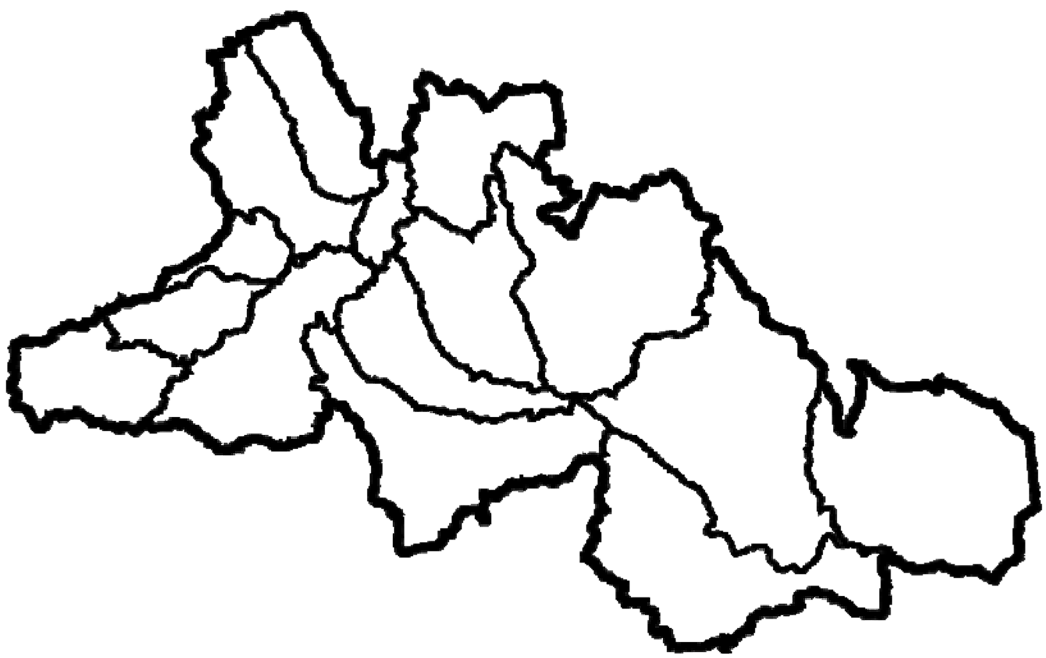
Red Deer River Watershed



Red Deer River Watershed Alliance

State of the Watershed

3.0 The Red Deer River Watershed

A watershed, or basin, is the area of land that catches precipitation and drains it to a common waterbody, such as a wetland, lake, stream or river. Watersheds can range in size from a few hectares to thousands of square kilometers (RDRWA, 2008). Healthy, functioning watersheds can provide clean and abundant water resources to agricultural, municipal, industrial and recreational users, help maintain healthy crops and crop yields, support wildlife habitat, and regulate natural processes such as soil erosion and sedimentation. Healthy watersheds greatly contribute to the overall health of the environment.

Watershed management is an adaptive, comprehensive and integrated multi-resource management planning process that seeks a balance of healthy ecological, economic, and cultural/social conditions within a watershed (RDRWA, 2008). Watershed management serves to integrate planning for land and water, accounting for ground and surface water flow, recognizing and planning for the interaction of water, plants, animals and human land use within the physical boundaries of a watershed. Watershed management provides a framework for integrated decision-making to help:

- assess the nature and status of the watershed;
- identify watershed issues;
- define and re-evaluate short- and long-term objectives, actions and goals;
- assess benefits and costs; and
- implement and evaluate actions (RDRWA, 2008).

Adopting a watershed approach is founded on the basis that Alberta's water resources must be managed within the capacity of individual watersheds and that all Albertans recognize there are limits to the available water supply. What happens on the land and water in a watershed can affect the water supply that rivers provide. While land and water are closely linked, these resources have not historically been managed in a fully integrated manner. Focusing efforts at the watershed level provides a comprehensive understanding of local management needs, and encourages locally led management decisions (RDRWA, 2008).

In 2000, Alberta Environment released an Integrated Management Plan (IMP) for the Red Deer River corridor that encompassed the area from Sundre to the Saskatchewan border. The planning area boundary was defined by the valley break-of-slope plus a 150 m setback above the break-of-slope (to a maximum distance of 3 km from the river). The planning area contains a mix of private and public land where a variety of jurisdictions, resource managers and private citizens are responsible for management of the corridor's diverse natural resources. The effective and coordinated management of these resources therefore requires that a broad plan or vision be developed to provide resource managers with some common direction to guide their decision making (Alberta Environment, 2000). The purpose of the IMP was to:

1. Coordinate existing municipal and provincial policies and resource management direction by setting integrated objectives and guidelines for resource managers;
2. Reduce the number of resource conflicts that might otherwise occur without a plan;

3. Minimize negative impacts on the environment, economy, communities and lifestyle of the corridor's residents;
4. Optimize economic opportunities while balancing other interests and values;
5. Allow the public to confirm that government is managing the corridor in the public's interest;
6. Help everyone to make better and more efficient land and resource use decisions;
7. Respect the existing rights of landowners, private mineral rights holders, leaseholders and water rights holders; and
8. Enable the long-term sustainable development of the corridor's resources and communities (Alberta Environment, 2000).

The IMP has made recommendations on aesthetics, access, air quality, agricultural resources, natural heritage resources, fisheries, forest resources, historical resources, mineral resources/industrial development, recreation and tourism resources, multi-lot residential development, surface materials, transportation infrastructure, water resources and wildlife resources in the planning area (Alberta Environment, 2000).

The IMP is strictly a policy document and does not change or supersede any existing provincial acts or regulations. Municipal authority will remain unchanged by any policy direction in the IMP. It is optional for municipal governments to adopt any IMP policies into their own statutory plans and/or bylaws. Application of the IMP to private land will therefore be at the voluntary discretion of municipal governments and landowners. Provincial resource agencies and managers will apply and implement the IMP's policy direction to provincial lands and resources under their jurisdiction (Alberta Environment, 2000). The Red Deer River Corridor IMP has been approved by the Parkland and Bow Regions Environmental Resource Committees and Alberta Environment in March 2000 and is being used as a guide by most municipalities along the river.

3.1 Watershed Overview

The Red Deer River watershed forms the largest sub-basin of the South Saskatchewan River basin. The Red Deer River originates in the Canadian Rocky Mountains in Banff National Park and flows over and through mountains, foothills, rangeland, residential land, industrial land, oil and coal deposits, cities, towns, parks, reserves, forests and croplands across southern Alberta, joining up with the South Saskatchewan River 8 km past the Saskatchewan border (RDRWA, 2008). The Red Deer River has a length of 724 km, a drainage area of 49,650 km^2 and a mean discharge rate of about 70 m^3/sec. The river got its name from the translation of *Was-ka-soo* ("elk river" in Cree). The Red Deer River is fed by numerous freshwater springs, i.e., groundwater, tributaries, including Fallentimber Creek, James River, Raven River, Little Red Deer River, Medicine River, Blindman River, Threehills Creek, Kneehills Creek, Rosebud River, Bullpound Creek, Berry Creek, Blood Indian Creek and Alkali Creek, the waters of Ewing Lake and Little Fish Lake and glacial meltwater streams from Mount Drummond and Cyclone Mountain in the Rocky Mountains. Its watershed includes 55 urban centres and 18 rural or regional municipalities (RDRWA, 2008).

The Red Deer River, like most rivers in southern Alberta, was particularly important to aboriginal survival in prehistoric times. Native peoples required wood resources of the valley for their semi-permanent wintering villages. The hunters of the last 11,000 years similarly required access to river water during the summers. Archaeological research has demonstrated that the highest archaeological site densities occur within and up to 2.4 km from the valley escarpments (Table 3) (Alberta Environment, 2000). Valley bottom sites, rapidly buried by flood water deposits, constitute some of the most significant historical resources known due to the exceptional preservation of organic materials. Valley margin sites include the more common domestic tipi-ring sites as well as rare stone feature sites of a ceremonial nature (e.g., medicine wheels, effigies). Relatively little archaeological survey work has occurred along the Red Deer River. The most intensive inventory was conducted from the Saskatchewan border to the mouth of Blood Indian Creek, with particular attention paid to the Alkali Creek area. Although this survey recorded hundreds of archaeological sites, no systematic sub-surface exploration was conducted. Occasional work elsewhere in the valley has demonstrated the presence of terrace campsites of great value and integrity, and such sites are certainly more widely distributed than current numbers suggest. To date, over 1,400 archaeological sites have been recorded along the river. Of these, 26 sites are of such extraordinary significance that they should be preserved in perpetuity. Undoubtedly, other sites of similar significance remain to be discovered (Alberta Environment, 2000).

The Red Deer River and its major tributaries run through some of Alberta's most sensitive palaeontological areas. In general, significant palaeontological resources may be present anywhere in the corridor where bedrock exposures are present (Alberta Environment, 2000). The Royal Alberta Museum (formerly the Provincial Museum of Alberta) supports a curatorial program devoted specifically to the collection and study of Quaternary (the most recent Ice Age) palaeontological resources. The majority of known Quaternary resources along the Red Deer River are located between Sundre and the Dickson Dam, between Highway 21 and Drumheller and between Drumheller and the Saskatchewan border (identified as Reaches 1, 4 and 5 of the Red Deer River in Alberta Environment (2000)); however, Quaternary fossils can be found virtually anywhere in the Red Deer River valley (Table 3) (Alberta Environment, 2000).

Table 3. Historical resources in the Red Deer River valley (Alberta Environment, 2000).

