1.0 INTRODUCTION

Water is a renewable resource, but it is also a finite resource that is approaching the limit of sustainable development internationally. Often, in situations with high water demand, all the competing demands cannot be met (UNCSD 1999). As greater volumes of water are diverted for human use, the effect on surface and groundwater systems increases, causing a reduction in the quality of the water supply. The necessity of maintaining the health of aquatic resources is increasing though as Postel (2000) states, the

> *"opportunities to protect and restore natural freshwater systems will be limited without a concerted effort to reduce human demands for water."*

Postel (2000) further suggests that with the current trends in global population growth and ecosystem declines, society will need to double its water productivity during the next three decades. That is, we will need to get twice as much value from each unit of water removed from a river, lake, or aquifer.

In the early 1990s the Province of Alberta introduced a Water Management Policy for the South Saskatchewan River Basin (Alberta Environment 1990). Within this initiative, the policy called for determination of the maximum amount of water that could be allocated for irrigation in the Red Deer, Bow, Oldman, and South Saskatchewan River sub-basins, considering the requirements for all other uses, including instream uses.

In the late 1990s, the South Saskatchewan River Basin Water Management Plan (SSRB WMP) was initiated under the new *Alberta Water Act*. A Steering Committee was struck, with representation from several Government of Alberta departments. The Steering Committee appointed the Instream Flow Needs Technical Team (referred to hereafter as the Technical Team) to develop instream flow needs (IFN) determinations for the mainstem reaches of the South Saskatchewan River Basin.

The SSRB WMP provides an opportunity to improve aquatic biodiversity conservation. It will bring new scientific and technical understanding of flow requirements for riverine ecosystems into the water management decision arena in Alberta.

Maintaining the ecological integrity and biodiversity of riverine ecosystems is dependent on preserving the dynamic qualities of the flow regime of a river. The approach adopted by the Technical Team for the development of instream flow recommendations is based on the premise that an IFN determination should emulate the seasonal pattern and general magnitude of the natural flow hydrograph of a given water year. That is, intra- and inter-annual variability of flow must be maintained. The intent is to provide an instream determination relative to the ecological basis of the natural flow regime or to accommodate the natural flow paradigm (see Poff et al. 1997 and Annear et al. 2002 for a detailed discussion).

As directed by the Steering Committee for the SSRB WMP, the IFN recommendations are based on the latest scientific understanding of riverine ecosystems. The intrinsic values of natural habitats and organisms of rivers can only be maintained by preserving the processes and functions of the river ecosystem. Management of one riverine component, such as instream habitat for a single or limited number of species in isolation is typically not effective, because each hydrologic component is in continuous interaction with the other components (Winter et al. 1998). Thus the Technical Team incorporated four ecosystem components, water quality, fish habitat, riparian vegetation, and channel maintenance, to address the full spectrum of flows that occur within the natural flow regime.

Bringing the latest scientific and technical understanding of the biological implications of water resource management into the decision-making arena facilitates the development of more sensitive and sophisticated policies for meeting human needs while preserving natural ecosystems. An iterative process of communication between instream flow practitioners and decision-makers is essential if we are to apply what we have learned from the results of past water resource management in a way that positively influences future water management decisions. As Poff et al. (1997) state,

> *"Just as rivers have been incrementally modified, they can be incrementally restored, with resulting improvements to many physical and biological processes."*

This report documents how the Technical Team developed an integrated aquatic ecosystem IFN based on fish habitat, water quality, riparian vegetation, and channel maintenance. The integrated IFN determination is presented in a format suitable for input to the SSRB WMP water-balancing model, the Water Resources Management Model.

2.0 South Saskatchewan River Basin Water Management Plan

In 1990, the Province of Alberta announced the Water Management Policy for the South Saskatchewan River Basin (Alberta Environment 1990). The policy called for determination of the maximum amount of water that could be allocated for irrigation in the Red Deer, Bow and Oldman River basins, and the South Saskatchewan River sub-basin, with due consideration of the requirements for all other uses, including instream uses.

In 1991, Alberta Environment worked with the Alberta Water Resources Commission and Alberta Agriculture to establish the sizes and locations of irrigation expansion that could be supported by the available water supply in the South Saskatchewan River Basin. These agencies discussed the determination of the expansion limits with the Irrigation Council, irrigation districts, private irrigators, Members of the Legislative Assembly and government committees. The result of these efforts was the irrigation expansion guidelines implemented in Alberta Regulation (307/91).

A commitment to review the irrigation expansion guidelines was made in the Water Management Policy for the South Saskatchewan River Basin (Alberta Environment 1990). It was recognized that the information available for decision-making was limited, particularly with regard to the determination of instream flow needs. Consequently, the policy committed the government to a review of the irrigation expansion guidelines in the year 2000.

Adequate and reliable water supplies are also essential to municipal and industrial water users, and indeed, all water users in the South Saskatchewan River Basin. Consequently, the commitment to review irrigation expansion guidelines necessitates a comprehensive examination and assessment of the needs of all water uses within the basin. The review of irrigation expansion guidelines is occurring in the context of an overall review of water management in the basin, referred to hereafter as the South Saskatchewan River Basin Water Management Plan (SSRB WMP).

Alberta Environment (AENV) is the lead agency responsible for water management and setting the water allocation limit. AENV also owns and operates a system of headworks in Alberta. Alberta Agriculture, Food and Rural Development (AAFRD) is responsible for agricultural issues, including irrigation farming and water distribution systems within irrigation districts.

The SSRB WMP will be consistent with the requirements of the *Alberta Water Act.* As directed by the *Water Act,* a Framework for Water Management Planning was produced in 2001 (Alberta Environment 2001a). The framework includes a Strategy for the Protection of the Aquatic Environment and promotes the establishment of Water Conservation Objectives that are defined in Section 1(1)(iii) of the *Water Act* as the amount and quality of water necessary for the:

- protection of a natural water body and its aquatic environment, in whole or in part;
- protection of tourism and recreation, transportation, or waste assimilation uses of water; and
- management of fish and wildlife.

The *Water Act* also sets requirements for:

- public involvement;

- attention to cumulative environmental effects; and
- authorization for water transfers, including provisions for withholding up to 10% to protect the aquatic environment.

The process that will be followed for the SSRB WMP will be to review the limit on maximum water allocation for all water uses. Protecting the aquatic environment will be accomplished by:

- determining instream needs;
- identifying the amount of water potentially available for allocation, (including examination of risks to consumptive and instream uses);
- setting recommendations for Water Conservation Objectives (WCO); and
- determining the maximum amount of water available for allocation.

The SSRB WMP is guided by a Steering Committee with representation from Alberta Environment, Alberta Sustainable Resource Development and Alberta Agriculture, Food and Rural Development. The Steering Committee instructed the Technical Team to develop IFNs using existing information.

2.1 Instream Flow Needs Technical Team

The Steering Committee appointed the Instream Flow Needs Technical Team to prepare instream flow needs (IFN) values as input to the SSRB WMP. The objective of the Technical Team is:

> *"To develop science-based IFN determinations for the protection of the aquatic environment for the mainstem reaches within the SSRB. The IFN values to protect the aquatic environment are based on the integration of flows required to maintain water quality, fish habitat, riparian vegetation and channel maintenance."*

The goal of the Technical Team is to provide a flow determination that will vary with the season of year (intra-annually), and with the water supply (inter-annually). IFN values are generated for each reach on a weekly time-step in a duration curve format. A weekly time-step is appropriate for an ecosystem-based IFN because a monthly time-step is too coarse and would not account for some of the seasonal biological issues to be addressed. A daily time-step is too detailed and unnecessarily large for the current planning level study. The weekly duration format of the IFN is also compatible with the format required for the Water Resources Management Model (WRMM) that will be used during the SSRB WMP process.

The aquatic environment is vastly complex and determining an IFN for every potential component would be enormously difficult. For the SSRB WMP, the Technical Team used surrogate measures to represent the aquatic environment: water quality, fish habitat, riparian vegetation, and channel maintenance processes. The water quality IFN is based on flows required to protect against high instream temperatures and occasionally, high ammonia levels, and to ensure minimum dissolved oxygen values for the protection of fish species are maintained. The fish habitat IFN is based on flows required to protect physical fish habitat. The riparian IFN is based on flows required to sustain the growth and recruitment processes of poplar forests. The channel maintenance IFN is based on flows that would ensure substrate flushing and channel forming processes continue. Although the methods for determining instream flow needs for each of these components are described separately in this report, all components must be considered in the context of the other components. Each ecosystem component is interconnected with the other ecosystem components. In isolation, one component cannot protect the aquatic ecosystem in and of itself.

2.2 Purpose of the SSRB IFN Report

This report provides instream flow needs recommendations to the SSRB WMP Steering Committee designed to protect the aquatic ecosystem. The report:

- Provides an overview of the aquatic ecosystem resources in the SSRB.
- Presents the current scientific knowledge of the flows necessary to protect the aquatic ecosystem by recognizing the interconnectivity of different ecosystem components.
- Outlines the specific methods used by the Technical Team to develop an IFN determination for each riverine component: channel maintenance, riparian vegetation, fish habitat, and water quality.
- Describes the method used to integrate the various ecosystem components into a single IFN determination for the protection of the aquatic ecosystem.
- Provides the ecosystem IFN determination flows for each reach, on a weekly time-step based on the 1912 - 1995 flow record provided by Alberta Environment (2001b).
- Concludes that, with an accompanying adaptive management approach to managing flows, an ecosystem-based IFN determination will provide for the protection or restoration of riverine resources in the SSRB.

Fundamentally, the approach taken acknowledges that fish, wildlife, and riparian vegetation communities evolved and adapted to the fluvial processes and habitat characteristics of the pre-disturbance rivers within the South Saskatchewan River Basin. Protecting, maintaining or restoring the aquatic ecosystem must be founded on rehabilitating and managing fluvial processes that create and maintain habitat vital to fish, wildlife, and riparian species.

The Technical Team was assigned the task of determining the flow regime needed to provide protection for the aquatic ecosystem. However, the Technical Team also recognizes that historic land use and water management practices have altered the current landscape. Although the existing condition must be considered in deciding the potential for ecosystem restoration, determining a restoration strategy with due consideration of the current social, legal and structural limitations is beyond the scope of the Technical Team mandate at this stage. The Technical Team provides a recommendation that incorporates the natural variability of flow that would have occurred, without the water management and land-use practices currently in place.

Regardless of flow management decisions, it should be mandatory to validate the predictions of the models used in this report. Any major change in current water management, as a result of implementing the IFN determinations, will require additional investigation to evaluate the impacts on the existing channel regime, aquatic biota, and the potential for flood-related property damage.

3.0 OVERVIEW OF THE SSRB AQUATIC RESOURCES

Detailed descriptions of the aquatic resources of the major river sub-basins within the SSRB are available elsewhere (Brayshaw 1965, Kellerhals et al. 1972, Longmore and Stenton 1981, Shaw and Kellerhals 1982, Environmental Management Associates [EMA] 1983, Fernet and Matkowski 1986, Martin J Paetz Enterprises 1986, Rood et al. 1986, EMA 1989, Alberta Environmental Protection 1996, R.L. & L. 1996, R.L. & L. 1997). The complete Fisheries Management Objectives for the SSRB are included in Appendix A. Details of existing water management within the SSRB are also provided in more detail elsewhere (Alberta Environment 1984, BRWQTF 1991, BRWQTF 1994, Alberta Environment 2001a, Alberta Environment 2002). The following section provides an overview of water management and the aquatic ecosystems within the study area of the SSRB WMP.

3.1 Study Area

There are large onstream water management structures on each of the major tributaries within the SSRB (Figure 3.1). For the purpose of the SSRB WMP, instream needs were defined for reaches downstream of these structures. The study area included reaches on the Red Deer River downstream of the Dickson Dam, the Bow River downstream of the Western Irrigation District (WID) weir, the Oldman River downstream of the Oldman River Dam, the St. Mary River downstream of the St. Mary River Dam, the Belly River downstream of the Belly River diversion weir, the Waterton River downstream of the Waterton reservoir, and the entire extent of the South Saskatchewan River to the Alberta-Saskatchewan border (Figure 3.2).

The Technical Team, in consultation with Alberta Environment flow modelling staff, defined river reaches to be used for the SSRB evaluation. Reach boundaries had been set for existing fish habitat IFN studies, water quality studies, channel maintenance studies, and the Water Resources Management Model (WRMM). The Technical Team concluded it was critical to use a single set of reach boundaries for the development of integrated instream flows. Modifications were made to the original sets of reach boundaries to best accommodate every component without sacrificing detail. Each reach was then assigned either a single Water Survey of Canada (WSC) gauging station, a pair of WSC stations to be added together, or a calculated flow file provided by AENV (2001b) to provide the hydrologic data for conducting the IFN evaluations. Members of the Technical Team, in consultation with Alberta Environment flow modelling staff, selected representative gauging stations for each reach. The naturalized and recorded flow data were obtained from Alberta Environment (2001b). The reach boundary descriptions and associated hydrological data source are presented in Tables 3.1 through 3.5.

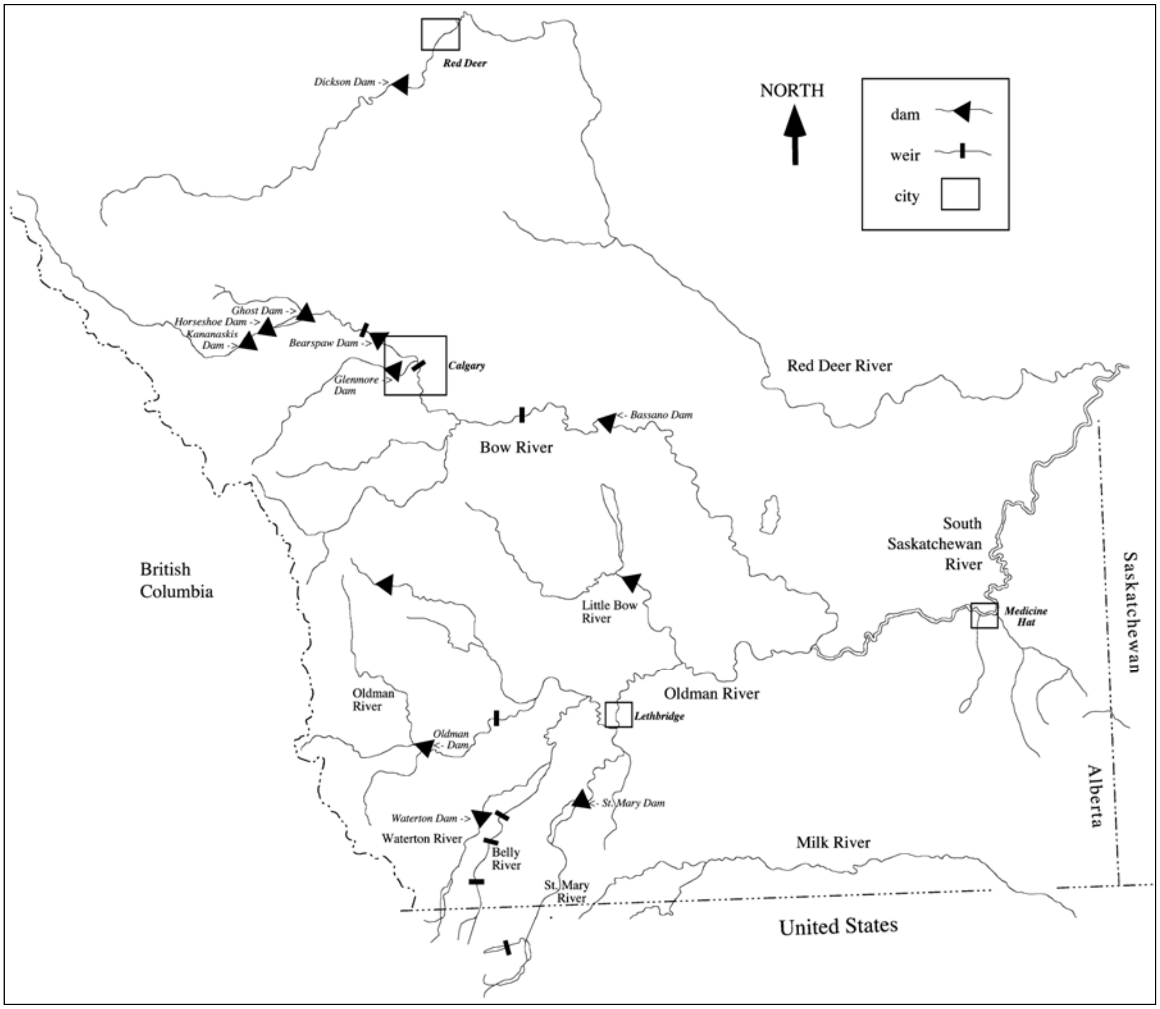


Figure 3.1. Major flow regulating structures on the mainstem reaches of the Red Deer, Bow, Oldman, St. Mary, Belly, and Waterton Rivers (after Gom and Mahoney 2002).

