	48,900	112,850	961,439	1,332,190	1,550,366	979,160	1,273,940	1,369,710	42,605	43,900	1,983,204	2,762,880	3,076,826
-- Irrigation (Net) Use	48,900	112,850	748,200	1,072,480	1,256,640	826,180	1,120,450	1,214,730	42,605	43,900	1,665,885	2,349,680	2,628,120
-- Livestock	17,992	33,820	8006	15,050	15,050	15,970	30,020	30,020	8004	11,310	49,972	90,200	90,200
Commercial	1037	1748	7295	12,299	12,299	4957	8358	8358	743	1253	14,032	23,658	23,658
Petroleum	18,108	17,960	1244	671	671	822	655	655	4069	4069	24,243	23,355	23,355
Industrial	13,929	13,929	20,137	20,137	20,137	0	0	0	17,167	17,167	51,233	51,233	51,233
Other	55,616	55,616	8487	8487	8487	43,629	43,629	43,629	0	0	107,732	107,732	107,732
Totals – Net Use	167,675	262,621	837,071	1,198,025	1,382,185	900,349	1,186,607	1,310,171	76,203	80,432	1,981,145	2,758,577	3,037,017

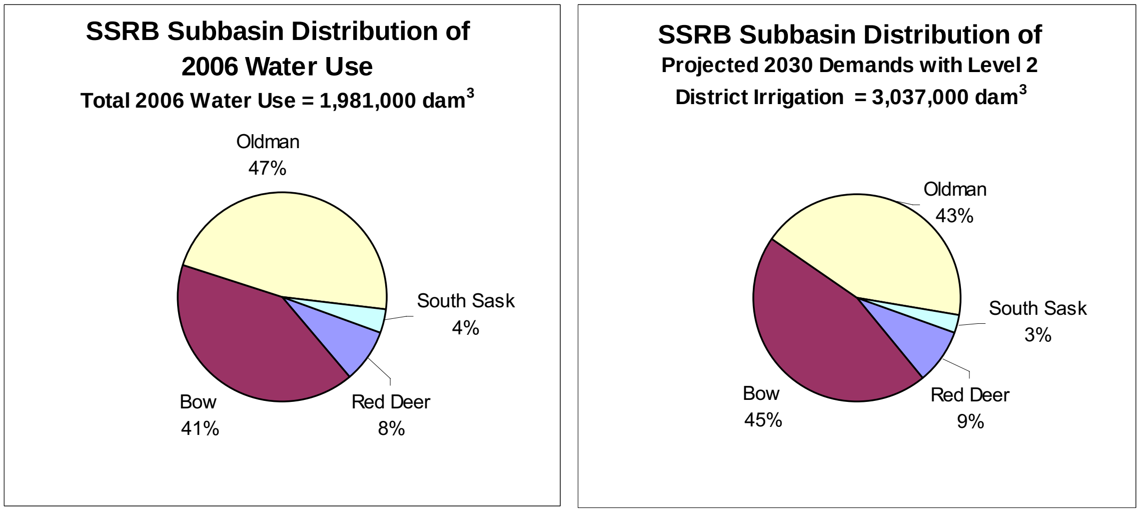
Notes:

1. Municipal -- Urban Withdrawals and Uses are for urban municipal and regional surface water projects.
2. Urban and Irrigation (Net) Uses equal withdrawals minus return flows. Only municipal return flows to mainstem streams are considered. Some irrigation return flows are to subbasins adjac source sub-basins.
3. Subbasin totals are for actual net uses. Withdrawals (yellow highlighting) are not included in totals.


South Saskatchewan River Basin
Total 2006 Water Use = 1,981,000 dam^3

South Saskatchewan River Basin
Projected 2030 Water Demand with Level 2 District Irrigation = 3,037,000 dam^3

Figure 2 Distribution of Water Use and Demand by Purpose


SSRB Subbasin Distribution of 2006 Water Use
Total 2006 Water Use = 1,981,000 dam^3

SSRB Subbasin Distribution of Projected 2030 Demands with Level 2 District Irrigation = 3,037,000 dam^3

Figure 3 Distribution of Water Use and Demand by Sub-basin

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5.0 CLOSURE

This report has been prepared for the exclusive use of the **SSRB Water Supply Steering Committee**. This report is based on, and limited by, the interpretation of data, circumstances, and conditions available at the time of completion of the work as referenced throughout the report. It has been prepared in accordance with generally accepted engineering practices. No other warranty, express or implied, is made.

Yours truly,

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Permit to Practice No. P-4546

UNIT CONVERSION FACTORS

SI Units (metric)	Imperial Units
Area	
1.0 hectare (ha)	= 2.471 acres
1.0 square kilometres (km^2)	= 0.386 square miles
Length	
1.0 millimetre (mm)	= 0.039 inches
1.0 metre (m)	= 3.281 feet
1.0 kilometre (km)	= 0.621 miles
Volume	
1.0 litre (L)	= 0.0353 cubic feet
1.0 cubic metre (m^3)	= 35.315 cubic feet
1.0 decametre (dam^3) = 1000 m^3	= 0.811 acre feet