Reach	Archaeological resources	Palaeontological resources	Quaternary palaeontological resources
Banff National Park	Few site known; house pits near Divide Creek (1,970-2,850 years old) *	None known	None known
Banff National Park to Sundre	None known	None known	None known
Sundre to Dickson Dam	98 known sites; no significant or designated sites have been recorded	Invertebrate and plant fossils abundant; however, good outcrops are uncommon	Mammoth tibia (leg bone) found in the James River Bridge area (10,240 ± 200 years old)
Dickson Dam to Queen Elizabeth II Highway	Only 4 sites are known; more are likely to be discovered with additional research	Invertebrate and plant fossils abundant; however, good outcrops are uncommon	None known
Queen Elizabeth II Highway to Highway 21	59 known sites, include tipi rings and medicine wheels	Fossil plants, insect, fish, mammals and other vertebrates and invertebrates common in numerous locations, including Blindman River confluence with Red Deer River, Burbank, Canyon Ski Hill and Joffre bridge	None known
Highway 21 to Drumheller	178 sites known (6 are considered *extraordinarily significant*); high density of medicine wheels and tipi rings; buried campsites	Extensive fossil vertebrates (e.g., dinosaurs) in numerous locations, including Dry Island Buffalo Jump, Horseshoe Canyon and near Drumheller	Mammoth bone found in Dinosaur Provincial Park; prairie dog colonies near East Coulee; potential for additional finds is great

Drumheller to the Saskatchewan border	1,080 sites known (18 are considered significant); medicine wheels primarily; potential for additional finds is *very high*	Extensive fossil vertebrates (e.g., dinosaurs) upstream and downstream of Dinosaur Provincial Park; over 200 different fossil species, including 35 dinosaur species; UNESCO World Heritage site; potential for additional finds is *very high*	Abundant horse, bison, camel, caribou and mammoth remains found near Empress (14,200-20,400 years old); lion, mammoth and horse fossils found near Bindloss (not dated).

* Magne (1994) and Langemann (1995).

3.1.1 Land Use

3.1.1.1 Urban and Rural Developments

In 2006, 69% of the population of the Red Deer River watershed lived in urban areas, with the remaining 31% in rural communities (Table 4). The disparity in urban and rural population was similar in 2001 (66.2% vs. 33.8%) but less pronounced in 1996 (61.1% vs. 38.9%). From 1996-2006, the population in the Red Deer River watershed has increased by 27%, or 2.7%/year (Alberta Environment, 2007a; Statistics Canada, 2008). From 1996-2001, the population of the watershed grew by 11.4%, or about 2.2%/year. From 2001-2006, the population grew by 46.8%, or about 9.4%/year. The recent rapid population growth is likely a reflection of the economic growth of the natural resource sector in Alberta, particularly in the oil and gas industry.

Table 4. Population distribution and growth in the Red Deer River watershed from 1996-2006 (Alberta Environment, 2007a; Statistics Canada, 2008).

	1996		2001		2006	
	Population	**%**	**Population**	**%**	**Population**	**%**
Urban	128,842	61.1	158,803	66.2	184,751	69.0
Rural	81,984	38.9	81,072	33.8	83,112	31.0
Total	**210,826**		**239,875**		**267,863**	

Within the Red Deer River watershed, the major urban centres include the Cities of Red Deer (82,772 residents) and Brooks (12,498 residents) and the Towns of Strathmore and Sylvan Lake (10,225 and 10,208 residents, respectively) (Table 5, Figure 2). The highest rates of population growth in cities occurred in Red Deer (increase of 22.0% from 2001-2006) and in towns occurred in Blackfalds (increase of 46.7% from 2001-2006), Sylvan Lake (increase of 36.1% from 2001-2006) and Strathmore (increase of 34.2% from 2001-2006) (Table 5). Overall, mean population growth in the cities in the Red Deer River watershed exceeded that in towns and villages from 2001-2006 (14.9% vs. 9.8%, respectively). Over the same time period, the mean population in villages decreased by 1.8% (Alberta Environment, 2007a; Statistics Canada, 2008).

The largest rural populations are found in Red Deer County (19,108), the Municipal District of Rocky View No. 44 (14,864) and Mountain View County (12,391) (Alberta Environment, 2007a; Statistics Canada, 2008), with the Municipal District of Rocky View No. 44 showing the most dramatic increase in rural population from 2001-2006 (14.3%) (Table 6). While ten of the 18 counties in the Red Deer River watershed experienced a population decrease from 2001-2006, the rural population experienced an overall mean increase of 2.5% over the past two census periods (Table 6) (Statistics Canada, 2008).

Table 5. Urban population and change in the Red Deer River watershed in 2001 and 2006.

Urban centre		**2001 population**	**2006 population**	**Change in population (%)**
Cities	Brooks	11,604	12,498	7.7
	Red Deer	67,829	82,772	22.0
Towns	Bashaw	825	796	-3.5
	Bassano	1,320	1,345	1.9
	Bentley	1,040	1,083	4.1
	Blackfalds	3,116	4,571	46.7
	Bowden	1,174	1,205	2.6
	Carstairs	2,254	2,656	17.8
	Crossfield	2,399	2,648	10.4
	Didsbury	3,932	4,275	8.7
	Drumheller	7,785	7,932	1.9
	Eckville	1,019	951	-6.7
	Hanna	2,986	2,847	-4.7
	Innisfail	6,943	7,316	5.4
	Irricana	1,043	1,243	19.2
	Olds	6,607	7,248	9.7
	Oyen	1,020	1,015	-0.5
	Penhold	1,729	1,961	13.4
	Rimbey	2,154	2,252	4.5
	Strathmore	7,621	10,225	34.2
	Sundre	2,277	2,518	10.6
	Sylvan Lake	7,503	10,208	36.1
	Three Hills	2,902	3,089	6.4
	Trochu	1,033	1,005	-2.7
Villages	Acme	648	656	1.2
	Alix	825	851	3.2
	Beiseker	838	804	-4.1
	Big Valley	340	351	3.2
	Carbon	530	570	7.5
	Caroline	556	515	-7.4
	Cereal	187	126	-32.6
	Clive	591	562	-4.9
	Cremona	415	463	11.6
	Delburne	719	765	6.4
	Delia	215	207	-3.7
	Duchess	836	978	17.0
	Elnora	290	275	-5.2
	Empress	171	136	-20.5
	Linden	636	660	3.8
	Mirror	492	481	-2.2
	Morrin	252	253	0.4
	Munson	222	217	-2.3
	Rockyford	375	349	-6.9

	Rosemary	366	388	6.0
	Youngstown	184	170	-7.6
Summer Villages	Birchcliff	105	125	19.0
	Burnstick Lake	10	43	330.0
	Gull Lake	143	204	42.7
	Half Moon Bay	37	32	-13.5
	Jarvis Bay	124	183	47.6
	Norglenwold	267	270	1.1
	Parkland Beach	97	135	39.2
	Rochon Sands	58	66	13.8
	Sunbreaker Cove	86	137	59.3
	White Sands	73	120	64.4
Total		**158,803**	**184,751**	**16.3**

Note: Alberta Environment (2007a) and Statistics Canada (2008).

Table 6. Rural population and change in the Red Deer River watershed in 2001 and 2006. Population figures have been adjusted for the proportion of the county within the Red Deer River watershed.

Municipality	2001 population	2006 population	Change in population (%)
Camrose County	374	358	-4.3
Clearwater County	4,206	4,328	2.9
County of Newell No. 4	4,127	3,931	-4.7
County of Paintearth No. 18	294	285	-3.1
County of Stettler No. 6	3,106	3,025	-2.6
County of Wetaskiwin No. 10	227	221	-2.6
Cypress County	193	215	11.4
Kneehill County	5,319	5,218	-1.9
Lacombe County	8,680	8,580	-1.2
Mountain View County	12,096	12,391	2.4
Municipal District of Acadia No. 34	493	545	10.5
Municipal District of Bighorn No. 8	652	635	-2.6
Municipal District of Rocky View No. 44	13,006	14,864	14.3
Ponoka County	4,370	4,294	-1.7
Red Deer County	18,639	19,108	2.5
Special Areas 2, 3 and 4	3,080	2,743	-10.9
Starland County	2,210	2,371	7.3
Wheatland County	4,059	4,204	3.6
Total	**81,072**	**83,112**	**2.5**

Note: Alberta Environment (2007a) and Statistics Canada (2008).

It is forecast that the Red Deer River watershed will experience a 40% increase in population over the next 25 years and a further 10% increase in the following 25 years. Most of this growth will be in the

Calgary-Edmonton corridor, resulting in 61.5% of the population being in that part of the watershed by 2031. In addition, it is anticipated that the population growth in the City of Red Deer will be substantially greater than in all other municipalities (4.11% vs. 2.2%) (Associated Engineering Alberta Ltd., 2008).

In response to a growing economy and increasing population base, province-wide pressures on the landscape have increased considerably over the past decade. Consequently, the Government of Alberta has developed new *Land Use* and *Parks Planning Frameworks* (Government of Alberta, 2008a, d). The goals laid out by the *Land Use Framework* will guide future parks planning at regional and provincial levels in the province of Alberta to enhance visitor experiences and conserve Alberta's ecosystems (Alberta Tourism, Parks and Recreation, 2008a).

3.1.1.2 Agricultural Developments

Based on estimates derived from the 2001 Census of Agriculture, there were about 13,058 farms in the Red Deer River watershed, with an average size of 373 ha. These farms account for 25% of all farms in Alberta. At the provincial level, there are about 49,400 farms with an average size of 445 ha. Farms in the Red Deer River watershed cover an area of nearly 4.87 million ha (Table 7), which is equivalent to about 48,700 km^2. About 43% of the land in the basin is used to raise crops, which include barley, alfalfa, canola and spring wheat. About 5% of agricultural land is summer fallowed. Most of the remaining land is pasture (about 48%) (Table 7).