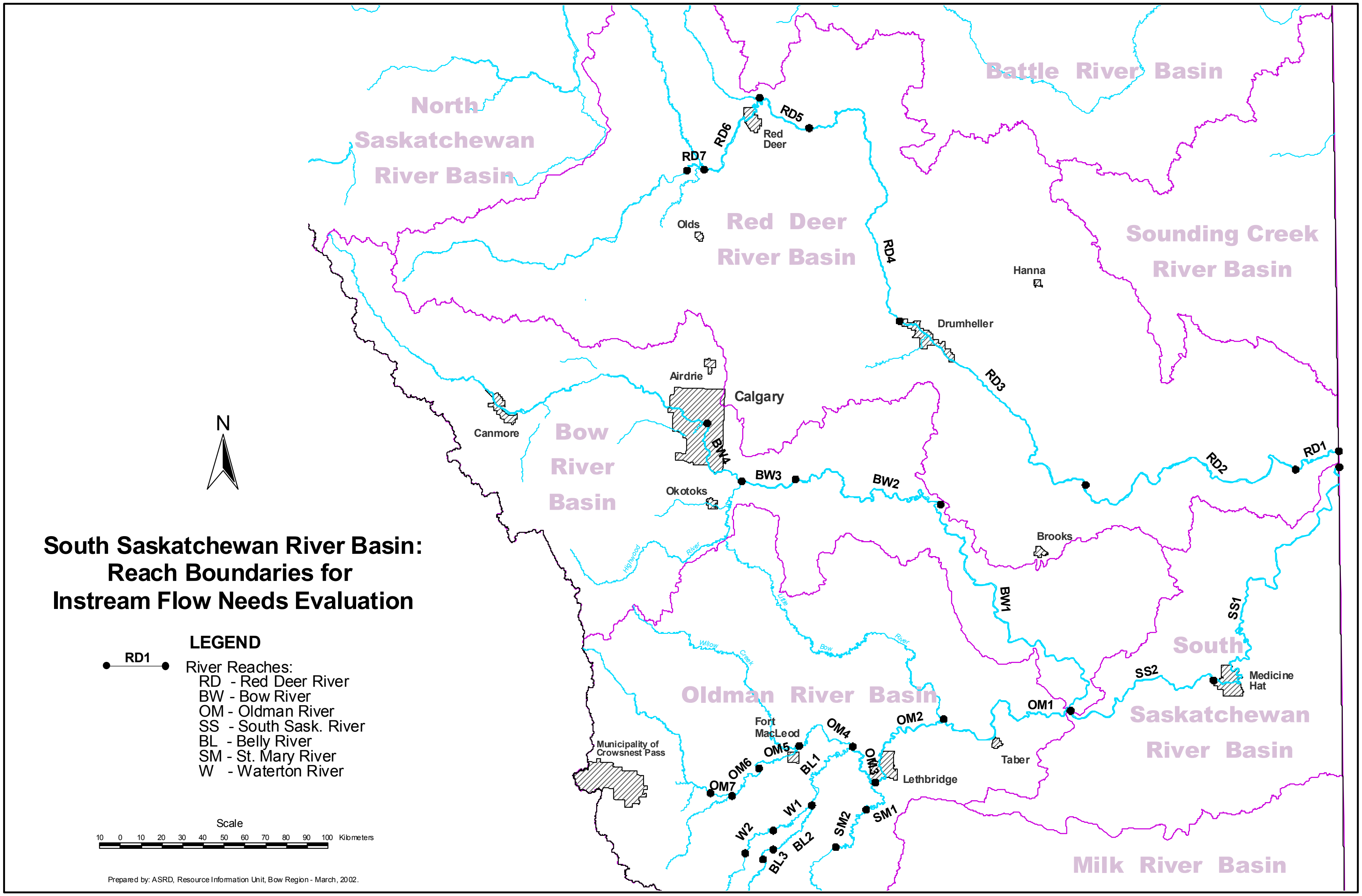


Figure 3.2. Location of the IFN reach boundaries for the Red Deer (RD), Bow (BW), Oldman (OM), St. Mary (SM), Belly (BL), Waterton (W) and South Saskatchewan (SS) Rivers.

Table 3.1. Red Deer River reach boundaries and gauging stations.

*Note: * indicates flow file was generated by AENV (2001b) and is not at a WSC gauge location.*

Reach Boundaries	Reach Code	WSC Gauge	Location
Saskatchewan/Alberta border upstream to Bindloss gauging station	RD1	05CK004	Near Bindloss
Bindloss upstream to the western boundary of Dinosaur Provincial Park	RD2	GRDJEN*	Near Jenner
Dinosaur Provincial Park upstream to the western boundary of Drumheller	RD3	05CE001	Near Drumheller
Drumheller upstream to the SAWSP diversion site	RD4	GRDBIG*	Near Big Valley
SAWSP diversion upstream to the Blindman River confluence	RD5	05CD004	Near Nevis
Blindman River confluence upstream to the Medicine River confluence	RD6	05CC002	Near Red Deer
Medicine River confluence upstream to the Dickson Dam	RD7	05CB007	Dickson Dam

Table 3.2. Bow River reach boundaries and gauging stations.

Reach Boundaries	Reach Code	WSC Gauge	Location
Grand Forks upstream to the Bassano Dam	BW1	05BM004	Below Bassano Dam
Bassano Dam upstream to the Carseland weir	BW2	05BM002	Below Carseland weir
Carseland weir upstream to the Highwood River confluence	BW3	05BM002	Below Carseland weir
Highwood River confluence upstream to the WID weir	BW4	GBOWID*	Below WID weir

Table 3.3. South Saskatchewan River reach boundaries and gauging stations.

Reach Boundaries	Reach Code	WSC Gauge	Location
Saskatchewan/Alberta border upstream to Medicine Hat	SS1	05AK001	Near Hwy 41
Medicine Hat upstream to the Grand Forks	SS2	05AJ001	Medicine Hat

Table 3.4. Oldman River reach boundaries and gauging stations.

*Note: * indicates flow file was generated by AENV (2001b) and is not at a WSC gauge location.*

Reach Boundaries	Reach Code	WSC Gauge	Location
Grand Forks upstream to the Little Bow River confluence	OM1	05AG006	Near Mouth
Little Bow River confluence upstream to the St. Mary River confluence	OM2	05AD007	Near Lethbridge
St. Mary River confluence upstream to the Belly River confluence	OM3	05AD019 + GBEMOU*	Monarch + Belly River
Belly River confluence upstream to the Willow Creek confluence	OM4	05AD019	Near Monarch
Willow Creek confluence upstream to the LNID weir	OM5	05AB007	Near Ft. MacLeod
LNID weir upstream to the Pincher Creek confluence	OM6	05AA024 + 05AA004	Brocket + Pincher Cr.
Pincher Creek confluence upstream to the Oldman Dam	OM7	05AA024	Near Brocket

Table 3.5. Belly, St. Mary and Waterton river reach boundaries and gauging stations.

Reach Boundaries	Reach Code	WSC Gauge	Location
Belly River			
Confluence with the Oldman River upstream to the Waterton River confluence	BL1	GBWCON*	Waterton River confluence
Waterton River confluence upstream to a point 5km downstream of St. Mary canal	BL2	05AD002	Near Standoff
5km downstream of the canal upstream to the St. Mary Canal	BL3	05AD041	Near Glenwood
St. Mary River			
Confluence with the Oldman River to 37km upstream	SM1	05AE006	Near Lethbridge
37km upstream of the Oldman River upstream to the St. Mary River Dam	SM2	GSTDAM*	St. Mary River Dam
Waterton River			
Confluence with the Belly River upstream to 25km downstream of the Waterton Reservoir	W1	05AD008	Near Standoff
25km downstream of the reservoir upstream to the Waterton Reservoir	W2	05AD026	Waterton Reservoir

3.2 Background of Water Management in the SSRB

Irrigation, hydroelectric power generation, industrial water uses, and municipal uses are the main uses of water that can alter the flow regime within the SSRB system. Irrigation is the largest consumer of water in the SSRB, accounting for more than 90% of the total allocated water in the Bow and Oldman systems and 25% in the Red Deer system.

Withdrawals for irrigation include water licensed to irrigation districts and to private irrigators, including First Nations' irrigation projects. There are 13 irrigation districts in the SSRB, the largest being the St. Mary River, Eastern, Bow River, Lethbridge Northern, and Western Irrigation Districts. These districts provide water to more than 450,000 hectares of farmland. At present, the amount of land that can be irrigated is limited by Alberta Regulation (307/91) and the Irrigation Districts Act (Chapter I-11, RSA 2000).

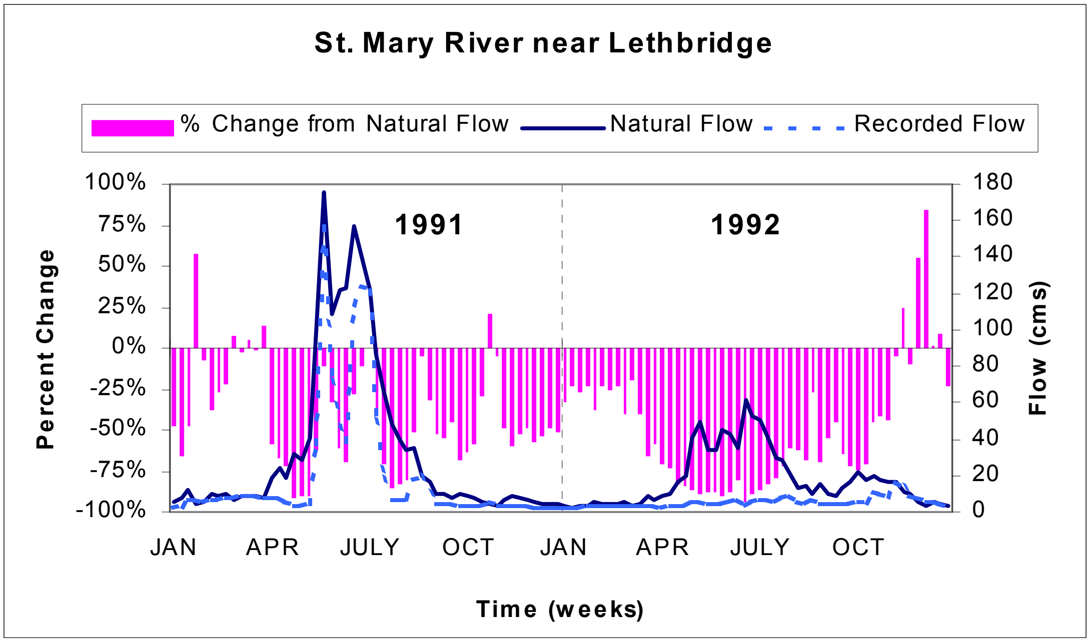
The pattern of water use in irrigated systems is dependent on the specifics of each storage or diversion license. However, most reservoirs are filled during spring runoff and drawn down for the remainder of the irrigation season. As illustrated in Figure 3.3 for the St. Mary River Dam and the Oldman River Dam, the capacity to store or divert water during the spring runoff will depend on antecedent conditions and the amount of natural flow in the system. During wetter years (1991), a higher proportion of the spring runoff remains in the river. In drier years (1992), almost all the spring runoff is stored (Figure 3.3). The pattern of water use from the Belly and Waterton Rivers is similar.

Hydro-electric power generation is not considered a consumptive use as virtually all water eventually makes its way downstream. However, hydroelectric dams can alter the timing of water delivery downstream. Typically, water is stored during spring runoff, resulting in decreased downstream flows. Water is released in the fall and winter, resulting in augmented flows. The flow regime in Calgary is, in large part, a result of TransAlta Utilities' operations and is shown in Figure 3.4. The Bow River system has the most extensive hydroelectric system, with three dams on the Bow River mainstem (Figure 3.1), and another eight dams on its tributaries upstream of Calgary, all owned and operated by TransAlta Utilities.

Water management structures on the Bow River system have a limited capacity to alter the flow regime during a wetter than average year, but do have a noticeable effect during a drier year (Figure 3.4). Once downstream of the City of Calgary, the flow regime of the Bow River becomes more influenced by irrigation diversions. Downstream of the Bassano Dam, the flow during some parts of the year is altered substantially from natural (Figure 3.4).

Municipal uses are prevalent in each of the sub-basins of the SSRB, with the City of Calgary on the Bow River being the largest municipal user within the SSRB. The major municipal users include Red Deer and Drumheller on the Red Deer River; Fort Macleod and Lethbridge on the Oldman River; and Medicine Hat on the South Saskatchewan River. A large percentage of the water withdrawn for municipal uses is returned to the river downstream of the diversion, after being treated at wastewater treatment facilities.

Major industrial uses of water in the SSRB include petrochemical plants, food processing operations, and thermal power generation plants. The Red Deer River has the highest percentage of water allocated to industrial uses. The Dickson Dam on the Red Deer River is the main water management structure used to alter the flow regime in the Red Deer River Basin (Figure 3.5). The major change to the flow pattern in the Red Deer River is augmentation of winter flows. The recorded flow during the rest of the year is much closer to the natural flow pattern when compared with the Bow and Oldman rivers.