Table 7. Agricultural land use in the Red Deer River watershed in 2001.

Land Use	Hectares	Proportion (%)
Crop land	2,103,068	43.1
Summer fallow	220,388	4.5
Tame/seeded pasture	523,835	10.7
Natural pasture	1,831,610	37.6
Other	195,472	4.0
Total	**4,874,373**	

Note: Alberta Environment (2007a).

About 49% of the farms in the watershed raise beef cattle and about 16% of the farms are grain and oilseed farms (Table 8) (Alberta Environment, 2007a). Specialty farms make up about 11% of the farms. As is true province-wide, cattle (beef) farms are the most common farm type in the watershed; however, the Red Deer River watershed has a higher proportion of dairy, hog and poultry farms than the rest of Alberta (Table 8).

There are about two million cattle and calves which, together, accounted for about 85% of the livestock population in the Red Deer River watershed in 2001 (Table 9) (Alberta Environment, 2007a). The watershed is home to nearly one quarter of all hens, chickens, cattle, calves, sheep and lambs in the province. Nearly 35% of all pigs in Alberta live in the watershed (Table 9) (Alberta Sustainable Resource Development, 2007). The population of cattle and calves is about ten times the human population of the watershed.

Table 8. Classifications of farms in the Red Deer River watershed compared to Alberta in 2001.

Farm type (farms with gross receipts > $2,500)	Types of farms (%)	Share of Alberta (%)	Alberta farm type (%)
Dairy farms	2.1	33.2	1.5
Cattle (beef) farms	49.2	26.6	45.4
Hog farms	2.3	33.3	1.7
Poultry and egg farms	1.2	32.7	0.9
Wheat farms	6.1	20.3	7.4
Grain and oilseed farms	16.1	21.4	18.4
Field crop farms	7.5	19.5	9.3
Fruit farms	0.1	24.7	0.1
Miscellaneous specialty farms	11.4	25.8	10.9
Sum of livestock combined farms	2.2	23.7	2.3
Sum of vegetable farms	0.1	15.8	0.1
Sum of other combined farms	1.7	21.3	2.0
Average		**24.5**	

Note: Alberta Environment (2007a).

Table 9. Estimated livestock populations in the Red Deer River watershed compared to Alberta in 2001.

Livestock Species	Watershed total	Alberta	% Alberta
Hens and chicken	3,096,101	12,175,246	25.4
Turkey	134,394	864,438	15.5
Cattle	1,692,255	6,615,201	25.6
Calves	555,218	2,169,607	25.6
Pig	705,622	2,027,533	34.8
Sheep and lamb	73,529	307,302	23.9
Horse and ponies	44,529	159,962	27.8
Bison	12,179	79,731	15.3
Deer	723	8,331	8.7
Elk	5,336	31,304	17.0

Note: Alberta Environment (2007a).

The highest density of cattle and calves in the watershed are near Brooks in the southern region of the watershed, near Acme-Linden-Carbon in the south-central region of the watershed and near Clive, Innisfail-Bowden-Eckville and Rimbey-Bentley in the northwestern region of the watershed (0.56-2.03 cattle/ha) (Figure 3). Consequently, most of the manure is produced in these regions as well (5.77-15.71 tonnes of manure/ha) (Figure 4). The upper ranges for both variables are reached only in the Brooks area as a result of the disproportionally heavy concentration of livestock processing facilities.

Cattle feedlot density is greatest in the central region of the Red Deer River watershed near Linden, Acme, Carbon and Beiseker and in the north-western region of the watershed near Clive, Blackfalds, Bentley, Sylvan Lake, Red Deer and Olds (Figure 5) (Alberta Sustainable Resource Development, 2007), i.e., in the vicinity of the Queen Elizabeth II Highway.

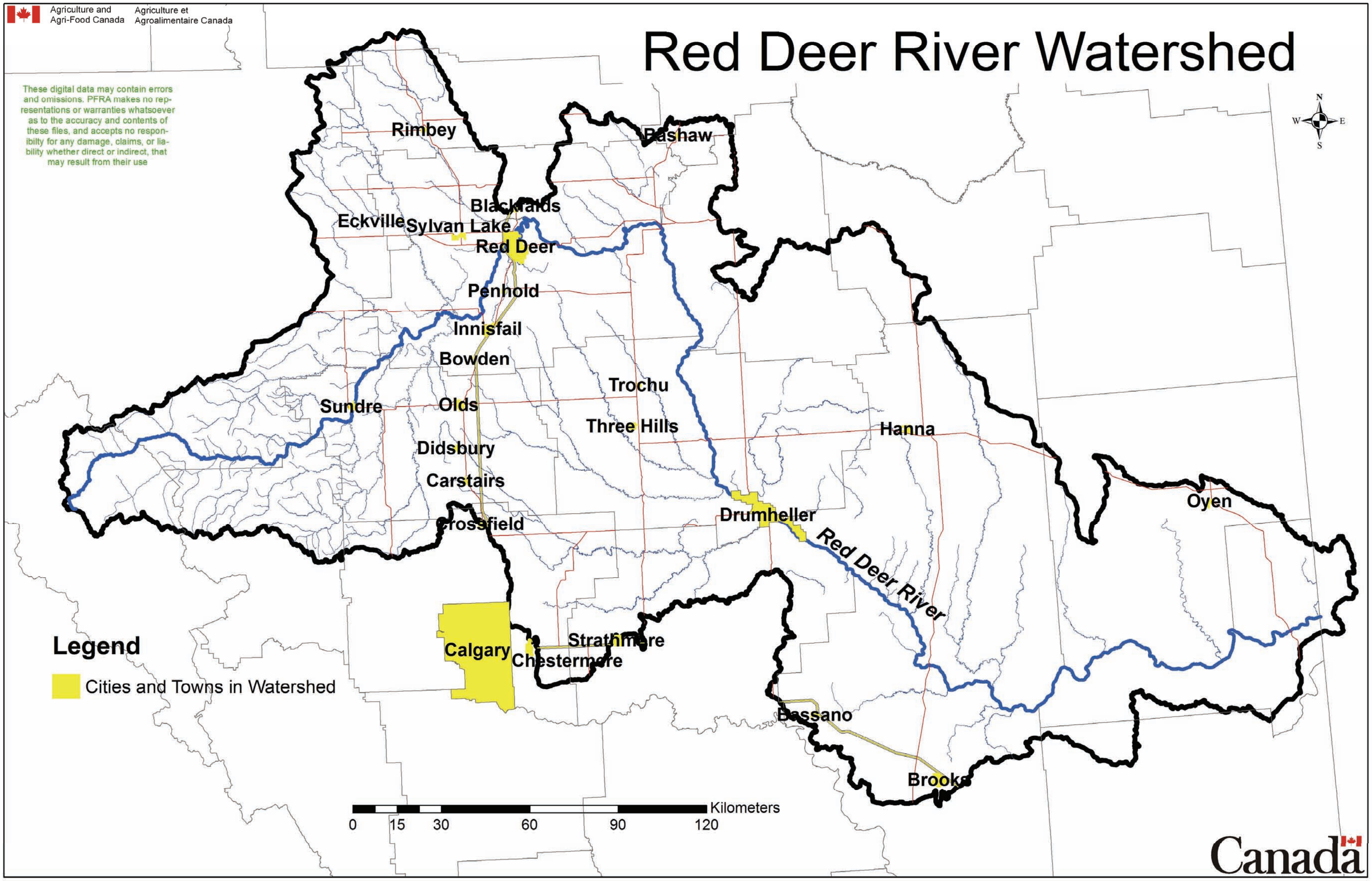


Figure 2. Major urban centres in the Red Deer River watershed (AAFC-PFRA, 2008).