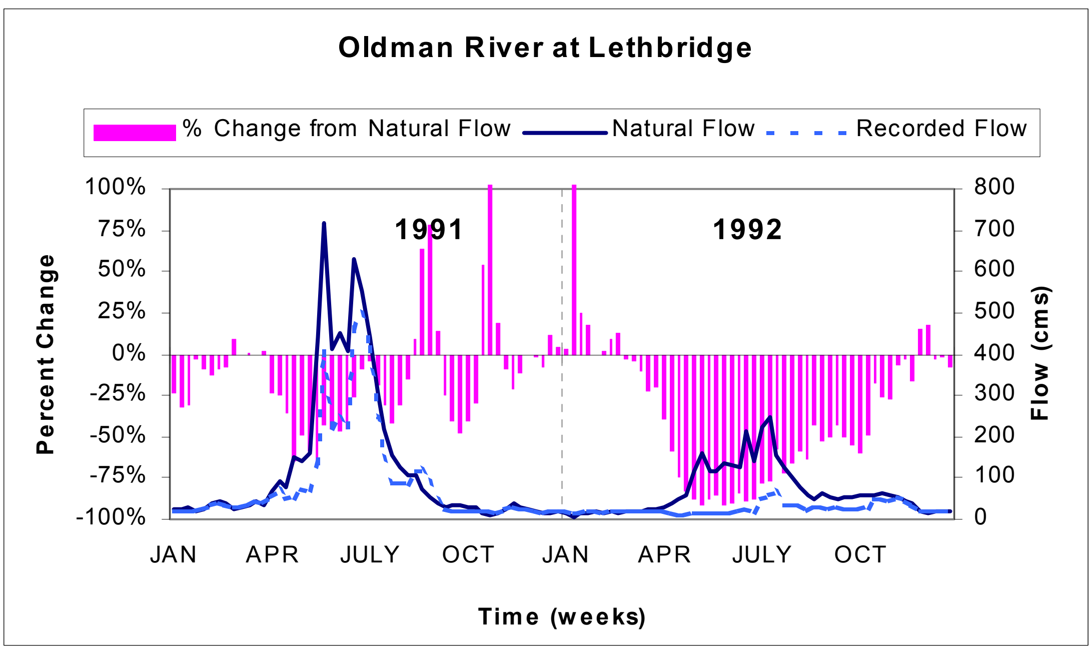
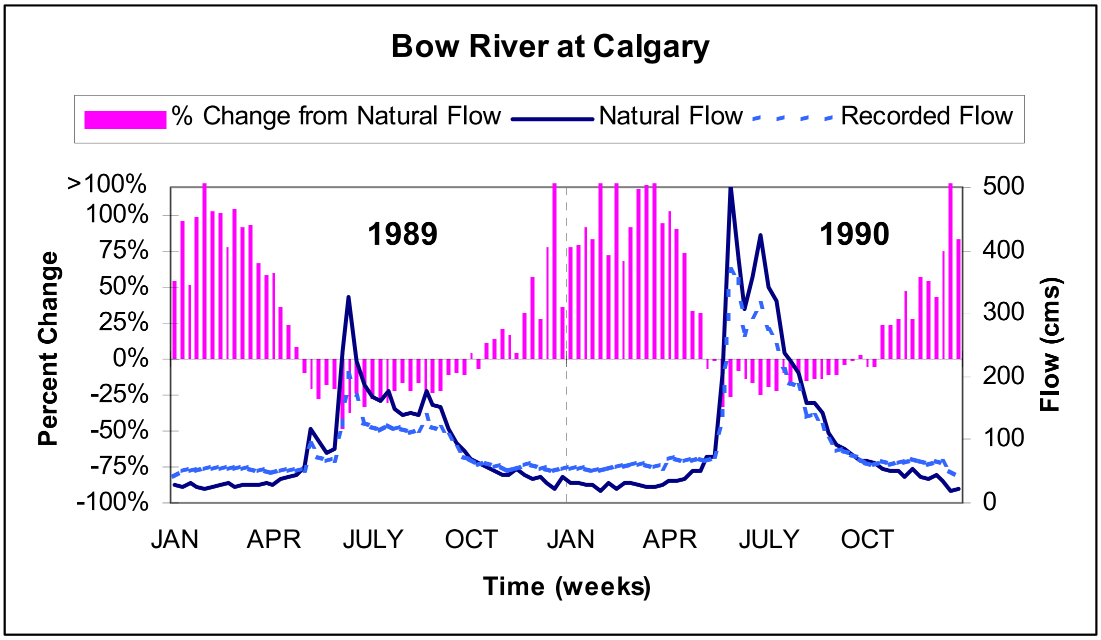


Figure 3.3. The natural and recorded flow downstream of the St. Mary River Dam (top) and the Oldman River at Lethbridge (bottom) showing the effects of current water management in a wet year (left) versus a dry year (right). The percent change in flow is the difference between the natural flow and the recorded flow.



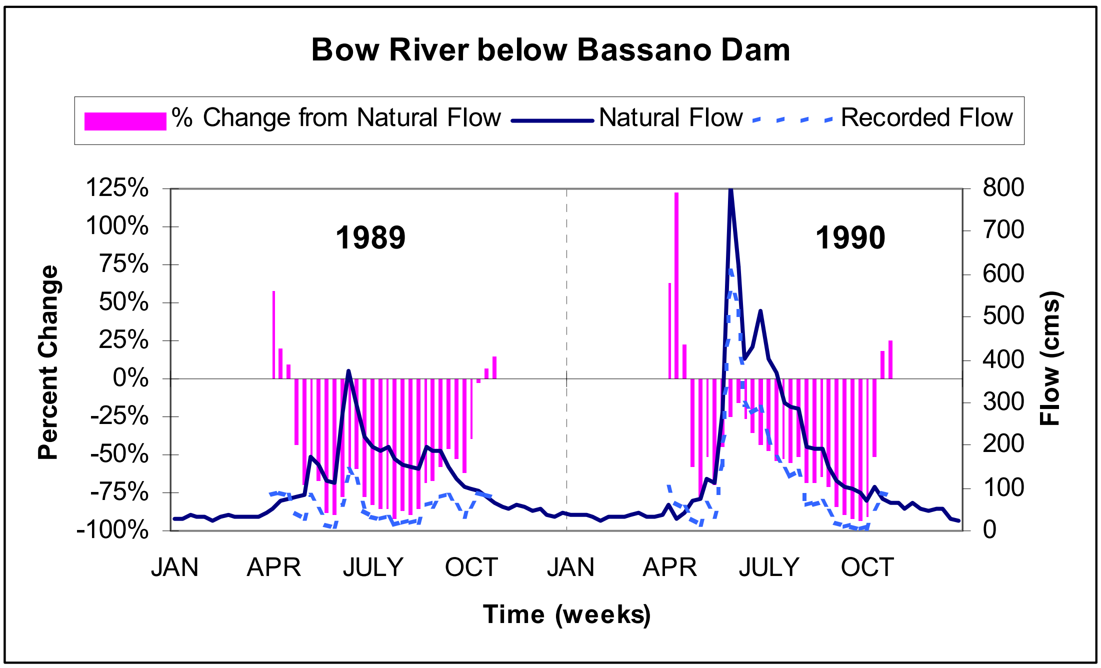


Figure 3.4. The natural and recorded flow for the Bow River at Calgary (top) and downstream of the Bassano Dam (bottom) showing the effects of current water management in a drier than average year (left) and a wetter than average year (right). The percent change in flow is the difference between the natural flow and the recorded flow. Recorded flow data for the winter season is not available below Bassano Dam.

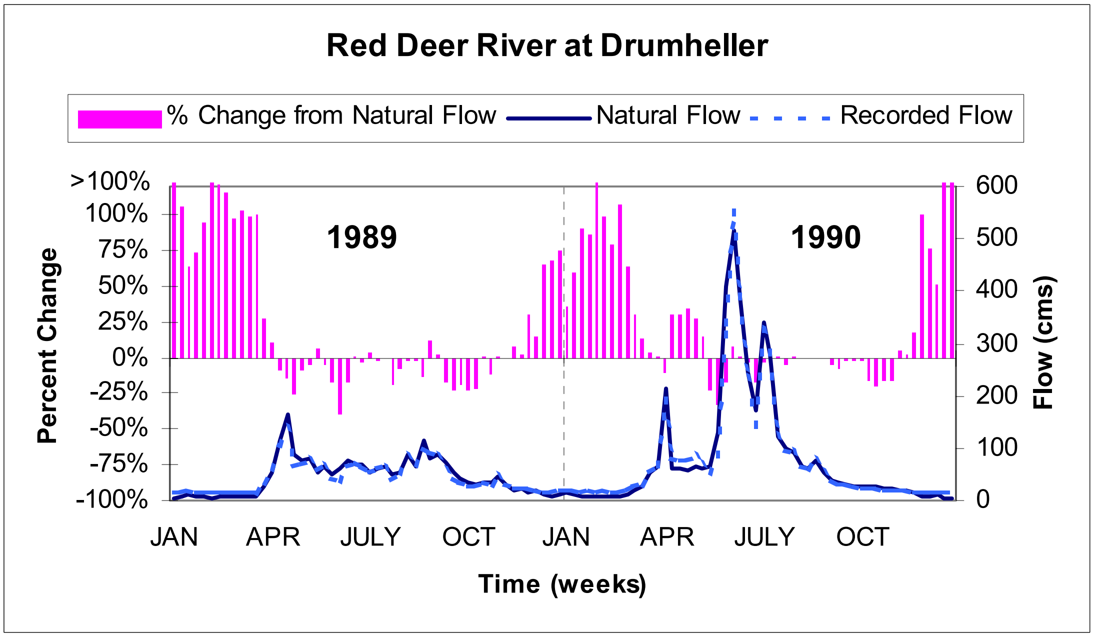


Figure 3.5. The natural and recorded flow downstream of the Dickson Dam for the Red Deer River at Drumheller, showing the effects of current water management in a drier than average year (left) and a wetter than average year (right). The percent change in flow is the difference between the natural flow and the recorded flow.

3.3 Red Deer River Basin

The Red Deer River is the most northerly of the three major tributaries of the South Saskatchewan River and flows for approximately 708 km, from its headwaters to the Alberta-Saskatchewan border. It is the largest sub-basin of the SSRB by area. However, it is the smallest basin by flow volume, contributing an average of 20% to the annual flow of the South Saskatchewan River. It originates in the Rocky Mountains within Banff National Park and flows north-easterly through foothills and parkland to the City of Red Deer. Near Nevis, the Red Deer River turns sharply to the south, flows through grassland to Dinosaur Provincial Park, then continues eastward toward the Alberta-Saskatchewan border and its confluence with the South Saskatchewan River. Except in the mountain and foothills regions, most land use in the Red Deer River Basin is agricultural. There are two cities along the river, Red Deer in the central part of the province, and Drumheller to the south and east.

The Red Deer River is the least regulated major tributary in the South Saskatchewan River Basin. The only major regulatory structure is the Dickson Dam, which is located on the mainstem of the Red Deer River upstream from the City of Red Deer. The Dickson Dam is a low capacity dam built for flow regulation. It has been in operation since 1983.

3.3.1 Fisheries Resources

The general fluvial characteristics of the Red Deer River are provided in Longmore and Stenton (1981). Prior to the construction of the Dickson Dam, the river below Red Deer supported mainly cool-water fish species and mountain whitefish, a cold-water species.

Upon completion of the Dickson Dam, an attempt was made to establish a tail-water fishery for rainbow trout. During the period 1985–1988, more than 250,000 rainbow trout were stocked below the dam. Although rainbow trout initially survived the stocking and were reported in angler's creels, successful reproduction was not adequate to establish and sustain a viable population. Brown trout that were already present in the Red Deer River Basin (Fallentimber Creek, Little Red Deer River and Raven River) were starting to increase in numbers below the Dickson Dam in the late 1980s. Stocking of adult brown trout was done in 1991 and 1992, to aid in the development of this fishery. These stocks of brown trout were successful in finding spawning habitat and recruitment was documented (Wieliczko et al. 1992). The future potential of this population of brown trout will be dependent on the spawning and early rearing habitats available within the Red Deer River system.

Warmer water temperatures, compared with upstream reaches, and additional nutrients contributed by the City of Red Deer, significantly increase biological productivity in the section of the river below Red Deer. Summer water temperatures frequently reach 24^0 C; maximum summer temperatures approach 27^0 C, occasionally exceeding the tolerance of mountain whitefish. Baker et al. (1982) noted that dissolved oxygen (DO) levels in the Red Deer River fall dangerously low during the winter months due to heavy loading of oxygen-demanding organic substances in the water, particularly during the period of ice-over. The operations of the Dickson Dam are designed to address the issues of low winter oxygen by sustaining a winter flow of approximately 16 m^3/s.

3.3.2 Riparian Resources

Two species of riparian cottonwoods occur in the Red Deer River Basin, the plains cottonwood (*Populus deltoides*) and the balsam poplar (*P. balsamifera*). The two species hybridize where their ranges overlap in the Drumheller area (Figure 3.6). The differences in the ranges of the two species appear related to differences in their regenerative strategies and temperature tolerances. Although both species are capable of producing seedlings, *P. balsamifera* is better able to reproduce clonally by suckering (Gom and Rood 1999). This clonal ability may be increasingly adaptive to the north and west, where conditions are less conducive for seedling establishment due to increasing stream gradients and coarser floodplain substrates.

The riparian forests along the Red Deer River tend to be dominated by mature and aging cottonwoods that were established as seedlings between the 1890s and 1930s (Marken 1993). This period of widespread recruitment was associated with a series of large floods that were of approximately 1-in-100 year magnitude (Cordes et al. 1997). A series of more moderate floods (greater than 1-in-10 year magnitude) occurred in the 1950s. Seedling recruitment was stimulated by these flows but was less widespread and occurred lower on the streambanks (Cordes et al. 1997). Comparisons of aerial photographs indicate there has been little change to overall riparian forest abundance along the Red Deer River since the 1950s (Table 3.6).

Since 1950, there have been no large floods and negligible channel migration (Marken 1993). Subsequently, there have been fewer opportunities for cottonwood seedling establishment. Terraces of the lower Red Deer River floodplain are now well above the 1-in-100 year flood level. Thus, the majority of the large cottonwood stands that were established there more than 50 years ago are not likely to be replaced until large floods, of greater than 1-in-50 year magnitude, occur again (Cordes et al. 1997). Currently the establishment of seedlings is limited to a narrow zone of barren, moistened substrates closely paralleling the active channel. This pattern of 'fringe' replenishment has become the dominant form of regeneration for cottonwoods along the Red Deer River.

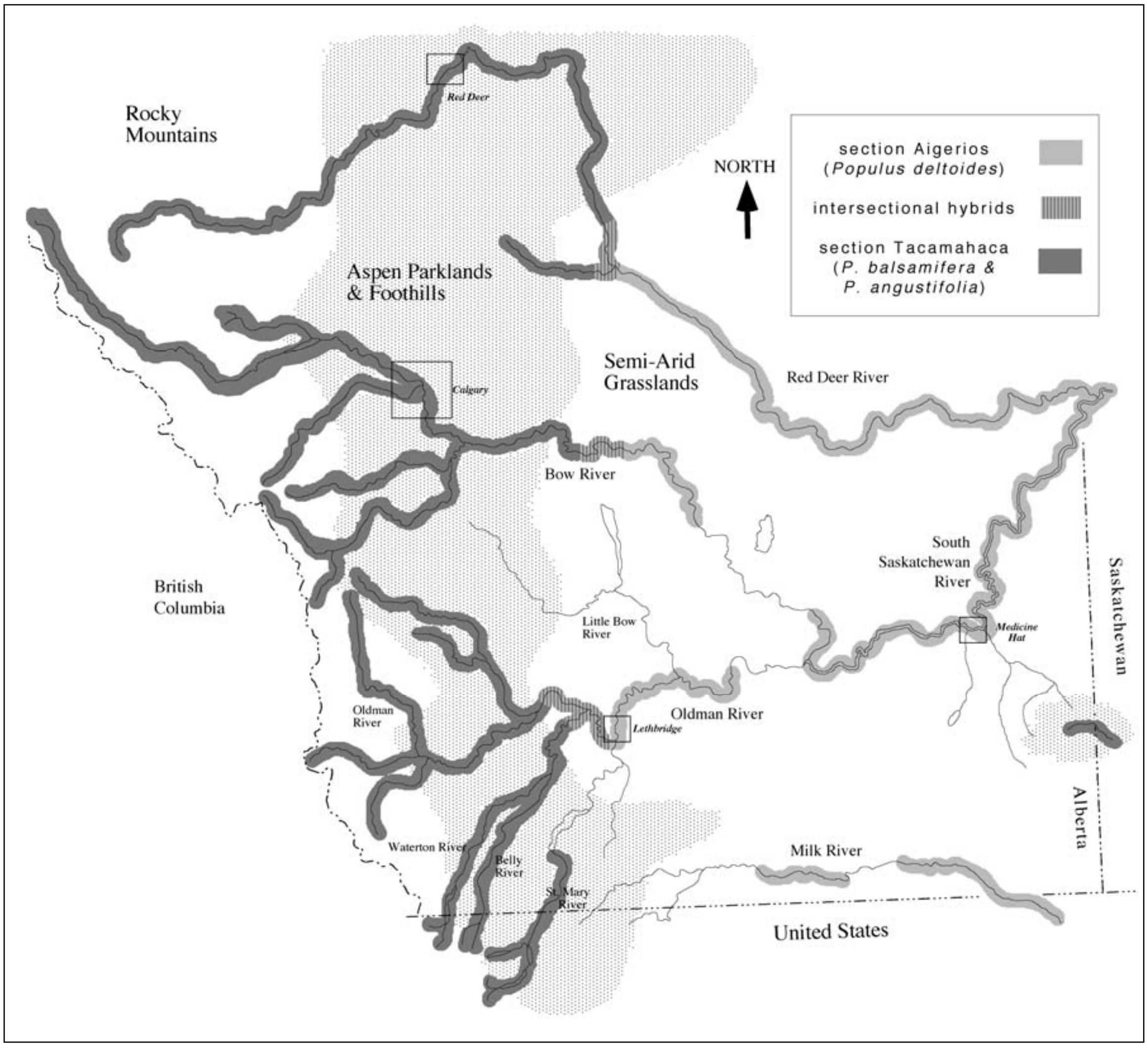


Figure 3.6. Geographic ranges of the cottonwood species that occur in the SSRB (after Gom and Mahoney 2002).

Table 3.6. Assessments of riparian forest abundances along the Red Deer River in the 1880s, 1950s, 1980s, and late 1990s using historic surveys and aerial photographs.

Current Study Reach Code	Reach:	-----------1980s----------- Length (km)	Floodplain Width (m)	Channel Type	Riparian Poplar Density: 1880s	1950s	1980s	1997-99	General Change 1880-1999
RD5	R1	22.86	200-300	CM		3	3	2	less dense
RD4	R2	32.06	300-400	CM		2	2	2	-
RD3	R3	32.13	200-400	CM-ST	1	3	3	3	more dense
RD3	R4	39.98	100	CM-ST	2	2	2	2	-
RD3	R5	16.48	300-500	CM	2	3	3	3	more dense
RD3	R6	78.23	500	CM	3 to 5	4	4	4	-
RD2	R7	37.14	200-300	CM-ST	1	3	3	3 to 4	more dense
RD2	R8	51.33	500-1300	CM-FM	2	3	4	3 to 4	more dense
RD2	R9	18.45	300-500	ST-CM		3	3	3	-
RD1	R10	37.99	1000-1500	FM-BR		3	3	3 to 4	-

(1880-1980 content adapted from Bradley et al. 1991)

Channel Type categories:
FM = freely meandering ST = straight
CM = confined meandering BR = braided

Density categories:
1 = none / negligible
2 = sparse 4 = dense
3 = moderate 5 = very dense

After the Dickson Dam became operational in 1983, mean monthly discharge during the spring and summer has been lowered (Marken 1993). By attenuating flood flows and reducing summer flows, the Dickson Dam may be exacerbating an already declining situation for cottonwoods along the Red Deer River; all but eliminating the rare opportunities for seedling establishment.

In addition to streamflow modifications, there are a variety of other activities that impact cottonwoods along the Red Deer River. In particular, livestock grazing has had moderate to severe impacts (Marken 1993), as browsing and trampling tends to destroy seedlings and degrade nursery sites. Additionally, expansion of settlements and other land uses continues to encroach on riparian areas, removing forests and increasing the demand for flood protection.

3.3.3 Water Quality

The Red Deer River is a well-buffered, relatively hard-water system, dominated by calcium and bicarbonate. Flow regulation has resulted in generally lower median levels of calcium, magnesium, sulphate, conductivity, and alkalinity in reaches between the Dickson Dam and the Alberta-Saskatchewan border. Suspended solids increase progressively as the river traverses the highly erodable substrates of the badlands in the lower basin.

Historically, the principal concern for the water quality of the Red Deer River has been low levels of dissolved oxygen (DO) during the winter, particularly in the lower reaches (Morrin Bridge at Highway 27 to the Alberta-Saskatchewan border). With the construction of the Dickson Dam, flow regulation has resulted in a significant increase in winter minimum DO levels in the lower river. However, concentrations of less than 5 mg/L (Alberta surface water quality acute guideline for the protection of aquatic life) still occur in some areas between the City of Red Deer and the Alberta-Saskatchewan border (Shaw and Anderson 1994).

Several point and non-point contributors of fecal coliforms include municipal discharges, irrigation return flows, tributaries, and direct access to the river for livestock watering. The cities of Red Deer and Drumheller, and some smaller municipalities such as Blackfalds, East Coulee, and Rosedale, discharge their wastewater effluent to the Red Deer River. The City of Red Deer has the largest municipal discharge to the Red Deer River; Blackfalds and Drumheller discharge about 10% of that city's volume. The Red Deer wastewater treatment plant is presently being upgraded to implement tertiary treatment. This upgrade will include nutrient (ammonia and phosphorus) removal, dissolved air flotation, and ultra-violet disinfection. The nutrient removal conversions have been operational since 2003. The disinfection component is slated for construction in 2006-2007.

Until 1997, chlorine treatment of effluent was a license requirement for Drumheller, East Coulee and Rosedale. Currently, these plants do not add chlorine. They use physical treatment by aeration with activated sludge and subsequent clarification. Other municipalities, such as Delia, Hanna, Duchess, Rosemary and Patricia, discharge their effluent intermittently (spring and fall) into tributaries of the Red Deer River. The town of Brooks has biannual discharges to One Tree Creek. In 1992, the sewage treatment plant at Dinosaur Provincial Park became operational. It treats wastewater produced by park visitors during the tourist season (June-September). Visitor numbers influence frequency and duration of discharges to the Red Deer River.

Populations of phytoplankton and attached algae are considerably higher immediately downstream of Dickson Dam than in reaches farther downstream. Increased algal growth is probably a result of the more stable temperature and flow regimes as well as the lower concentration of suspended sediments in water released from the reservoir. (The increased clarity allows greater penetration of light giving rise to greater algal growth.) Flow regulation has noticeably altered the zoo-benthic communities of the Red Deer River, particularly immediately downstream of the dam. The number of invertebrates has increased dramatically, whereas the diversity of zoo-benthic organisms has decreased. Aquatic earthworms and midges are numerous, and mayflies and stoneflies have declined. Changes in the Red Deer River zoo-benthos are attributed to alteration of the habitat and food base and to temperature and water quality changes caused by flow regulation (Shaw and Anderson 1994). Before construction of the Dickson Dam, insect larvae such as mayflies and stoneflies were more prevalent and more diverse in the erosional habitats (i.e., rocky substrate, swift water flow) that typified the upper reaches of the river. Burrowing organisms such as midges and worms were more numerous farther downstream in the silty, sandy substrates, and in areas of slow water flow. Studies have shown an increase in invertebrate numbers downstream of the City of Red Deer as a result of enrichment by treated wastewater discharges (Shaw and Anderson 1994).

There are significant changes in water quality in the Red Deer River between the Dickson Dam and Innisfail, and in the lower river reaches. These involve changes in bacteria, nutrients, odour and colour levels (Shaw and Anderson 1994, Anderson 1999). Variations in annual runoff conditions play an important role in the quality of water entering the river. Agricultural activities also contribute bacteria and nutrients to the Red Deer River and its tributaries that adversely affect water colour and odour.

Continued population growth in the basin will influence water withdrawals and effluent loading (e.g., nutrients, organic compounds, pesticides, and metals). Moreover, intensification of land use in the basin could result in increased loadings of contaminants such as nutrients and pesticides to the river. To maintain desired water quality in the Red Deer River in the future, reach-specific instream needs for water quality may need to be adjusted to account for increased loadings.

3.3.4 Geomorphology

Geomorphicly, the Red Deer River can be divided into two reaches; the upper Red Deer River (from its headwaters to Finnegan), and the lower Red Deer River (from Finnegan to the confluence with the South Saskatchewan River). The primary difference between these reaches is the bed material. The riverbed of the upper Red Deer River consists mainly of gravel. This changes in the vicinity of Finnegan to a mostly sand riverbed for the lower Red Deer River.

The Red Deer River channel in the upper reach is set in a broad valley and is frequently deflected by the valley walls and high terraces. The river exhibits a sinuous to irregular meander pattern, with frequent islands and mid-channel bars. The river profile features a regular sequence of shallow riffles and deep pools. The channel bed material is predominantly gravel with a D_{50} of approximately 38 mm. The banks are mostly alluvial, consisting of sands and gravel.

Prior to the operations of the Dickson Dam, the channel width at Red Deer averaged 89 m; at Drumheller it averaged 96 m. The river was shallower at Red Deer, with a mean depth of 0.8 m; at Drumheller the mean depth of the river was 1.0 m (Kellerhals et al. 1972).

The lower Red Deer River valley varies noticeably in both width and depth, though it is cut to a considerable depth below the surrounding arid prairie terrain throughout its run. In some places, several terrace levels are detectable between the top of the valley and the present floodplain. There are some areas of well-developed badland topography along the valley sides. The valley follows a sinuous course and the present river winds and meanders within it. The valley bottomland is generally flat, relatively fertile, and subject to occasional flooding. The region traversed by the river is sparsely populated and mostly used for cattle ranching. Much of the floodplain is unoccupied and covered with trees and brush, but towards the eastern end a considerable proportion is cultivated, generally with the aid of irrigation.

Little detailed work has been reported on the geology of the valley. The valley walls generally show the prairie till sheet at the top overlying sandstones and shales of the Upper Cretaceous series. The bottomlands appear to consist principally of alluvial deposits laid down by the river, fan deposits washed down from the decomposing valley walls, sand and gravel terraces presumably of glacial origin, and wind-blown sand.

The lower river exhibits many sand and mud-bars at low stage. At steady low discharges it may be relatively clear, but even small rises can cause it to become silty. High stages are generally due to ice-jams in the spring, or to upstream runoff in the summer. Variations in flow pattern from year to year are marked, but there is frequently a general rise in May and June, and a gradual decline through July and August. The sand bars and banks in many locations are subject to shifting. The geographic characteristics of the Red Deer River and the river valley are summarized in Table 3.7.

Table 3.7. Geographic characteristics of the Red Deer River and river valley.

Location	Red Deer River Geographic Features (from Kellerhals et al. 1972)									
	General Setting	Valley features			Channel features, environment and processes					Bankfull conditions (valley flat level)
(water survey of Canada Index Number)	Terrain surrounding valley	Description	Depth [ft]/ Top width [mi]/ Bottom width [mi]	Terraces	Description of valley flat/ Width [mi]	Channel pattern	Relation of channel to valley	Sinuosity/ Wave length/ Belt width [mi]	Lateral activity/ Lateral stability	Dschge (cfs)/ Stage (ft)/ Return Period (yrs)
Near Sundre 05CA001	Moderately forested foothills, no cultivation	Stream-cut valley in wide valley, forested valley walls.	150 1.00 0.20	Several continuous levels.	Indefinite and narrow; covered by shrubs. 0.02	Sinuous, tumbling flow; mid-channel bars.	Partly entrenched, confined; braided with broad valley flat downstream.	1.04 - -	Slightly unstable.	--
at Red Deer 05CC002	Mainly cultivated and partly built-up till plain.	Stream-cut valley with occasional slumping of forested valley walls.	100 1.50 0.50	Several continuous levels.	Fragmentary and narrow; covered with shrubs. 0.05	Irregular meanders with pool and riffle sequence, diagonal and mid-channel bars.	Partially entrenched and frequently confined.	1.40 1.40 0.50	Downstream progression. Slightly unstable	--
at Drumheller 05CE001	Mainly cultivated lacustrine and till plain.	Deep, stream-cut valley; badland topography.	400 1.50 0.30	Two levels, main low terrace and upper dissected terrace.	Fragmentary and narrow; covered with shrubs. 0.07	Sinuous with occasional islands; uniform rapids in reach; side bars.	Partly entrenched and confined.	1.10 - -	Downstream progression. Slightly unstable	36,000 13.9 10.5
Near Empress 05CK002 near Bindloss 05CK004	Grass vegetated hummocky till plain, mainly pasture, partly cultivated	Stream-cut valley, valley walls in grass or bare	250 2.00 1.00	Two continuous levels.	Fragmentary and narrow; covered with shrubs, not cultivated. 0.20	Sinuous with occasional islands; mid-channel bars and large dunes	Not obviously degrading or aggr., frequently confined.	1.06 - -	Downstream progression. Moderately unstable.	30,000 7.5 8

3.4 Bow River Basin

The Bow River flows for approximately 500 km, from its headwaters in the Rocky Mountains to its confluence with the Oldman River at the Grand Forks. The Bow is the largest contributor of water to the South Saskatchewan River system, providing an average of 43% of the annual flow to the South Saskatchewan. The Bow River begins its flows through the largely forested and undeveloped areas of Banff National Park. As it leaves the park, it flows through the foothills and becomes a prairie river by the time it reaches the City of Calgary. Approximately 50 km of the Bow River is contained within the city limits of Calgary, which has a population that is quickly approaching 1 million people. Downstream of the City of Calgary, the river slows as it winds through a wide prairie valley, bordered mostly by farmland. At the confluence of the Bow and Oldman, the rivers become the South Saskatchewan River.

The Bow River Basin is probably the most regulated river system in Alberta (Figure 3.1). Upstream of the City of Calgary, there are 11 hydroelectric dams operating on the Bow River and its tributaries. Major dams on the mainstem of the Bow River include the Kananaskis Dam (operating since 1914), Horseshoe Dam (1911), Ghost Dam (1929) and Bearspaw Dam (1954). These dams are operated to meet peak electricity demands and tend to moderate natural high and low flows, but they do not divert water away from the river. Further downstream, major flow diversions are made via the Western Irrigation District diversion weir (1912) at Calgary, the Carseland diversion weir (1918) for the Bow River Irrigation District, and the Eastern Irrigation District diversion at the Bassano Dam (1914). These diversions have the capacity to substantially de-water the river downstream (Rood and Bradley 1993, Rood et al. 1999).