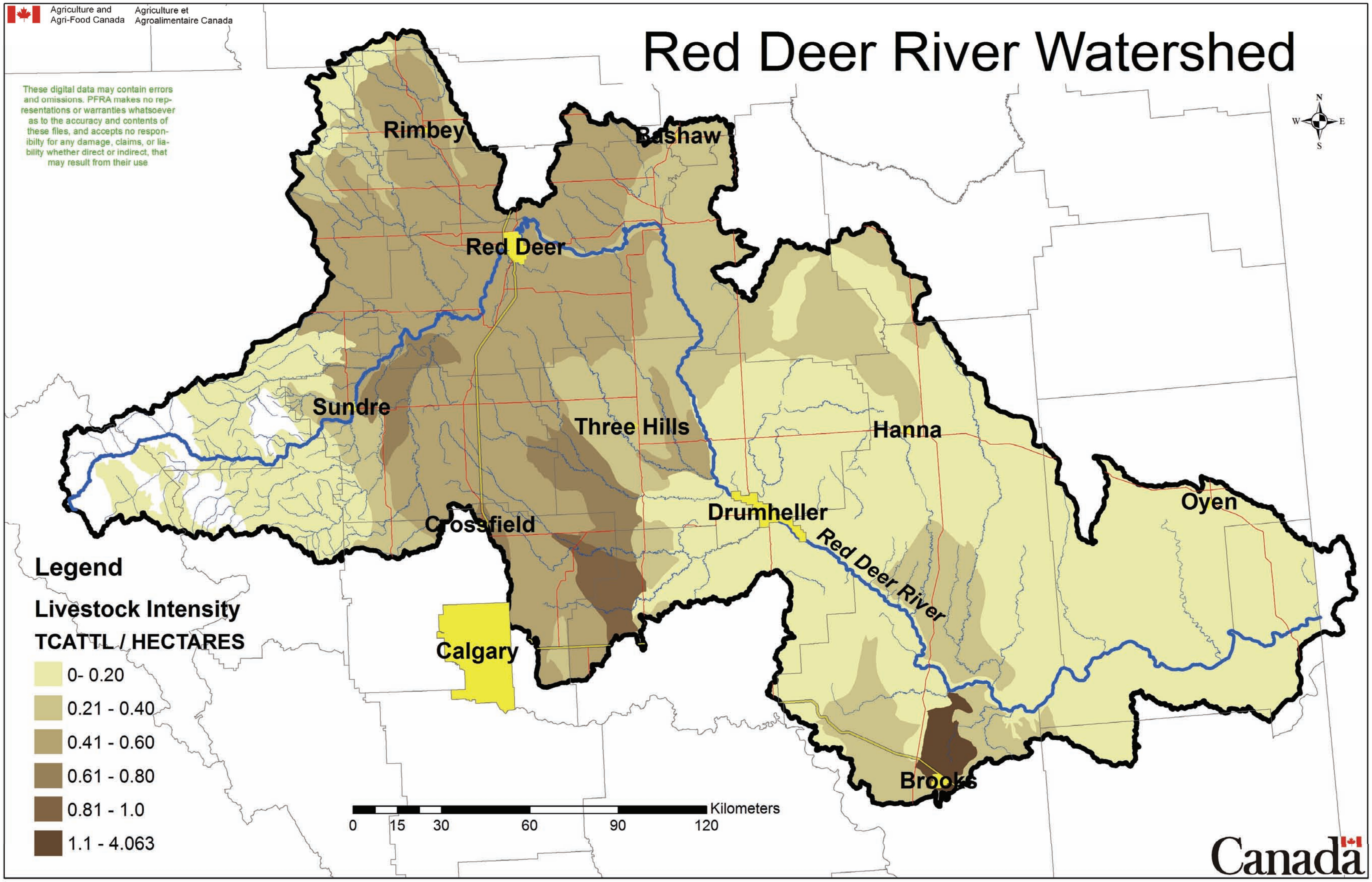


Figure 3. Cattle density (cattle/ha) in the Red Deer River watershed in 2006 (AAFC-PFRA, 2008).

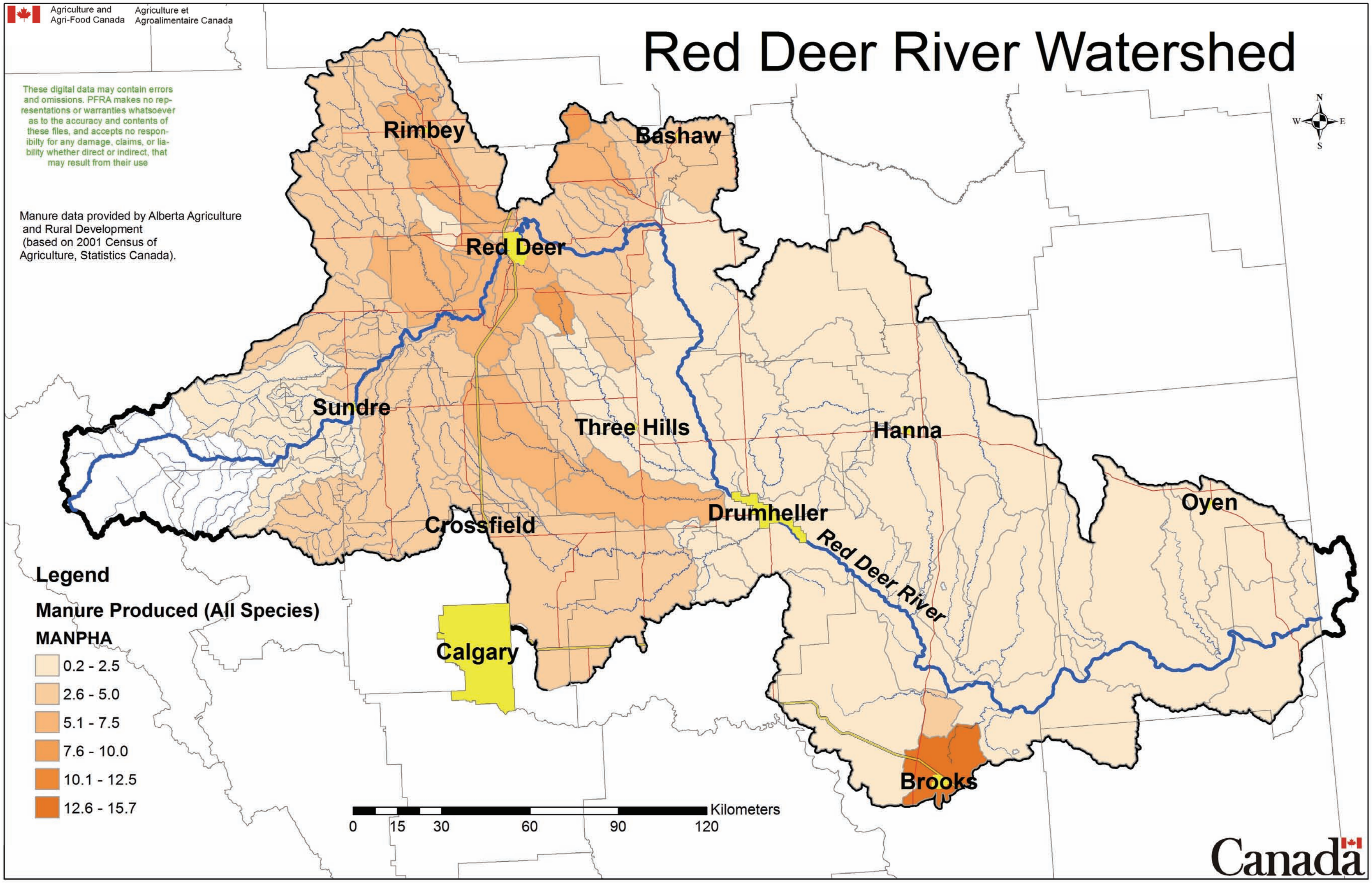


Figure 4. Manure production (tonnes/ha) in the Red Deer River watershed in 2001 (AAFC-PFRA, 2008).

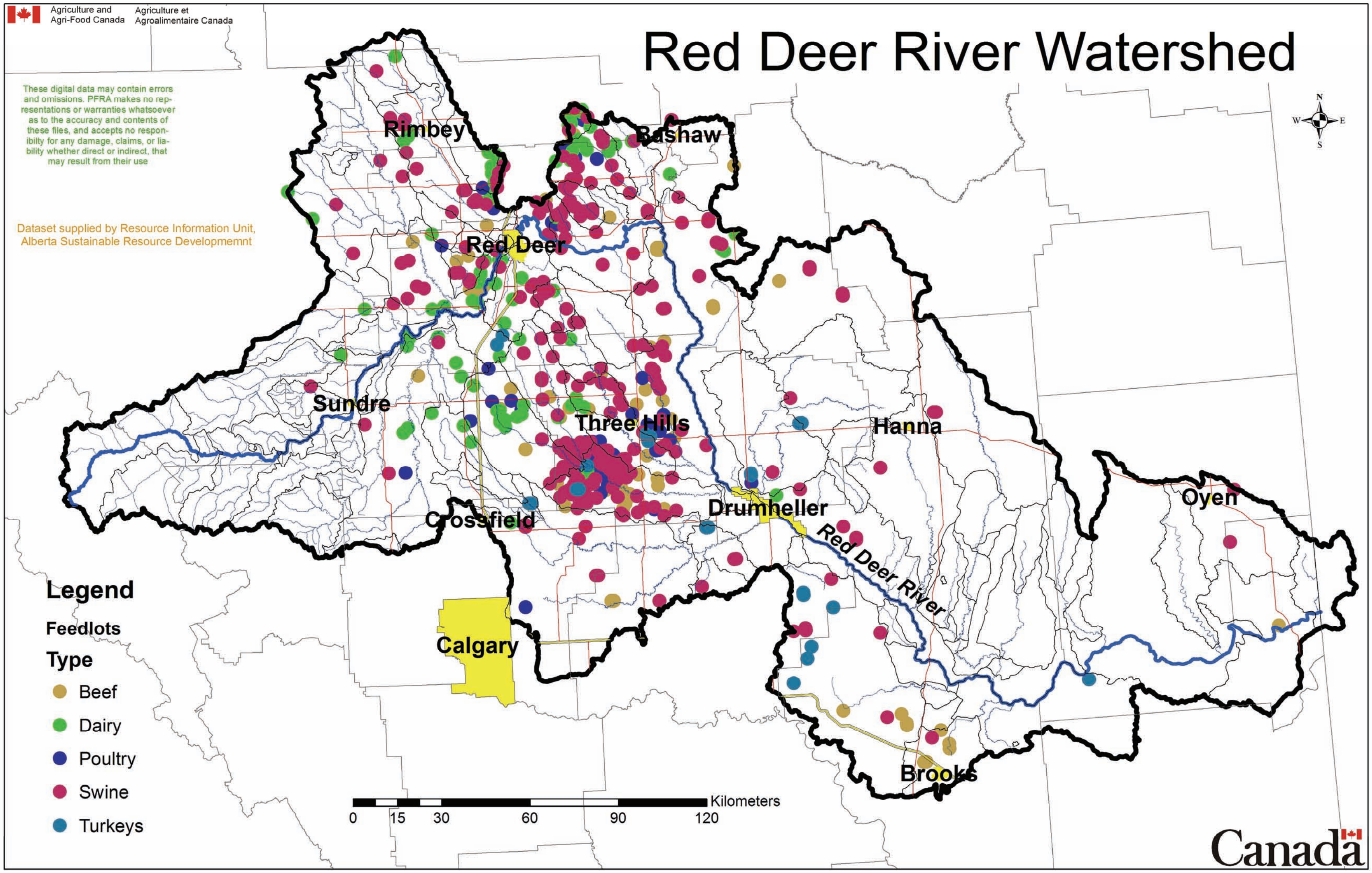


Figure 5. Feedlots and intensive livestock operations in the Red Deer River watershed in 2006 (AAFC-PFRA, 2008). Dots indicate quarter sections with permits for a CFO (confined feedlot operation), although one CFO may be larger than 1 quarter section or 1 quarter section may contain more than one CFO.