The Bow River and its reservoirs are used extensively for fishing, rafting, canoeing, kayaking and power boating. The best-known and most heavily angled section of the Bow River is the 50 km reach from Calgary to Carseland, which supports an internationally renowned catch-and-release trout fishery.

Irrigation is the major consumptive use of Bow River water, using 96% of all water actually consumed in 1991. Three irrigation districts withdraw 98% of the diversions for irrigation between Calgary and Bassano: the Western Irrigation District (WID), the Bow River Irrigation District (BRID), and the Eastern Irrigation District (EID).

3.4.1 Fisheries Resources

The Bow River from the Banff Park boundary to the Carseland weir is cold-water aquatic habitat. Mountain whitefish are the most abundant sport fish species, although rainbow trout, brown trout and bull trout are common. Mountain whitefish and rainbow trout migrate seasonally from the Bow River to spawning habitat in the cold upper tributaries of the Sheep and Highwood Rivers.

Unlike rainbow trout, the distribution of brown trout tends to be restricted to the Bow River mainstem. Some brown trout are found in the Bow River downstream of the Carseland Weir, but they are generally limited to the upper part of the reach where the water temperatures are cooler. Major spawning areas for brown trout have been identified downstream of the Bearspaw Reservoir within the City of Calgary adjacent to the Inglewood Bird Sanctuary, in the side channel of St. George's Island, and along the length of the Elbow River between Glenmore Reservoir and the Bow River confluence (Courtney and Fernet 1990).

The mainstem of the Bow River from the Banff Park boundary to the Bearspaw Dam exhibits marked daily fluctuations in discharges as a result of variable water releases at hydroelectric dams. Habitat instability resulting from these regular fluctuations in discharge limits fish production. River flow is re-regulated at the Bearspaw Dam, and the amplitude of fluctuations is greatly moderated. More stable discharges, and the addition of treated wastewater at Calgary, increases biological and fish production in the river between Bearspaw Dam and the Carseland weir.

Between the Carseland weir and the Eastern Irrigation District dam at Bassano, the Bow River is gradually transformed from cold to cool water aquatic habitat. The diversion of up to 90% of the streamflow for irrigation at the EID dam at Bassano has drastically reduced discharge, and consequently the fish-producing capability of the remaining 167 km of the river. The Bow River between the Bassano Dam and the Grand Forks is cool water aquatic habitat, but water temperatures of up to 29^{0}C exceed the tolerance of even cool water fish species. During low discharges, aquatic plants in the warm, shallow river cause low dissolved oxygen concentrations and fluctuations in pH. These factors combine to stress and occasionally kill fish.

3.4.2 Riparian Resources

Two, and possibly three, species of riparian cottonwoods occur on the floodplains along the Bow River and its tributaries (Figure 3.6). *Populus balsamifera* is especially common and *P. deltoides* is common downstream from the Bassano Dam. *P. angustifolia* (narrowleaf cottonwood) has been reported to occur along the Highwood River (Michalsky et al. 1991). Abundant mature cottonwood groves occur in the river valleys across the region. The existing mature trees appear to be generally healthy, with little evidence of branch or crown die-back. Overall forest abundance has not changed appreciably in more than 100 years (Table 3.8). Thus, dams and diversions upstream have probably not produced appreciable drought stress in recent years (Rood and Bradley 1993). This finding is consistent with stabilized flows downstream of major water management structures (Rood and Mahoney 1995). However, a deficiency of younger trees suggests that rates of regeneration are insufficient to maintain the present extent of these forests.

The existing mature forests along the Bow River were probably established as seedlings during a few major recruitment events between 1915 and 1932 (Cordes 1991, Rood and Bradley 1993, Rood et al. 1999). Since then, flows have become more stabilized due to regulation and drier climatic conditions (Rood and Bradley 1993) and disproportionately fewer trees have been recruited (Cordes 1991, Rood et al. 1999). Some recruitment occurred after moderate flood flows along some reaches in 1990 and 1995 (Rood et al. 1999).

In addition to flood magnitude, the timing and pattern of the flood flows must also be conducive for seedling recruitment. Recent high flows that occurred at the beginning of July, toward the end of the period that seeds are available to germinate, were not conducive to seedling growth because the flows declined rapidly after the peak and drought stress killed any newly sprouted seedlings. Even when the magnitude and pattern of flood flows are suitable, as occurred in 1967, recruitment may still be limited by subsequent flow conditions. Flood flows in 1969 surpassed those in 1967, probably causing seedlings established in 1967 to be scoured away or buried by sediment (Rood et al. 1999).

If the deficient rate of recruitment that occurred between 1960 and 1990 continues, it is expected the area of cottonwood forest will diminish to zero in about 100 to 150 years (Cordes 1991). Asexual reproduction, which is becoming the dominant form of regeneration, may extend relict groves beyond this time frame. However, declines in forest abundance and genetic diversity are likely to continue unless seedling replenishment is restored (Rood and Bradley 1993). Impacts associated with grazing by livestock, harvesting by beaver, and disturbances by humans are also becoming increasingly severe and need to be reduced to improve long-term forest survival.

Table 3.8. Assessments of riparian forest abundances along the Bow River in the 1880s, 1950s, 1980s, and late 1990s using historic surveys and aerial photographs.

Current Study Reach Code	Reach:	Length (km)	1980s Floodplain Width (m)	1980s Channel Type	Riparian Poplar Density: 1880s	1950s	1980s	1997-99	General Change 1880-1999
BW3&BW4	B1	42.58	300-1500	FM-CM	3 to 5	3	3	3	less dense
BW2	B2	38.86	500-1500	FM-BR	3 to 5	4	4	4	
BW2	B3	48.14	500-2500	FM-BR	3 to 5	4	5	5	
BW2	B4	36.26	500-1000	FM	3 to 5	3	3	3	less dense
BW1	B5	60.38	200-500	ST	1	2	2	2	more dense
BW1	B6	55.79	200-500	ST	1	1	1	1	
BW1	B7	41.39	200-500	ST	1	1	1	1	
BW1	B8	23.22	200-500	ST	2	2	2	2	

(1880-1980 content adapted from Bradley et al. 1991)

Channel Type categories:
FM = freely meandering ST = straight
CM = confined meandering BR = braided

Density categories:
1 = none / negligible
2 = sparse 4 = dense
3 = moderate 5 = very dense

Downstream of the inflow of the relatively free-flowing Highwood River, there is a more continuous range of tree sizes, suggesting that ongoing recruitment has been more successful there (Rood and Bradley 1993, Rood et al. 1999). Restoration of seedling recruitment along the Bow River probably requires the implementation of high flows with more natural magnitude, timing and pattern. However, extensive urban and industrial developments on the floodplain of the Bow River complicate the re-introduction of over-bank flows. Minor changes to upstream dam operation might encourage some channel migration, bar formation and subsequent cottonwood seedling establishment (Rood and Bradley 1993).

3.4.3 Water Quality

Water quality is generally excellent upstream from Calgary. Water quality guidelines are occasionally not met in the Bow River downstream from Calgary due to impacts of municipal wastewater and runoff from rapidly expanding urban development. Water quality below Calgary has greatly improved since 1982 (BRWQTF 1991, Culp et al. 1992, BRWQTF 1994, Sosiak 2002) due to a series of improvements in wastewater treatment, including full UV disinfection in 1997. The Sierra Legal Defence Fund rated Calgary wastewater treatment the best of 21 urban centres in Canada in 1999 (Wristen 1999). To control the effects of urban runoff, a total loading limit for wastewater and runoff is now being developed.

Although 68 industries were licensed to withdraw water from the Bow River in 1991, only three currently discharge treated effluent directly to surface water in the basin. Their impacts on water quality are minor. Runoff from rural non-point sources requires further investigation.

3.4.4 Geomorphology

In the study area, the Bow River valley is generally stream-cut in a wide valley. The channel is partly entrenched and frequently confined. The valley depth varies from approximately 60 m in Calgary to approximately 35 m below Carseland. The valley top width varies from 1.9 km in Calgary to 1.6 km below Bassano.

The channel pattern varies from sinuous with mid-channel and diagonal bars and frequent islands, to an irregular channel with diagonal bars and occasional islands. The sinuosity is around 1.10. The bed material is predominantly gravel, with D_{50} varying between 40 mm and 32 mm. The channel banks are mostly sand and gravel.

The geographic and river valley features of the Bow River are summarized in Table 3.9.

3.5 Oldman River Basin

The Oldman River originates in the Rocky Mountains and flows for approximately 450 km to its confluence with the Bow River at the Grand Forks. From its headwaters, the Oldman River flows southwards through the Livingstone Range to join with the Crowsnest and Castle Rivers in the foothills. The location where these three rivers meet is now within the Oldman River Reservoir, completed in 1991. From the dam, the Oldman River flows eastwards through semi-arid grasslands to join with the Bow River near Grassy Lake where they form the South Saskatchewan River. Major regulatory structures within the basin include the Oldman River Dam (operating since 1992), Lethbridge Northern Irrigation District *d*iversion weir (since 1922), Waterton Dam (since 1964), Belly River diversion weir (since 1935), and St. Mary River Dam (since 1951) (Figure 3.1). These projects, together with more than a dozen other structures, supply water to 13 irrigation districts and to other water users in the Oldman River Basin.

Peak flows, fed by mountain snowmelt, occur in May and June. At other times of the year, flows can be very low. The Oldman River Dam evens out these highly variable flows by storing water when flows are naturally high, and releasing it when flows are lower. This ensures downstream water supplies for human consumption, irrigation, and the protection of the aquatic and riparian environments. Human activity in the Oldman River Basin includes forestry, recreation, agriculture, and oil and gas development. Much of the agriculture in this basin depends on irrigation, relying on water from the Oldman River and its major tributaries to support a variety of crops. This basin also supports a large number of confined livestock feeding operations, particularly north of Lethbridge.

3.5.1 Fisheries Resources

The operation of the Oldman River Dam has altered the historical flow regime of the Oldman River by affecting both discharge and temperature patterns. Water flow tends to be more stable and water temperatures are cooler in summer and warmer in winter (Hazewinkel and Saffran 2002). The altered flow regime will doubtless affect fish populations downstream of the dam; however, it is unclear how these changes will be manifested.

Table 3.9. Geographic characteristics of the Bow River and river valley.

Location (water survey of Canada Index Number)	Bow River Geographic Features (from Kellerhals et al. 1972)									
	General Setting	Valley features			Channel features, environment and processes					Bankfull conditions (valley flat level)
	Terrain surrounding valley	Description	Depth [ft]/ Top width [mi]/ Bottom width [mi]	Terraces	Description of valley flat/ Width [mi]	Channel pattern	Relation of channel to valley	Sinuosity/ Wave length/ Belt width [mi]	Lateral activity/ Lateral stability	Dschge (cfs)/ Stage (ft)/ Return Period (yrs)
at Lake Louise 05BA001	Mountainous area, moderately forested, no cultivation	Wide mountain valley.	- - 0.25	One fragmentary level.	Fragmentary and narrow; sparsely forested or grass-covered 0.06	Sinuous with occasional islands; tumbling flow; diagonal and side bars.	Partly entrenched and confined.	1.01 - -	Slightly unstable.	1,900 6.7 2
at Banff 05BB001	Mountainous area, no cultivation moderately forested and open areas.	Wide mountain valley.	- - 0.80	Old lake bottom.	Continuous and wide; uncultivated, shrubs shallow lakes and swamps. 0.70	Irregular, point bars.	Not obviously degrading or aggr., occasionally confined.	1.10 - -	Slightly unstable.	10,000 11.5 9
at Kananaskis 05BE003	Mountainous area, sparsely forested, no cultivation.	Wide mountain valley; reach lies at eastern edge of Rockies.	- - 0.25	One fragmentary level; corresponds to valley flat.	Fragmentary and narrow; moderately forested, no cultivation. 0.10	Sinuous with occasional islands; mid-channel bars.	Entrenched.	1.10 - -	Stable	--
Near Seebe 05BE004	Foothills, near large outwash plain, no cultivation	Stream-cut, gorge-like valley in wide valley, three lateral constrictions.	200 0.10 0.05	Several indefinite levels.	None.	Irregular, with bedrock and boulder rapids; mid-channel and diagonal bars.	Entrenched.	1.10 - -	Stable	--
Below Ghost Dam 05BE006	Foothills, open range and partly cultivated	Stream-cut valley in wide valley, one constriction; valley walls partly forested.	100 1.20 0.40	One fragmentary level.	Fragmentary and narrow; covered with shrubs 0.05	Sinuous with occasional islands; uniform flow, boils and irreg. side and mid-channel bars.	Partly entrenched and confined.	1.10 - -	Stable	--
at Calgary 05BH004	Urbanized plain	Stream-cut valley in wide valley.	200 0.10 0.05	Three continuous levels; lowest corresponds to valley flat.	Fragmentary and narrow; sparsely forested or in grass. 0.10	Sinuous with frequent islands; mid-channel bars and diagonal bars.	Partly entrenched and frequently confined.	1.10 - -	Slightly unstable.	84,000 14.7 >100
below Carseland Dam 05BM002	Mainly cultivated till plain.	Stream-cut valley with bare or sparsely forested valley walls.	120 0.80 0.65	One continuous level.	Continuous of moderate extent; sparsely forested, not cultivated, 0.20	Irregular, with occasional islands; diagonal bars; split D/S of reach.	Partly entrenched and frequently confined.	1.02 - -	Stable	38,000 10.3 11
Below Bassano Dam 05BM004	Till plain, partly cultivated, or open range.	Stream-cut valley with frequent slumps, almost bare valley walls.	130 1.0 0.4	One continuous level, fans on terrace.	No valley flat.	Sinuous, with occasional islands, side bars and mid-channel bars, boulder rapids.	Entrenched.	1.16 - -	Stable	--

Mitigation for the Oldman River Dam included an enhancement program on the Oldman River downstream of the dam. One project was designed to provide high quality habitat for adult brown trout, using boulders placed in existing deep water areas. It is anticipated the hatchery brown trout that were stocked during the 1992–1997 period will use these areas, thereby facilitating the development of a self-sustaining brown trout population downstream of the reservoir.

The fish community within the Oldman River system below the Oldman River Dam is influenced by a temperature gradient and the availability of different habitat types (R.L. & L. 2000a and 2000b). Rainbow trout and bull trout are confined to the cold water upper reach, immediately below the Oldman River Dam. In contrast, cool water species such as sauger and lake sturgeon are restricted to downstream areas. In the transition zone, northern pike, lake sturgeon and walleye (cool water species) are found in association with the cold water species.

Mountain whitefish provide a good example of a species that is influenced by the transition between cold and cool water habitats. This cold water species is present in all sections. However, catch per unit effort values decreased from upstream to downstream. Mountain whitefish dominate the fish community in the upper sections, exhibit reduced abundance indices in the mid sections, and are largely absent from the sample in the lower section (R.L. & L. 2000a and 2000b). In addition to the influence of temperature, changes in river gradient, flow velocities and bed substrates could impact the distribution of mountain whitefish.

3.5.2 Riparian Resources

Three riparian cottonwood species occur on floodplains in the Oldman River Basin (Brayshaw 1965). Each has slightly different life-history characteristics that suit it to its particular geographic range. *Populus deltoides* (plains cottonwood) occupies the eastern half of the Oldman River Basin, while *P. balsamifera* (balsam poplar) and *P. angustifolia* (narrowleaf cottonwood) occur to the west and south. All these species can interbreed to produce hybrids wherever their ranges overlap (Figure 3.6). An additional species, the black cottonwood (*P. trichocarpa*), is nearly indistinguishable from *P. balsamifera.* It usually occurs west of the continental divide, but is found in the headwaters of the Oldman River Basin. The riparian forests of the Oldman River and its southern tributaries are the most studied and best understood riparian forest systems in Alberta.

The Oldman River remains entrenched in mountain and foothills valleys with limited floodplains until it enters the Oldman River Reservoir near Pincher Creek. The floodplains of these upper reaches are generally forested with poplar and willow as described by Dawson in 1885 (Appendix B). Extraction of water upstream of the Oldman River Dam is minor and does not significantly affect the natural flow regime. Reduction in riparian forest quantity or quality is not extensive, being limited to sites used for agricultural purposes (grazing or cultivation), human habitation, natural cycling due to flood events, or beaver activity.

Downstream of the Oldman River Dam, the river is generally either freely meandering or confined meandering, with wide floodplains and moderate to very dense riparian forests (Table 3.10). The forests are naturally reduced downstream of Lethbridge and are negligible along the final reach before the confluence with the Bow River. The reach of the Oldman River between Pincher Creek and Lethbridge is generally recognized as significant on a national and international scale. This reach supports broad, dense stands of riparian poplars, including the narrowleaf cottonwood that has a restricted range in Canada. The hybrid poplars found along this reach are unique in Canada (Rood et al. 1986).

Table 3.10. Assessment of riparian forest abundance along the Oldman River in the 1880s, 1950s, 1980s, and late 1990s using historic surveys and aerial photographs.

Current Study Reach Code	Reach:	-----------1980s----------- Length (km)	Floodplain Width (m)	Channel Type	Riparian Poplar Density: 1880s	1950s	1980s	1997-99	General Change 1880-1999
OM7	OM1	17.26	200-500	FM	3 to 5	2	2	2	**less dense**
OM6&OM5	OM2	98.82	1500-1700	BR-FM	3 to 5	5	5	5	**more dense**
OM4	OM3	21.28	200-1000	ST	3 to 5	2	2	2	**less dense**
OM3	OM4	61.93	500-2000	FM-CM	3 to 5	4	4	4	
OM2	OM5	78.64	300-2000	CM-FM	2	2	2	2 to 3	
OM1	OM6	62.08	300-700	ST-CM	2	1	1	1	**less dense**

(1880-1980 content adapted from Bradley et al. 1991)

Channel Type categories:

FM = freely meandering ST = straight
CM = confined meandering BR = braided

Density categories:

1 = none / negligible
2 = sparse 4 = dense
3 = moderate 5 = very dense

Bradley et al. (1991) report a slight decline in the abundance of riparian poplars along the Oldman River between 1880 and 1990. All reaches showing a change in forest abundance during that period exhibited the change between 1880 and 1950. Flow management along the mainstem of the Oldman River was minimal during this period, indicating that other factors must have caused the observed decline. Bradley et al. (1991) noted cultivation of floodplains was prevalent downstream from Fort Macleod.

Although flow regulation of the Oldman River began in the 1920s, with the construction of the Lethbridge Northern Irrigation District headworks, the downstream riparian forests were not significantly reduced during that period. The addition of larger reservoirs on the Waterton and St. Mary rivers has significantly altered the downstream hydrological regime and contributed to the reduction in abundance of riparian poplars along those rivers (Rood and Heinze-Milne 1989). The completion of the Oldman River Dam in 1991 means all major flow contributors to the Oldman River are controlled. This added control has improved the minimum flow condition for riparian poplars in the Oldman River, but has also reduced the frequency and magnitude of larger flows necessary for riparian poplar seedling recruitment.

3.5.3 Water Quality

The water entering and exiting the Oldman River Reservoir is generally of excellent quality. Levels of nutrients, bacteria, and pesticides are low, and levels of dissolved oxygen are high. The water is low in total dissolved solids and is relatively hard, with bicarbonate and calcium ions being the most abundant.

Water quality in the Oldman River changes as it leaves the foothills and flows through the prairies. Some of this change is the natural result of a fast flowing mountain stream becoming a slower, wider, meandering prairie river. The rest is due to human influence. Concentrations of nutrients, bacteria, and pesticides tend to increase with distance downstream from the dam, reaching a peak downstream of the City of Lethbridge.

There are eight wastewater treatment facilities in the basin that discharge effluent directly into the Oldman River. The largest of these, located in Lethbridge, was upgraded in 1999. This has significantly reduced the load of bacteria, nitrogen, and phosphorus contributed by the city to the river. Runoff from rural non-point sources requires further investigation.

Extensive monitoring of water temperatures and dissolved oxygen has occurred since the construction of the Oldman River Dam. Post-impoundment flows have resulted in an improvement in dissolved oxygen levels relative to historic conditions. Prior to impoundment, diel (24 hour) minima often fell to critically low levels between Monarch and the confluence of the Bow and Oldman rivers. Under the existing (post-impoundment) flow regime, the incidence of dissolved oxygen levels falling below the 5 mg/L Alberta Surface Water Quality Acute Guideline (Alberta Environment 1999) is far less frequent (Hazewinkel and Saffran 2002). Water quality within the Oldman River Reservoir is excellent and is suitable for all intended purposes (Mitchell 2001).

3.5.4 Geomorphology

The Oldman River is a gravel bed stream that flows through mountains, foothills and plains. At its confluence with the Bow in southern Alberta, the rivers become the South Saskatchewan. The Oldman River has an elevation of 3,300 m above sea level at its headwaters in the mountain ranges, dropping to about 700 m at the confluence with the Bow River.

The upper Oldman River basin, above Brocket, is comprised of four major physiographic units: the Rocky Mountain front range and border ranges (the mountains); the Southern Foothills; the Cardston Plain; and the Porcupine Hills Upland.

The lower Oldman River moves through mostly cultivated till plain. The Oldman River and its valley features are summarized in Table 3.11.

Table 3.11. Geographic characteristics of the Oldman River and river valley.

Location	Oldman River Geographic Features (from Kellerhals et al. 1972)									Bankfull conditions (valley flat level)
	General Setting	Valley features			Channel features, environment and processes					
(water survey of Canada Index Number)	Terrain surrounding valley	Description	Depth [ft]/ Top width [mi]/ Bottom width [mi]	Terraces	Description of valley flat/ Width [mi]	Channel pattern	Relation of channel to valley	Sinuosity/ Wave length/ Belt width [mi]	Lateral activity/ Lateral stability	Dschge (cfs)/ Stage (ft)/ Return Period (yrs)
near Waldron's Corner 05AA023	Foothills, partly cultivated or open range.	Stream-cut valley in wide valley, grass-covered valley walls.	100 0.60 0.40	Several continuous levels.	None	Irregular, with tumbling flows; diagonal bars; boulders.	Entrenched	1.30 - -	Entrenched loop development. Slightly unstable.	--
near Cowley 05AA001	Mainly cultivated foothills.	Stream-cut valley, valley walls grass-covered.	150 0.35 0.15	One continuous level. Valley flat might be low terrace.	Fragmentary and of mod. extent; grass-covered or sparsely for., no cult. 0.08	Irregular, with tumbling flows; diagonal and side bars.	Not obviously degrading or aggr., confined.	1.20 - -	Slightly unstable.	--
near Brocket 05AA024	Plain with lacustrine and till deposits, open range and partly cultivated.	Stream-cut valley, widening in reach. Valley walls shrub and grass-covered.	150 0.50 0.35	Several fragmentary levels.	Continuous and of moderate extent, sparsely forested or shrub-covered. 0.20	Sinuous, with occasional islands, pool and riffle sequence, mid-channel and diagonal bars.	Not obviously degrading or aggr., frequently confined.	1.30 - -	Slightly unstable.	18,000 8.4 8.6
near Fort MacLeod 05AB007	Mainly cultivated plain.	Stream-cut valley. Valley walls shrub or grass-covered.	50 0.70 0.35	Several continuous levels.	Continuous and of mod. extent, sparsely forested or shrub-covered. 0.20	Sinuous, with occasional islands, pool and riffle sequence; diagonal transverse and side bars.	Not obviously degrading or aggr., occasionally confined.	1.20 - -	Moderately unstable.	17,200 9.2 3.7
near Monarch	Mainly cultivated till plain.	Stream-cut valley with bare or grass-covered valley walls.	175 0.30 0.20	Several continuous levels.	None	Irregular with occasional islands; diagonal and mid-channel bars, long straights.	Entrenched	1.40 - -	Entrenched loop development. Stable.	--
Lethbridge 05AD007	Cultivated and urbanized plain.	Stream-cut valley, occasional slumps.	300 0.80 0.40	One fragmentary level.	Continuous and of moderate extent; sparsely forested, no cultivation. 0.25	Irregular with frequent islands; pool and riffle sequence; diagonal and side bars.	Not obviously degrading or aggr., confined.	1.40 - -	Slightly active.	61,000 17.1 9.1
Mouth 05AG006	Plain, partly cultivated or open range.	Stream-cut valley in wide valley, occasional slumps, valley walls grass-covered.	200 1.00 0.60	Several continuous levels; slip-off slopes.	None	Irregular meanders with occasional islands; pool and riffle sequence; mid-channel bars, boulders.	Entrenched	1.30 1.80 0.50	Entrenched loop development. Stable.	--

3.6 Southern Tributaries

The Belly, Waterton, and St. Mary rivers are commonly referred to as the Southern Tributaries of the Oldman River.

The Belly River flows for approximately 200 km, of which 181 km are in Canada. Of these, 170 km occur downstream of the Waterton Lakes National Park/Blood Timber Reserve boundary. The river flows through foothills and prairie to its confluence with the Oldman River. Over this distance, the physiography and ecology of the river change dramatically. A distinct transition from cold to cool-water aquatic habitat is apparent, and the Belly River therefore supports a diverse game fish population of both cold and cool-water species. The Belly River is a relatively small tributary of the Oldman River. Its peak weekly flow averages only about 40 m^3/s; less than half the flow of the Waterton or St. Mary rivers. Despite this disparity in magnitude of flow, the Belly River floodplain is at least as wide, or wider than those of the Waterton and St. Mary rivers (Table 3.14). Along most of its length, the channel of the Belly River freely meanders within its wide floodplain, whereas the Waterton and St. Mary river channels tend to be more constrained.

The Waterton River flows for approximately 100 km within Alberta. It is bordered by open rangeland in the foothills. Irrigated, cultivated fields surround the Waterton Reservoir and the river downstream of the dam. Upstream of the reservoir, the Waterton River is a clear, cold, fast-flowing, unregulated mountain stream. Downstream of the reservoir, the river is warmer and slower. Natural annual peak weekly flows for the Waterton River average about 80 m^3/s, about twice the magnitude of those along the nearby Belly River. However, the width of the Waterton River floodplain is approximately equivalent to that of the Belly (Table 3.12).

Discharges are regulated at the Waterton Dam (since 1964) to meet local irrigation demands and maximize the contribution to the SMRID farther east. Although the Waterton Dam does not substantially attenuate high peak flows, it has caused significant reductions to moderate and lower flows and abrupt reductions following high flood peaks. Flow patterns downstream from the Waterton Dam mainly resemble a diversion-affected flow regime, however, the operation of the Waterton Reservoir can supplement natural low flows later in the season.

The St. Mary River flows for approximately 163 km in Alberta. The river's annual peak weekly flow of approximately 90 m^3/s is comparable to that of the Waterton and about twice that of the Belly River. The upper third of the St. Mary River channel (from the Canada/US border to the confluence of Lee Creek) is mostly freely-meandering, within a moderately wide floodplain comparable in dimensions with that of the Waterton and Belly rivers. The St. Mary's flow regime has been regulated by small weirs since the turn of the century, but significantly more flow control was added in 1951 when the St. Mary River Dam became operational. The size of the St. Mary Reservoir allows it to store a considerable portion of the river's flow, but peak flood flows have not been dramatically altered (Rood et al. 1995). In contrast, the St. Mary River Dam causes significant flow reductions during average flow years, and extreme reductions during low flow years. Operation of the St. Mary River Dam has also caused abrupt reductions in flow immediately following peak flows.

3.6.1 Fisheries Resources

Belly River

Between the Belly River diversion weir and its confluence with the Oldman River, the Belly River is considered cool water aquatic habitat and supports a mixed warm and cold water fish population. Longmore and Stenton (1981) report that mountain whitefish are common in this portion of the Belly River, but other cold-water species, specifically trout species, are rare. Cool water species include northern pike, sauger, and lake whitefish. Pike are especially numerous in the lower reaches of the river, near the mouth. Although streamflow is somewhat greater through this lower portion of the Belly River than through upstream reaches, fish production is relatively low (Longmore and Stenton 1981).

Waterton River

The Waterton Dam, completed in 1964, is a permanent blockage to fish movements along the river. During periods when water is not spilled, all the streamflow passes through control valves. Regulated discharges to the Waterton River during the irrigation season are considerably less than natural streamflow. Irrigation water abstractions at individual pump sites along the river further reduce instream flows. Habitat available during these extremely low discharges is not adequate to maintain a productive fish population (Longmore and Stenton 1981).

Warmer water temperatures and slower flows in the Waterton River downstream of the reservoir result in a mixed warm and cold water species population. Mountain whitefish is the most abundant species, but northern pike and lake whitefish are also common. A few trout also inhabit this section of the river.

Water returned to the Waterton River from irrigated fields may carry significant amounts of silt eroded from unprotected earth irrigation canals. At times, infusion of this silty water during the irrigation season causes high turbidity in the river downstream of the reservoir (Longmore and Stenton 1981). As the silt gradually settles, it can negatively affect the fish populations if it covers food sources or spawning areas.

St. Mary River

Low water levels on the St. Mary River due to flow diversion greatly reduce fish living space, shelter areas, food sources, and spawning sites. The extensive loss of habitat lowers fish productivity accordingly. Low discharges also lessen the capability of the river to flush away accumulating silt, nutrients and pollutants. Furthermore, the St. Mary River Dam is a permanent blockage to upstream fish movements. During periods when water is not spilled, all the streamflow passes through control valves.

3.6.2 Riparian Resources

Belly River

Dawson (1885) reported moderate to very dense riparian woodlands along the upper part of the Belly River and scattered groves in the middle portion, upstream of the confluence with the Waterton River (Appendix B, Table 3.12). About 50 years later, in 1935, the Belly River diversion weir (BRDW) became operational. After more than 50 years of flow-regulation, downstream cottonwoods have remained relatively healthy and their abundance along previously sparse reaches has even increased (Table 3.13).

Table 3.12. Assessment of riparian forest abundance along the southern tributaries in the 1880s, 1950s, 1980s, and late 1990s using historic surveys and aerial photographs.