3.1.1.3 Commercial and Industrial Developments

In addition to municipal and agricultural developments, the Red Deer River watershed is characterized by a diverse commercial and industrial mosaic. Activities associated with the petroleum sector include drilling operations and refining facilities. Only that portion of the headwaters of the Red Deer River located in Banff National Park has no oil and gas footprint. On average, there are up to 2 oil or gas wells/km^2 (including abandoned and decommissioned wells) in the remainder of the watershed, although this density can increase up to 5 oil and gas wells/km^2 in the south-central and south-eastern regions of the watershed and up to 10 oil and gas wells/km^2 in the Drumheller, Red Deer, White Sands to Big Valley, Brooks-Bassano-Duchess and Eckville regions (Figure 6) (Alberta Sustainable Resource Development, 2007).

Commercial developments in the Red Deer River watershed include golf courses, bottling and food processing plants, gardening and landscaping establishments, aggregate washing facilities for the construction industry and parks and recreation facilities. Industrial developments in the watershed include fertilizer plants, manufacturing facilities, mines (e.g., coal) and forestry-related facilities (Alberta Environment, 2007a).

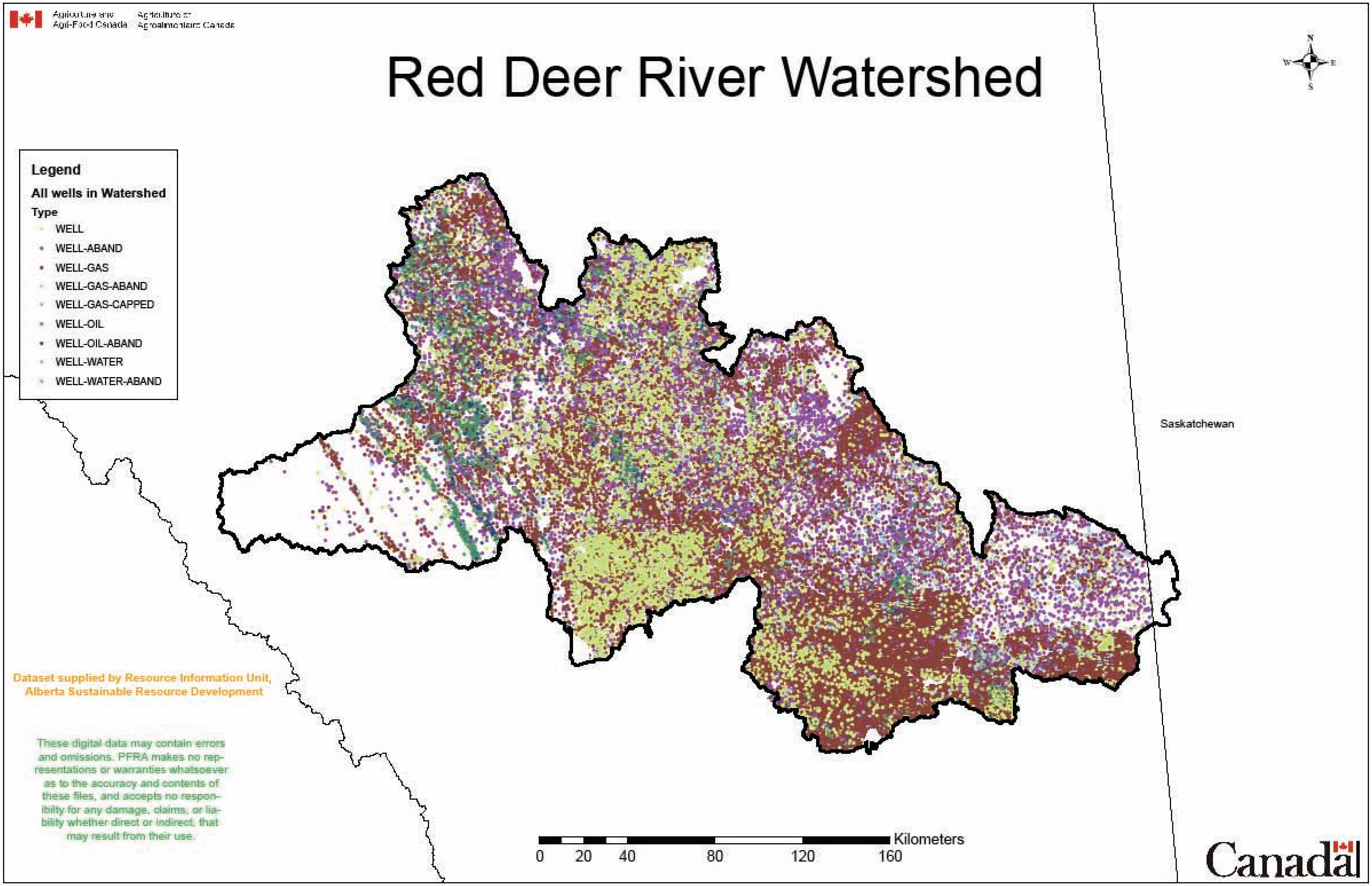


Figure 6. Oil and gas well density in the Red Deer River watershed in 2006 (AAFC-PFRA, 2008).

3.1.2 Water Quality

In 1969, the governments of Alberta, Saskatchewan, Manitoba and Canada signed the *Master Agreement on Apportionment*. The primary purpose of this agreement was to provide for the sharing of water in eastward flowing streams that cross interprovincial boundaries. The *Master Agreement* also established the Prairie Provinces Water Board (PPWB) to oversee the Agreement. While the authors of the *Master Agreement* were primarily concerned with water quantity (see Section 3.1.4.1), they also recognized the potential importance of water quality. Consequently, the *Agreement* states that interprovincial water quality problems are to be referred to the Board for consideration as well (Environment Canada, 2007).

Over the years, the PPWB has developed an active water quality program, including monitoring at 12 PPWB monitoring stations; however, given the increasing importance and the complexity of responding to both water quality issues, the Board considered it necessary to better define its roles and responsibilities in the area of interprovincial water quality matters. In recent years the PPWB has worked towards more integrated ecosystem and watershed approaches in dealing with environmental issues. Complementing these approaches is the recent adoption by governments of the source-to-tap, multi-barrier approach to protecting drinking water for Canadians. The multi-barrier approach highlights the importance of protecting lakes, rivers and aquifers, which are the sources of our drinking water, as well as ensuring effective treatment and distribution systems (Environment Canada, 2007). In addition to protecting the drinking water sources themselves, it is essential to maintain and protect vegetation communities in uplands and wetlands to ensure high water quality in aquatic ecosystems (DUC, 2004).

While provincial governments have the primary responsibility for managing and protecting water quality, including the provision and regulation of drinking water and wastewater services, the federal government is responsible for ensuring the safety of drinking water within areas of federal jurisdiction, such as national parks and First Nation reserves. The federal government also protects water quality by regulating toxic substances, conducting water quality research and promoting pollution prevention (Environment Canada, 2007).

The PPWB supports the multi-barrier approach, and its agencies are committed to identifying, understanding and reducing the human and environmental impacts of microbiological and chemical substances which contaminate water sources and aquatic ecosystems. All board agencies share the knowledge of the threats to water quality, strategies to reduce or eliminate the impacts and information on water quality issues and trends in ecosystem health (Environment Canada, 2007).

The *Agreement on Water Quality* was signed in 1992 and included as Schedule E in the *Master Agreement on Apportionment*. The *Agreement* defines the water quality mandate of the PPWB in interprovincial watercourses. It states that the Board shall “foster and facilitate interprovincial water quality management among the parties that encourages the protection and restoration of the aquatic environment”.

The *Agreement on Water Quality* defines the duties of the PPWB in relation to its water quality mandate (Environment Canada, 2007). The duties of the PPWB are to:

- monitor the quality of the aquatic environment in the river reaches and make comparisons with the PPWB objectives;
- review the appropriateness of the PPWB objectives;
- provide written reports on the quality of water in interprovincial river reaches and on water quality issues;
- promote the establishment of compatible water quality objectives in the prairie provinces;
- promote a preventive and proactive ecosystem approach to interprovincial water quality management; and
- promote the recognition of the interdependence of quality and quantity of water in the management of watercourses.

To encourage the protection and restoration of interprovincial streams, the *Agreement on Water Quality* includes a set of PPWB Water Quality Objectives. PPWB members will strive to meet these objectives to protect all downstream water uses, including the protection of aquatic life. The Water Quality Objectives are reach-specific to reflect the individual characteristics and uses of each river reach. These specific objectives are considered appropriate and acceptable for each of the 11 major interprovincial eastward flowing river reaches. Five of these reaches are along the Alberta-Saskatchewan border and six are along the Saskatchewan-Manitoba border. The PPWB river reach objectives were developed using provincial objectives or, where available, basin specific objectives. If these objectives were not available, then the CCME surface water guidelines were used (Environment Canada, 2007).