Current Study Reach Code	Reach:	Length (km)	-----------1980s----------- Floodplain Width (m)	Channel Type	Riparian Poplar Density: 1880s	1950s	1980s	1997-99	General Change 1880-1999
N/A	SM1	25.4	300-700	FM	3 to 5		4	4	
SM1&SM2	SM2	115.51	200-(1000)	CM	2		1	1	**less dense**
N/A	BL1	28.82	300-500	FM	3 to 5		3	3	**less dense**
BL2&BL3	BL2	48.81	500-1200	FM	2		5	5	**more dense**
BL1	BL3	37.59	1000-1500	FM-BR	3 to 5		4	4	
BL1	BL4	34.74	700-1500	FM	3 to 5		3	3	**less dense**
W1&W2	W1	75.31	500-700	FM	3 to 5		3	3	**less dense**

(1880-1980 content adapted from Bradley et al. 1991)

Channel Type categories:
FM = freely meandering ST = straight
CM = confined meandering BR = braided

Density categories:
1 = none / negligible
2 = sparse 4 = dense
3 = moderate 5 = very dense

Diversion at the BRDW has caused reductions to downstream flows typical of diversion-affected flow regimes. Because the BRDW is a relatively small structure, compared with the major dams on the Waterton and St. Mary rivers, the weir has had relatively little effect on high springtime peak flows, such as occurred in 1975. However, the weir has had a relatively greater impact on moderate and low flows throughout the growing season.

It is not known when the sparsely forested reach reported by Dawson in the 1880s (Appendix B) became the relatively dense woodland observed in air photos taken since 1950 (Table 3.12). Therefore, one cannot ascribe the increase to BRDW operations. Research has concluded that woodlands along the upstream reach of the Belly River have remained generally unchanged since the 1950s (Rood and Heinze-Milne 1989, Rood et al. 1995). Along the downstream reach, Reid et al. (1992) examined differences in general canopy health and stand composition between 1951 and 1990. They reported that apparent woodland increases were due largely to the expansion of closed canopy communities (Figure 3.7). They also observed that up to 15% of the poplars along the downstream reach exhibited some crown dieback and were decidedly less healthy than those along the upstream reach.

The exact role flow-regulation has played in changing riparian woodland abundance and health downstream from the BRDW is not completely understood. The expansion of existing woodlands and the increase in closed-canopy type stands suggest that the magnitude of flow-reductions downstream from the BRDW has not caused acute or lethal drought stress. However, the widespread symptoms of branch dieback indicate a more chronic level of drought stress. Simultaneous observations of both expansion and drought-stress suggest the forest is becoming adjusted to the new, regulated pattern of streamflow. These adjustments might include root elongation by established poplars to reach a lowered water table, and sucker or seedling colonization of the floodplain substrates revealed by lowered flows.

Table 3.13. A) Changes to cottonwood abundance in the Oldman River Basin from the 1950s to the 1980s, along reaches upstream (upper) and downstream (lower) from the Belly River diversion weir, Waterton River Dam, and St. Mary River Dam. The standard error for lineal measures is approximately 5% and for area measures is about 20% (bolded values indicate highly significant changes). **B)** Summary of magnitude of changes in cottonwood abundance using ranked categories (>10% = +2, 10 to 5% = +1, 5 to -5% = 0, -5 to -10 = -1, -10 to -20 = -2, <-20% = -3).

A)	**Percent change in the abundance of cottonwoods**					
	non-regulated reaches			**regulated reaches**		
	UBEL	UWAT	USTM	LBEL	LWAT	LSTM
Rood & Heinze-Milne 1989						
- 2D area (1961 to 1981)	-4.6	-6.1	-4.7	-0.1	**-22.9**	**-47.8**
Reid et al. 1992						
- lineal distance (1951-1985)	-7.4	-5.8	-7.2	+0.4	-9.0	**-73.7**
- lineal distance (1961-1981)	-4.5	-8.0	-7.1	-0.9	**-20.4**	**-45.4**
- 2D area (1951 to 1990)	-13.1	+4.7	-4.8	**+21.2**	+2.6	**-40.0**
Rood et al. 1995						
- 2D area (1951 to 1985)	-9.1	+1.9	-0.5	**+52.2**	+3.5	**-61**
- lineal distance (1951 to 1985)					-9.0	**-68**
B)	**Ranked change in abundance:**					
	UBEL	UWAT	USTM	LBEL	LWAT	LSTM
lineal distance:	-1	-1	-1	0	-2	-3
2D area:	-1	0	-1	+2	-1	-3
absolute value of total:	2	1	2	2	3	6
extent of change:	moderate	slight	moderate	moderate	severe	extremely severe

UBEL = upper Belly River, LBEL = lower Belly River, UWAT = upper Waterton River, LWAT = lower Waterton River, USTM = upper St. Mary River, LSTM = lower St. Mary River.

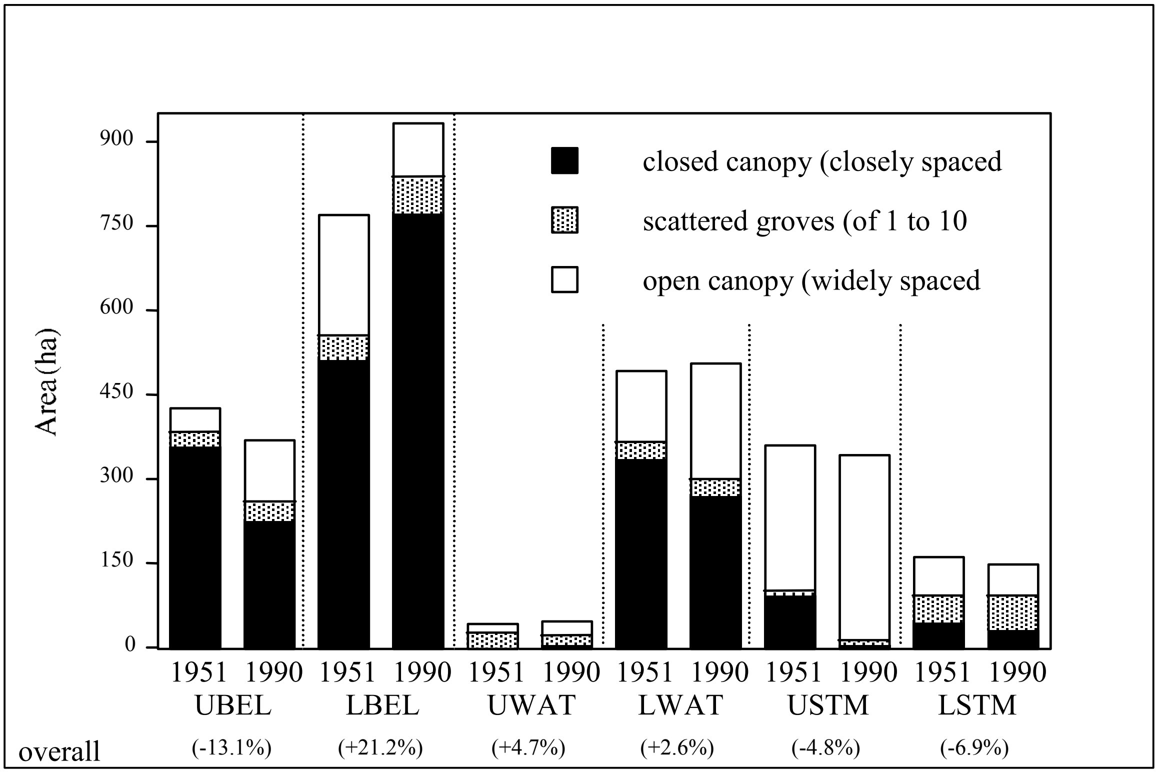


Figure 3.7. Changes in density of poplar communities from 1951 to 1990, as reported by Reid et al. (1992). (UBEL / LBEL = upper / lower Belly River, UWAT / LWAT = upper / lower Waterton River, USTM / LSTM = upper / lower St. Mary River).

Waterton River

In the 1880s, G.M. Dawson (1885) reported that riparian woodlands were present along the full length of the Waterton River (Appendix B). According to various researchers (Rood and Heinze-Milne 1989, Bradley et al. 1991, Reid et al. 1992, Rood et al. 1995), the extent and abundance of cottonwood forests has declined slightly upstream from the Waterton Dam and more severely downstream since that time (Table 3.12).

Reid et al. (1992) found that although the overall forested area remained relatively constant upstream and downstream of the reservoir from 1951 to 1990, the forest canopy downstream was becoming more open (Figure 3.7), suggesting gradual declines within established groves. They also reported that downstream poplars were generally less healthy, showing signs of both chronic and acute drought stress. Other field surveys made between 1988 and 1991 also reported considerable branch and crown die-back and numerous decrepit groves (Rood et al. 1995).

Based on these assessments, the regulated flow regime below the Waterton River Dam is believed to have had moderate negative impacts on the downstream cottonwood forest. Signs of chronic drought stress together with declines in canopy vigour suggest that flows have been inadequate during the cottonwood growing season. Signs of acute drought stress and general declines in forest abundance indicate that flow reductions during naturally dry years, such as 1977, have occasionally dropped streamflow below the minimum needed to support cottonwood survival.

In addition to affecting mature trees, regulated flows downstream from the Waterton Dam are also probably interfering with cottonwood regeneration processes. Although peak flows have not been substantially attenuated, the abrupt flow reductions following peak flows are not conducive to seedling establishment (Rood and Heinze-Milne 1989). Inadequate flows during the summer period are also likely to cause drought stress and mortality of any new seedlings. The long-term effects of reduced seedling-based replenishment, although not currently obvious, can significantly impact cottonwood forest populations.

St. Mary River

In the 1880s, G.M. Dawson (1885) reported that riparian woodlands occurred continuously along the upper part of the St. Mary River and along Lee Creek. However, they were scattered and sparse along the lower part of the St. Mary River, downstream from the inflow of Lee Creek and upstream from the inflow of Pothole Creek (Appendix B). These basic differences in woodland abundances are likely related to the geomorphic constraints of floodplain availability, but may also be accentuated by the increasingly semi-arid climate along the downstream reach (Figure 3.6). This would make the lower portion of the St. Mary River intrinsically less hospitable to riparian forests. Thus, this reach appears to be only marginally suitable for riparian forests, making these populations especially vulnerable to alterations of streamflow.

Reductions to riparian cottonwood forest abundance downstream from the St. Mary River Dam have been widely documented (Rood and Heinze-Milne 1989, Bradley et al. 1991, Reid et al. 1992, Rood et al. 1995). Forest declines ranging from 50% to more than 70% (Table 3.13) have occurred incrementally since 1951 (Rood et al. 1995). The progressive nature of this decline suggests that chronic drought stress is involved. Additionally, the rapid rate of decline, relative to the long lifespan (greater than 100 years) of cottonwoods, indicates that the severity of the drought stress has also been acute, causing accelerated mortality of mature trees. Combined chronic and acute drought stresses have probably resulted from excessive reductions to natural flow levels across the full range of exceedence. Because the moisture requirements for recruitment of seedlings and survival of saplings are even more stringent than for mature tree survival, it is reasonable to postulate that replenishment has also been minimal during this period (Rood et al. 1995).

3.6.3 Water Quality

Belly River

Agriculture, including the growing of cereal crops, grazing, and confined feeding operations, is the main human activity in the Belly River basin (WQA 1989). There are no major urban centres that discharge to the Belly River, however, the small municipality of Glenwood, discharges treated wastewater twice annually from their wastewater lagoon to the Belly River. The impact is not considered to be significant (Shaw 1994).

The water in the Belly River is moderately hard and clear. Water in the upper Belly at Highway 6 is dominated by calcium, bicarbonate, and to a lesser degree, magnesium ions. Near the confluence, the relative contribution of sulphate ions increases, which could indicate the presence of groundwater and tributary inflows or irrigation return flows (Shaw 1994).

Data from 1990 were used in water quality modelling. The maximum instream temperature for the Belly River at Highway 2 was 26.4° C; the maximum daily range was 4.69° C. In 1990, water temperature at this site exceeded the adult acute criteria for rainbow trout and mountain whitefish (24° C; Taylor and Barton 1992) on 23 days from July to mid August. The minimum

DO concentration was 6.01 mg/L and the maximum daily dissolved oxygen flux (diurnal variation) was 5.55 mg/L.

According to Shaw (1994), water quality in the Belly River is generally good. There are some exceedences of CCME water quality guidelines for Protection of Aquatic Life (CCME 2002), likely due to non-point source (NPS) surface runoff . More recent data, collected in 1998 to 2000 near the confluence with the Oldman River, suggests water quality is still generally good. For example, of more than 40 samples taken during that period, only two contained fecal coliform bacteria levels above the CCME Contact Recreation guideline of 200 CFU/100 ml. Nutrient and salt concentrations reported in recent data are generally low and do not significantly impact water quality in the Belly River, nor preclude any of the water uses for which guidelines are available: irrigation, stock watering, and protection of aquatic life.

Waterton River

Agriculture, including the growing of cereal crops, grazing, and confined feeding operations, is the main human activity in the Waterton Basin (WQA 1989). There are no major urban centres in this basin nor do any municipalities discharge treated wastewater into the Waterton River. The Shell-Waterton gas plant has a continuous discharge of treated process water and some surface runoff to Drywood Creek, a tributary to the Waterton River, but the impact of this to the Waterton River is rated as minimal (Shaw 1994).

The water in the Waterton River is moderately hard and clear. For example, water on the upper Waterton, at Highway 6, is dominated by calcium, bicarbonate, and to a lesser extent, magnesium ions.

Based on 1990 data, the maximum instream temperature reported in Shaw (1994) for the lower Waterton River, at Highway 810, was 23.1° C; the maximum daily range was 7.94 °C. Instream temperatures are partly affected by the extent of irrigation withdrawals during the open-water season. A gradual transition from cold to cool water aquatic habitat is apparent in the river downstream of the reservoir due to slower water velocities and the greater exposure to the sun. Near the dam, summer water temperatures averaged only 13.3^{0} C in 1980, but near the confluence of the Waterton and Belly rivers, average summer water temperatures exceeded 16^{0} C.

The minimum DO concentration recorded at the Highway 810 site in the summer of 1990 was 7.31 mg/L. The maximum daily dissolved oxygen flux (diurnal variation) was 4.34 mg/L (Shaw 1994). Dissolved oxygen levels usually vary more in rivers and river reaches subject to organic loadings from anthropogenic sources.

According to Shaw (1994) water quality in the Waterton River is generally good. There are some exceedences of CCME water quality guidelines for Protection of Aquatic Life (CCME 2002), likely due to non-point source runoff.

St. Mary River

Agriculture, including the growing of cereal crops, grazing, and confined feeding operations, is the main human activity in the St. Mary River Basin (WQA 1989). There are no major urban centres discharging to the St. Mary River. The towns of Magrath (lagoon, twice per year discharge) and Cardston (continuous discharge) discharge treated municipal effluent into the river, but with little impact (Shaw 1994).

The water in the St. Mary River is moderately hard and clear. It picks up salts along its course, some of which is a natural occurrence in all rivers. Water in the upper St. Mary, at the USA –

Alberta boundary, is dominated by calcium, bicarbonate and, to a lesser extent, magnesium ions. Near the confluence with the Oldman River, the relative contribution of sodium and sulphate ions increases, possibly indicating groundwater and tributary inflows or irrigation return flows (Shaw 1994).

Data from 1990 were used in water quality modelling. The maximum instream temperature for the St. Mary River, west of Raymond, was 27.37° C; the maximum daily range was 8.15 °C. In 1990, water temperature at this site exceeded the acute criteria for adult rainbow trout and mountain whitefish (24° C) on 29 days, from July to mid-August; and for brown trout (27° C) on one day in mid-July. The minimum DO concentration was 5.23 mg/L and the maximum daily dissolved oxygen flux (diurnal variation) was 5.86 mg/L. Instream temperatures are partly affected by the extent of irrigation withdrawals during the open-water season. Dissolved oxygen levels usually vary more in rivers subject to organic loadings from anthropogenic sources.

A review of the 1990 summer temperature and DO values in the southern tributaries showed that the highest temperatures, lowest DO values, and largest diurnal variation in temperature and DO occurred in the St. Mary River, followed by the Belly and Waterton rivers respectively. This suggests that of the three rivers, the St. Mary River is likely the most impacted by anthropogenic activities, in particular those related to flow management as this is the major activity affecting river flow. Based on temperature and DO data, the Waterton River is the least impacted of the three southern tributaries.

According to Shaw (1994), water quality in the St. Mary River, other than temperature and DO variables, is generally good. There are exceedences of CCME water quality guidelines for Protection of Aquatic Life (CCME 2002) for some metals, phenols and fecal coliform levels. These are likely due to non-point source runoff. NPS runoff is not well understood in the southern tributaries. It is not known if the impacts are due to human activities or to natural processes. The relationship between NPS runoff and river discharge is also not well defined (Shaw 1994).

More recent data (1998 to 2000) collected from the St. Mary River, near the confluence with the Oldman River, suggest water quality is still generally good. Similar to the data from near the mouth of the Belly River , fecal coliform bacteria levels were above the CCME Contact Recreation guideline of 200 CFU/100 ml only twice in more than 40 samples. Nutrient and salt concentrations in the recent data are generally low and do not significantly impact water quality in the St Mary River, nor preclude any of the water uses for which guidelines are available: irrigation, stock watering, and protection of aquatic life.

3.6.4 Geomorphology

Belly River

The Belly River, near Mountain View, is in foothills terrain with open range or moderately forested reaches. There is a general absence of cultivation in this area. The river's valley is stream-cut, with grass-covered valley walls. The valley depth is 15 m, with a top width of 400 m and a bottom valley width of 160 m. There are two continuous terraces in the valley.

In the vicinity of Standoff, the Belly River is in a lacustrine plain with open range and adjacent partly cultivated lands. The valley at this location is about 30 m deep, with a top width of 1.1 km and a bottom width of 0.90 km. Two continuous levels of terraces also exist at this location.

The Belly River changes from an irregular channel, with occasional islands through upstream reaches, to a more sinuous channel at Standoff. The channel bed is gravel throughout, although the channel bank changes from sand and gravel upstream of the Belly River diversion weir to sand and silt near Standoff. The channel slope varies from 0.0080 near Mountain View to 0.0017 at Standoff.

Waterton River

The Waterton River, near Waterton Lakes National Park, is set in the foothills with adjacent open range. The Waterton River, downstream of the dam, winds across the flat, arid prairie. Water flows slowly in pools and riffles through a broad, gravel-bottomed channel interspersed with occasional islands and bars. Near Standoff, the river valley cuts through a mainly cultivated lacustrine plain.

The river valley at both the park and Standoff is stream-cut in a wide valley, with a valley depth of approximately 15 m. The channel pattern is sinuous. The channel is entrenched near Waterton Lakes National Park and is frequently confined near Standoff. At both locations, the channel bed is predominantly gravel. The channel banks vary from gravel and sand along the upstream reach, to silt overlain by gravel near the confluence with the Belly River. The channel slope varies from 0.0019 to 0.0025 in the two reaches. Near its mouth, the Waterton River is approximately 67 m wide with a mean water depth of 0.8 m (Kellerhals et al. 1972).

St. Mary River

The reach of the St. Mary River near the international boundary is in foothills flowing through partially cultivated terrain. Near Lethbridge, the river is in the plains region, with adjacent open range and cultivated lands.

The river valley is stream cut, with grass or forest covered valley walls. It has several continuous terrace levels at both the international boundary and the mouth. Downstream of the St. Mary reservoir, the St. Mary River flows in broad loops through an entrenched valley 30 to 60 m deep, as it progresses across the flat, arid prairie to its confluence with the Oldman River. Occasional islands and side-bars intrude into the gravel-bottomed channel. The river averages 57 m in width near Lethbridge.

The riverbed is gravel throughout its length, and the riverbanks are sand and gravel. The channel slope varies from 0.0040 to 0.0020 near Lethbridge. Due to flow regulation and irrigation abstractions, mean water depth is only 0.6 m near Lethbridge (Kellerhals et al. 1972).

The geographic characteristics of the Belly, Waterton and St. Mary rivers and their valleys are provided in Table 3.14.

Table 3.14. Geographic characteristics of the southern tributaries of the Oldman River.

Location	Southern Tributaries Geographic Features (from Kellerhals et al. 1972)									Bankfull conditions (valley flat level)
	General Setting	Valley features			Channel features, environment and processes					
(water survey of Canada Index Number)	Terrain surrounding valley	Description	Depth [ft]/ Top width [mi]/ Bottom width [mi]	Terraces	Description of valley flat/ Width [mi]	Channel pattern	Relation of channel to valley	Sinuosity/ Wave length/ Belt width [mi]	Lateral activity/ Lateral stability	Dschge (cfs)/ Stage (ft)/ Return Period (yrs)
Belly River near Mountain View 05AD005	Foothills, open range or moderately forested, no cultivation.	Stream-cut valley, valley walls grass-covered.	100 0.25 0.10	Two continuous levels.	Fragmentary and narrow; covered with shrubs. 0.04	Irregular with occasional islands; tumbling flow; diagonal and mid-channel bars.	Entrenched and confined.	1.50 - -	Moderately unstable.	--
Belly River near Stand Off 05AD002	Lacustrine plain and prominent glacial spillway; open range and partly cultivated.	Stream-cut valley, grass-covered or bare valley walls.	100 0.70 0.55	Two continuous levels, lower one corresponds to valley flat.	Continuous and of moderate extent; mod. Forested or shrub-covered. 0.08	Sinuous, but almost tortuous beyond reach, pool and riffle sequence, diag. and point bars.	Not obviously degrading or aggr., occasionally confined.	1.20 - -	Mainly cut-offs. Moderately unstable.	6,300 8.3 59
Waterton River near Waterton Park 05AD003	Foothills, mainly open range.	Stream-cut valley in wide valley, valley walls shrub and grass-covered	- - 0.10	Several fragmentary levels, ill defined.	None	Sinuous with occasional islands; tumbling flow; boulders.	Entrenched.	1.20 -	Stable	--
Waterton River near Stand Off 05AD008	Large glacial spillway in lacustrine plain, mainly cultivated.	Stream-cut valley in wide valley.	50 0.20 0.10	Several indefinite levels, lowest corresponds to valley flat.	Continuous and of moderate extent; sparsely forested or shrub-covered. 0.10	Irregular, with occasional islands, pool and riffle sequence, diag. and point bars.	Not obviously degrading or aggr., frequently confined.	1.30 - -	Downstream progression. Moderately unstable.	--
St. Mary River at Cook's Ranch 05AE001 International Boundary 05AE027	Foothills, partly cultivated or open range.	Stream-cut valley, occasional slumps, valley walls grass or forest covered.	200 0.50 0.10	Several continuous levels.	Fragmentary and narrow; uncultivated and sparsely forested. 0.05	Irregular with occasional islands; pool and riffle sequence; diag. and mid-channel bars.	Partially entrenched and confined.	1.40 - -	Entrenched loop development. Moderately unstable.	--
St. Mary River Near Lethbridge 05AE006	Plain, partly cultivated or open range.	Stream-cut valley, occasional slumps, valley walls grass-covered or forested.	100 0.40 0.20	Several continuous levels.	Fragmentary and of moderate extent; uncultivated and grass vegetated. 0.08	Irregular meanders with occasional islands; pool and riffle sequence; diag and side bars.	Partly entrenched and confined.	1.80 1.00 0.40	Entrenched loop development. Slightly unstable.	17,300 10.1 >100

3.7 South Saskatchewan River Basin

The Bow and Oldman Rivers join at the Grand Forks, approximately 100 km upstream of Medicine Hat, to form a short section of the South Saskatchewan River in southeastern Alberta. The river flows in a wide, deep valley through prairie farmlands. Downstream of Medicine Hat, the river flows through the largest contiguous area of intact prairie grassland in western Canada, Canadian Forces Base (CFB) Suffield.

Human activities in the sub-basin include oil and gas development, a variety of industrial developments, mixed farming, and the military activities at CFB Suffield. Dense algae growth and low flow conditions have been recorded at the City of Medicine Hat.

3.7.1 Fisheries Resources

The South Saskatchewan River provides the major portion of the habitat for lake sturgeon in Alberta. The Grand Forks area is the only known lake sturgeon spawning area in the South Saskatchewan River (R.L. & L. 1994). Radio telemetry studies conducted with lake sturgeon have indicated major over-wintering habitats occur in the Rattlesnake and Boundary areas (R.L. & L. 1997). Other critical habitats may also occur within the portion of the river contained within the boundaries of the CFB. However, this area has not received sufficient sampling to date. Protection of nursery habitats for young-of-year sturgeon may be as important as protecting spawning sites. Information on the trans-boundary (Alberta/Saskatchewan) movements of all stages of the life cycle of lake sturgeon is required to complete management plans for this unique species.

Sauger and walleye utilize major over-wintering habitats in the South Saskatchewan River. During the spawning period, they move throughout the system; migrations into the lower sections of the Red Deer River and the Bow River have been recorded (R.L.& L. 1997).

3.7.2 Riparian Resources

The South Saskatchewan River supports a markedly different population of cottonwoods than portions of the Oldman and Bow rivers that occur immediately upstream. The plains cottonwood (*Populus deltoides*) dominates along the South Saskatchewan River, whereas the balsam poplar (*P. balsamifera*) and narrow leaf cottonwood (*P. angustifolia*) are found to the north and west. The plains cottonwood is a relatively fast-growing tree, with a short life span of 100-150 years (Cooper and VanHaverbeke 1990). Although Brayshaw (1965) reports the occurrence of poplar hybrids throughout the South Saskatchewan River, the frequency of hybrids is progressively reduced downstream from the confluence of the Oldman and Bow Rivers. Riparian forests are essentially pure *P. deltoides* from the City of Medicine Hat and downstream (Rood and Kalischuk 2003).

The riparian cottonwood ecosystem of the South Saskatchewan River is perhaps the least studied of all the reaches in the South Saskatchewan River Basin. Bradley et al. (1991) measured change in forest abundance from the 1880s to the 1980s for the reach between the Grand Forks and the City of Medicine Hat (SS1). Reid (1991) reported on the condition of perhaps the most extensive part of the forest, found at Police Point in the City of Medicine Hat. Usher and Strong (1994) completed detailed inventory work along the reach within CFB Suffield as part of the proposed Suffield National Wildlife Area. Most recently, an assessment of riparian forest condition and recruitment following the large flow event of 1995 was completed (Rood and Kalischuk 2003).

The riparian forest of the South Saskatchewan River has not changed substantially since first reported by Dawson (1885) (Gom and Mahoney 2002). In general, cottonwoods are sparse along the entire South Saskatchewan River with a few notable exceptions. Large groves of cottonwoods can be found at the confluence of the Bow and Oldman Rivers, Police Point Park in the City of Medicine Hat, and Sherwood Forest on CFB Suffield (Bradley et al. 1991, Usher and Strong 1994, Rood and Kalischuk 2003).

Despite the discontinuous nature of the forests, the trees that are present are in good condition, suggesting that current flow conditions are adequate to sustain the existing trees (Rood and Kalischuk 2003). However, there was a lack of significant seedling recruitment in the latter half of the 1900s until 1995. Seedling replenishment may be a naturally uncommon event along the South Saskatchewan River, with long-term occurrences only once in every 5-10 years (Braatne et al. 1996, Mahoney and Rood 1998). However, research indicates that significant diversion of streamflow can further reduce the occurrence of recruitment events (Rood and Mahoney 1990). The reduction of recruitment events will lead to the decline of forest abundance (Rood and Heinze-Milne 1989). Although free of significant water management diversions itself, the cumulative impact of water management programs in both the Oldman and Bow sub-basins appears to have contributed to a reduction in recent seedling recruitment opportunities along the South Saskatchewan River (Rood and Kalischuk 2003). Rood and Kalischuk (2003) also report the successful initial establishment of extensive cottonwood seedlings along the South Saskatchewan River following the high flow event of 1995 and subsequent high flow years of 1996 and 1997.

Plains cottonwood relies heavily on sexual (seedling) reproduction as the primary means of recruitment. The trees rarely reproduce by root suckering or by branch propagation, but may reproduce asexually by shoot suckering from stumps (coppice growth) (Bradley 1982, Gom and Rood 1999). The dependence of successful seedling recruitment on suitable streamflows (Mahoney and Rood 1998) can have serious implications on the long-term viability of the riparian forests along reaches with heavily altered flow regimes, such as the South Saskatchewan River. Even limited clonal propagation may be important in sustaining forest abundance until a more suitable flow regime is restored.

The substrates along the banks of the South Saskatchewan River are relatively fine, consisting of clay, silt and sand (Kellerhals et al. 1972). These substrates are ideal for supporting cottonwood seedling recruitment (Bradley and Smith 1986). The river follows a generally meandering pattern, but is often constrained within sandstone and shale canyons. These canyons limit floodplain size and the rate of meandering (Table 3.15). This results in a paucity of sites suitable for seedling recruitment on an ongoing basis and has probably contributed to the current sporadic riparian forest distribution.

Table 3.15. Assessments of riparian forest abundances along the South Saskatchewan River in the 1880s, 1950s, 1980s, and late 1990s using historic surveys and aerial photographs.

Current Study Reach Code	Reach:	-----------1980s----------- Length (km)	Floodplain Width (m)	Channel Type	Riparian Poplar Density: 1880s	1950s	1980s	1997-99	General Change 1880-1999
SS1&SS2	S1	197.20	200-3000	ST-FM-CM	2	2	2	2	
SS1	S2	35.95	200	ST		1	1	1	
SS1	S3	54.89	200-750	ST-CM		1	2	1 to 2	denser

(1880-1980 content adapted from Bradley et al. 1991)

Channel Type categories:
FM = freely meandering ST = straight
CM = confined meandering BR = braided

Density categories:
1 = none / negligible
2 = sparse 4 = dense
3 = moderate 5 = very dense

3.7.3 Water Quality

Water quality in the South Saskatchewan River is generally good, depending primarily on the quality of the lower Bow and Oldman Rivers. Industrial and municipal discharges at Medicine Hat have relatively minor effects on the water quality of the South Saskatchewan River.

3.7.4 Geomorphology

The general setting of the South Saskatchewan River valley is in a mainly cultivated plain. Through the City of Medicine Hat, this plain is urbanized. Downstream from the Medicine Hat the river flows through a plain that is partly cultivated and partly open range. The river valley is stream-cut, with sparsely forested valley walls and with occasional slumps through Medicine Hat. It is approximately 90 m deep, and 2.9 km wide at the top and 1.9 km wide at the bottom. The river channel meanders irregularly, with occasional islands, mid-channel and point bars, and is partly entrenched and frequently confined. Downstream from Medicine Hat at Highway #41, the river is entrenched with a sinuous channel containing occasional islands and point bars. The river bed through Medicine Hat and downstream is sand and gravel. The bank materials are gravel over silt, silt and sand, or till.