The PPWB makes quarterly comparisons of interprovincial water quality monitoring results with the objectives. When the objectives are exceeded, the Committee on Water Quality, an operating committee of the PPWB, prepares a report to the PPWB, with an explanation and a recommended course of action. The PPWB then makes recommendation to its member agencies on how to resolve any problems (Environment Canada, 2007).

The Agreement recognizes that if the quality of water in a river reach is better than the water quality objectives, all reasonable and practical measures will be taken to maintain the existing water quality. It also recognizes that in some situations the quality of water in a river reach may, as a result of human activities, not meet the water quality objectives. Where this occurs, the parties agree to take reasonable and practical measures to improve the quality to meet the objectives (Environment Canada, 2007).

Water quality assessments have been conducted for various locations in the Red Deer River watershed (Figure 7). Published assessments of water quality of the Red Deer River are generally limited by the age of the reports, the limited number of variables assessed and/or the limited spatial extent of studies. Various datasets have been analyzed in the past two decades. For example, Cross (1991) conducted an extensive evaluation of water quality along the Red Deer River, Shaw and Anderson (1994) reported on the effects of the Dickson Dam on water quality and non-fish biota after a 5-year monitoring study, Saffran and Anderson (1997) analyzed temperature and dissolved oxygen (DO) conditions in the Red Deer River and Anderson (1998) reported on water quality changes between Dickson Dam and the City of Red Deer. More recent studies have generally been limited to localized areas (e.g., Golder, 2001a, b).

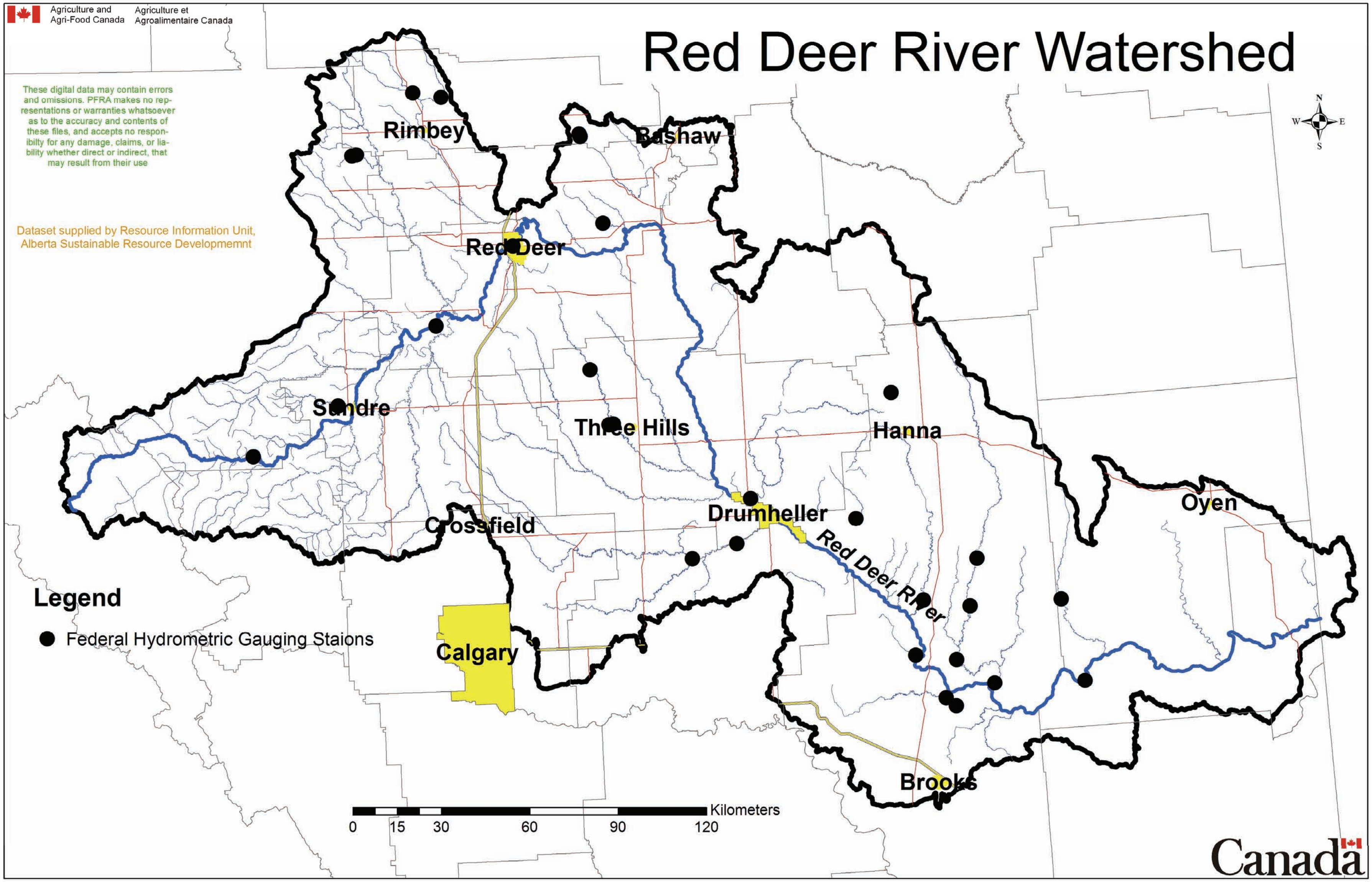


Figure 7. Federal hydrometric stations in the Red Deer River watershed (AAFC-PFRA, 2008).

The following description of water quality was based on a combination of published literature and analysis of recent (1999-2003) water quality data provided by Alberta Environment and the PPWB. Results of historical studies were incorporated to expand upon knowledge of overall spatial patterns of water quality along the river and, to a more limited extent, to provide information on potential temporal changes. Historically, naturally low DO levels in the lower reaches of the Red Deer River, especially in winter months with low flow rates and under ice cover, have been identified as the major problem with water quality (e.g., Cross, 1991; Shaw and Anderson, 1994). Low DO concentrations have negative impacts on aquatic life, potentially causing fish kills. The construction of the Dickson Dam in 1983 and the resulting increased winter flows have had an effect on declining DO levels in the Red Deer River, and especially on low winter DO levels. Minimum DO levels have increased in the entire length of the Red Deer River since the early 1980s (Shaw and Anderson, 1994).

Water quality data were analyzed for five monitoring sites, located within the four river reaches, on the Red Deer River as follows:

- Reach 1 (Headwaters to Gleniffer Lake Reservoir): Alberta Environment water quality monitoring station AB05CA0050 at Sundre ('Sundre');
- Reach 2 (Gleniffer Lake Reservoir to the City of Red Deer): Alberta Environment water quality monitoring station AB05CC0010 at Queen Elizabeth II Highway above Red Deer;
- Reach 3 (City of Red Deer to Drumheller): Alberta Environment water quality monitoring station AB05CD0250 at the Nevis Bridge ('Nevis') and AB05CE0010 at the Morrin Bridge 'Morrin'); these sites are located above Drumheller; and
- Reach 4 (Drumheller to the Saskatchewan border): PPWB water quality monitoring station 00AL05CK0001 near Bindloss at the Saskatchewan border ('Bindloss').

Stations Queen Elizabeth II Highway, Nevis and Morrin are three provincial Long-Term River Network (LTRN) sites. The period evaluated was 1999-2003, except for Sundre, where only data from 1997 were available. For Bindloss, data provided by the PPWB for the same 5-year period were analyzed. The following provides a discussion of water quality within each of these reaches.

3.1.2.1 Reach 1: Headwaters to Gleniffer Lake Reservoir

Water quality data collected at Sundre indicated the Red Deer River at this site was well-oxygenated, slightly alkaline and low in nutrients (Table 10) (Alberta Environment, 2007b). Concentrations of both total nitrogen (TN) and total phosphorus (TP) were indicative of oligotrophic conditions; however, no planktonic or epilithic chlorophyll *a* (chl. *a*) data were available to assess productivity within this reach. The only conventional water quality parameter that did not consistently meet either the Alberta Surface Water Quality Guidelines for the Protection of Aquatic Life (ASWQ PAL; Alberta Environment, 1999) or the Canadian Council of Ministers of the Environment Water Quality Guidelines (CCME WQG; CCME, 1999, 2001) was TP (25% of measurements exceeded guidelines) (Alberta Environment, 2007b). Data for metals/metalloids were unavailable for the Sundre location. Smith (2003) analyzed extractable metals at several sites in this reach in fall 2002 and spring 2003; however, no data were presented or discussed.

Table 10. Summary statistics for selected water quality parameters (1997) in the Red Deer River at Sundre (Alberta Environment, 2007b). n = sample size. All concentrations in mg/L unless otherwise indicated.

Parameter	Mean	Median	Minimum	Maximum	n	% ASWQG PAL compliance *
DO	9.71	9.49	9.00	11.26	6	100
TSS	37	4	< 2	148	6	
Chl. *a* **	---	---	---	---	---	
pH	8.17	8.16	8.13	8.24	6	100
TDS	216	242	150	250	5	
TP	0.018	0.006	< 0.002	0.065	6	75
TDP	0.007	0.002	< 0.002	0.030	6	
TN	0.196	0.196	0.154	0.230	6	100
NO_3^-	0.105	0.105	0.089	0.129	6	100
NH_3	0.010	0.004	< 0.005	0.041	6	100

* ASWQG PAL compliance = Alberta Surface Water Quality Guideline for the Protection of Aquatic Life compliance, DO = dissolved oxygen, TSS = total suspended solids, chl. *a* = chlorophyll *a*, TDS = total dissolved solids, TDP = total dissolved phosphorus, TN = total nitrogen; n = sample size, ** in µg/L.

3.1.2.2 Reach 2: Gleniffer Lake Reservoir to the City of Red Deer

The Red Deer River near Bowden experiences peaks in TP concentrations during unexpected times of the year, namely in the winter months (Figure 8). This is unusual but no conclusions can be drawn due to the large number of gaps in the sampling record for this parameter. TDP experiences peaks in concentrations during the months of April through June, which is concomitant with spring runoff and precipitation events. This form of TP is readily biologically available to plants and algae and is usually taken up quite quickly. Following a statistical analysis of the TP concentrations at this point in the river using linear regression in StatFi in Excel 2007, it was found that there is a significant increasing trend in TP concentrations over time ($p = 0.01$), i.e., TP loadings to the Red Deer River have increased, possibly due to an increase in loadings from agriculture, sewage or wastewater effluent.

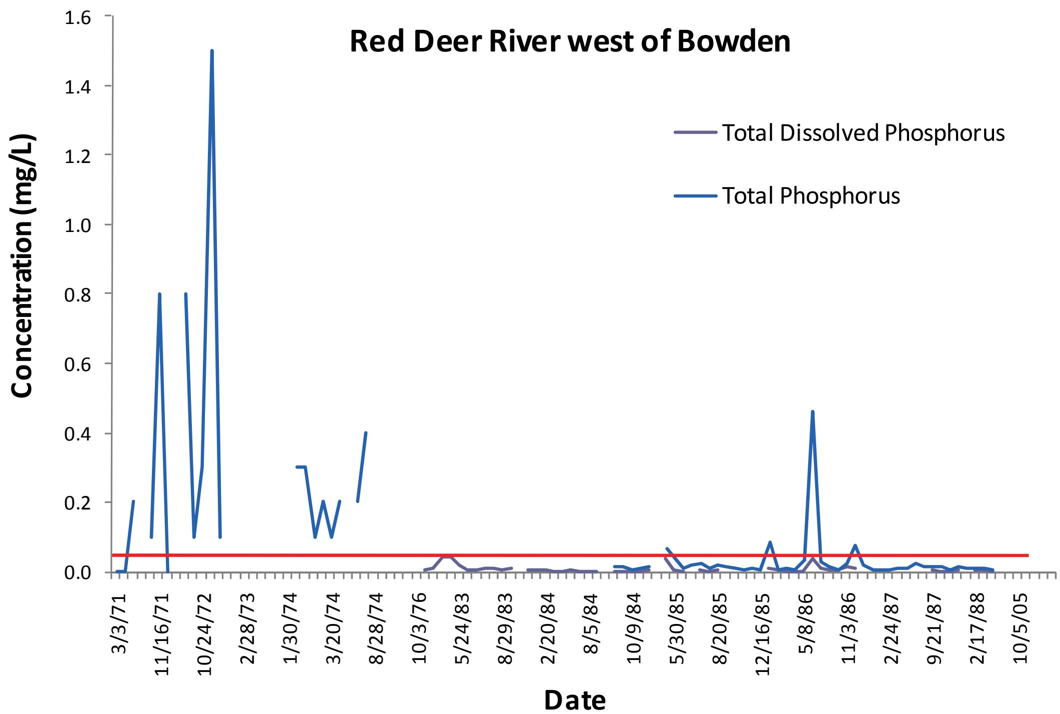


Figure 8. Total phosphorus (TP) and total dissolved phosphorus (TDP) concentrations in the Red Deer River near Bowden (data from Alberta Environment, 2008). The ASWQG PAL for TP (0.05 mg/L) is indicated by the red line.

There are no total nitrogen concentrations available from the Red Deer River near Bowden; only ammonia (NH_3) and nitrate-nitrite (NO_2^--NO_3^-) concentrations have been determined at this location. The Red Deer River at this location experiences peaks in NH_3 concentrations predominantly during the winter months (Figure 9), which is concomitant with ice cover and the associated depletion of oxygen levels within the water column. Data for this parameter is very limited for this time period. Following a statistical analysis of NH_3 concentrations at this point in the river using linear regression in StatFi in Excel 2007, it was found that there is no significant increasing or decreasing trend in NH_3 concentrations over time ($p > 0.05$).

The Red Deer River near Bowden experiences peaks in NO_2^--NO_3^- concentrations during the winter and early spring months (Figure 10), which is concomitant with ice cover and the buildup of waste products from decomposition and fish wastes. Higher levels of NH_3 will lead to higher levels of NO_2^--NO_3^- due to the conversion of nitrogen forms by bacteria in the nitrogen cycle. Following a statistical analysis of NO_2^--NO_3^- concentrations at this point in the river using linear regression in StatFi in Excel 2007, it was found that there is no significant increasing or decreasing trend in NO_2^--NO_3^- concentrations over time ($p > 0.05$).

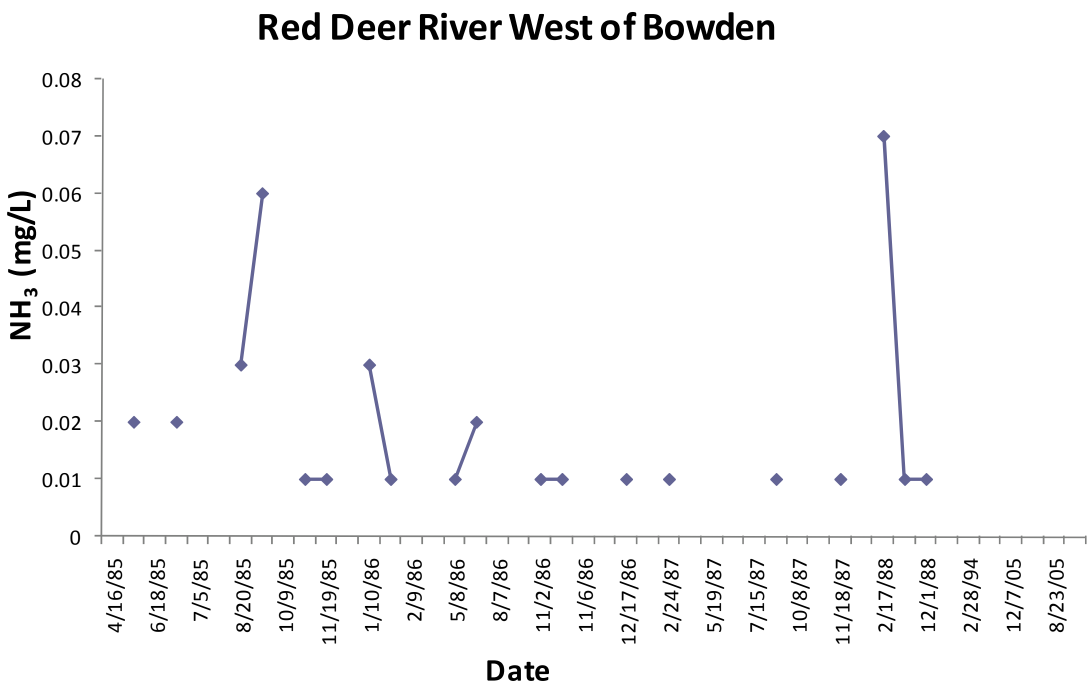


Figure 9. Ammonia concentrations in the Red Deer River near Bowden (data from Alberta Environment, 2008).

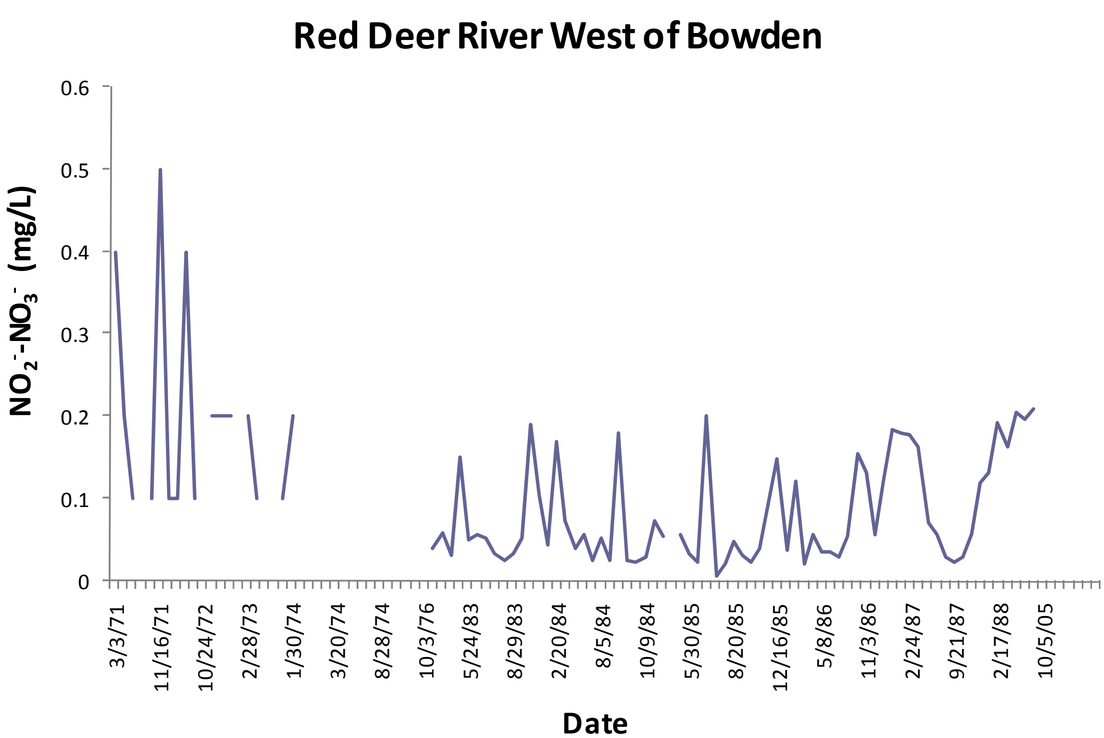


Figure 10. Nitrate-nitrite concentrations in the Red Deer River near Bowden (data from Alberta Environment, 2008).

The ASWQ PAL guideline for the Queen Elizabeth II Highway site upstream of the City of Red Deer indicated that metals, nutrients, pesticides and bacteria were reflective of 'good' to 'excellent' conditions from 1999-2003 (overall, water quality was ranked as 'good'); however, there was considerable interannual variability for some sub-indices, most notably nutrients and pesticides. Water quality data indicated that DO remained high (Figure 11), and there was no increase in total dissolved solids (TDS) relative to upstream. Saffran and Anderson (1997) reported that DO remained above the ASWQ PAL guideline of 5 mg/L at Queen Elizabeth II Highway from 1977-1995; however, 1% of measurements collected daily in the open-water season of 1992 were below the guideline, indicating that DO may be depleted to low levels on rare occasions. TSS / turbidity and particulate-related variables (i.e., nutrients and metals) reportedly decrease below the Dickson Dam, likely a reflection of settling in Gleniffer Lake Reservoir (Cross, 1991); however, scouring during planned release events from the reservoir increased downstream measurements of particulate-related variables.

DO concentrations appear to have an unusual trend; concentrations are typically lower in the summer in this location and higher in the winter (Figure 11), which is contrary to what would be expected in a natural setting. As stated above, this indicates an increased oxygen demand over the summer, which is likely due to an external loading of organic matter. The source of this organic matter is uncertain at this time. Following a statistical analysis of the DO and ammonia concentrations at this point in the river using linear regression in StatFi in Excel 2007, it was found that there is no significant relationship between DO and ammonia concentrations (data not shown; $p > 0.05$).

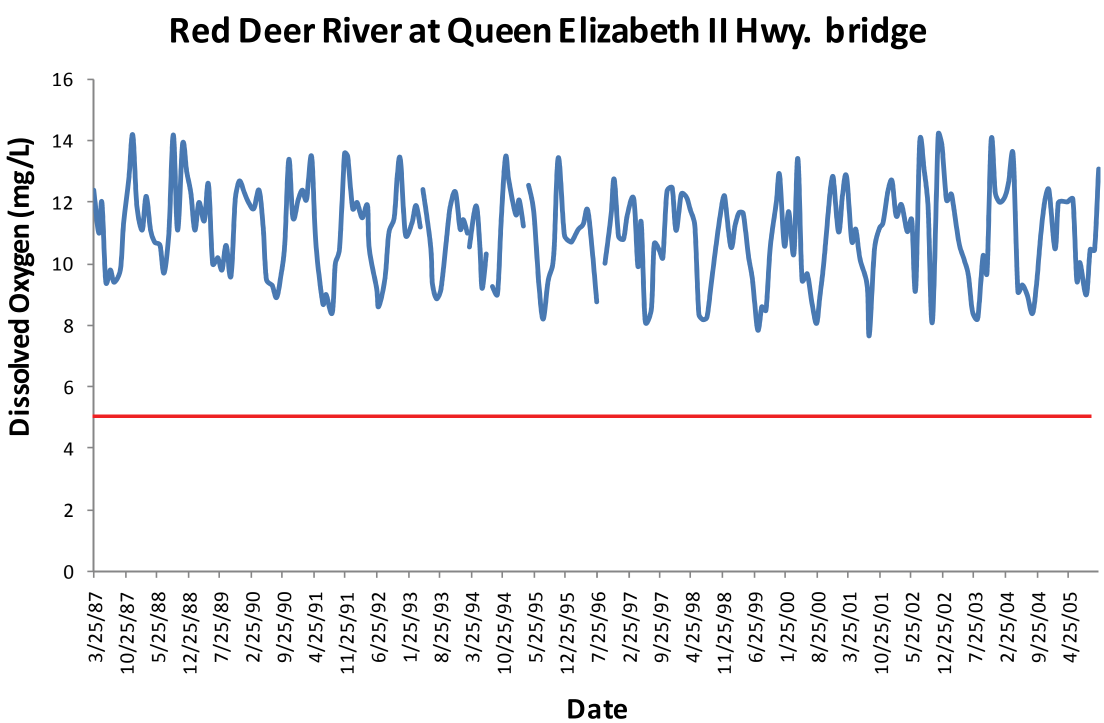


Figure 11. Dissolved oxygen (DO) concentrations in the Red Deer River at the Queen Elizabeth II Highway bridge (data from Alberta Environment, 2008). The ASWQ PAL lower limit for DO (5.0 mg/L) is indicated by the red line.

The Red Deer River at the Queen Elizabeth II Highway bridge experiences peaks in NH_3 concentrations predominantly during the winter months (Figure 12), which is concomitant with ice cover and the associated depletion of oxygen levels within the water column; however, occasional peaks are seen in summer and early fall, which may be harmful for fish populations and may indicate an external loading problem. Following a statistical analysis of NH_3 concentrations at this point in the river using linear regression in StatFi in Excel 2007, it was found that there is no significant increasing or decreasing trend NH_3 concentrations over time (data not shown; $p > 0.05$).

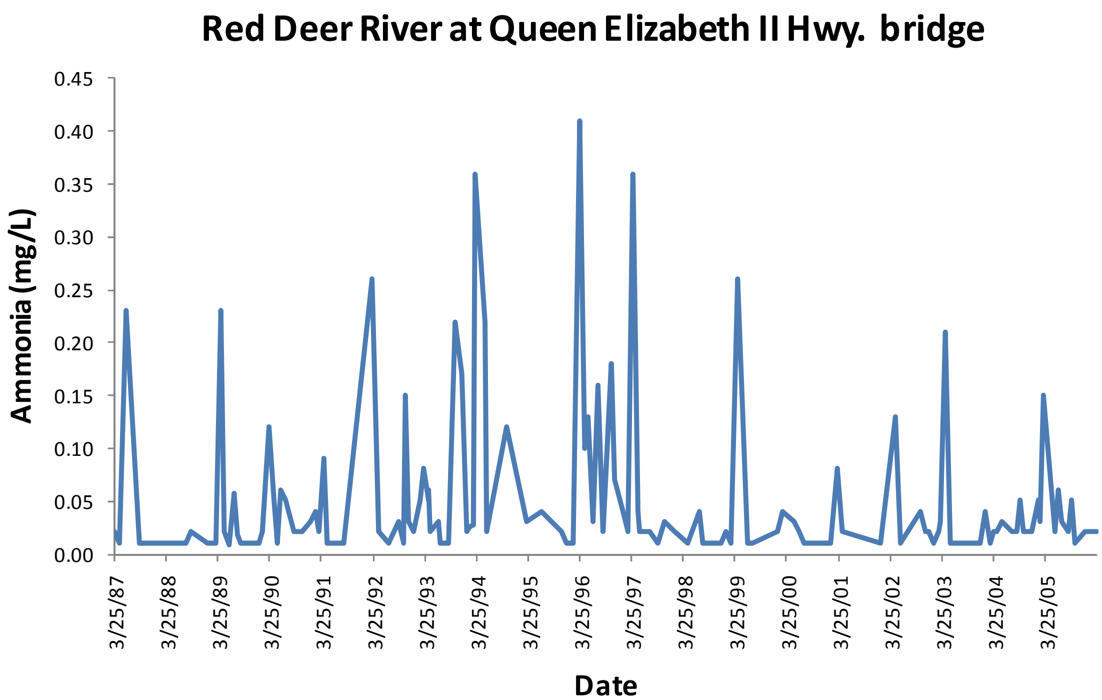


Figure 12. Ammonia concentrations in the Red Deer River at the Queen Elizabeth II Highway bridge (data from Alberta Environment, 2008).

Mean TP and TN concentrations were notably higher than at the Sundre site (Table 11), reflecting point and non-point source inputs. TP concentrations were indicative of mesotrophic conditions, while concentrations of TN and phytoplankton chl. *a* were lower and indicated oligotrophic conditions. Conversely, epilithic (associated with rock surfaces) chl. *a* levels were indicative of eutrophic conditions and abundant periphyton growth. TP, TN and pH had 78, 92 and 93% compliance with ASWQ PAL guidelines, respectively (Table 11).

The Red Deer River at the Queen Elizabeth II Highway experiences peaks in TP concentrations from April-July (Figure 13), which is concomitant with spring runoff and precipitation events. Sources of phosphorus may include surface application of manure and/or fertilizer by agricultural producers (Carpenter et al., 1998; Chambers et al., 2001), municipal wastewater effluents (Servos et al., 2001) and urban run-off (Marsalek et al., 2001), all of which have been demonstrated to be a source of excess nutrients to surface waterbodies. TDP, as expected, follows the same trend as TP, with peaks in the spring and summer

(Figure 13). This component of TP is readily biologically available to plants and algae and is usually rapidly assimilated. Following a statistical analysis of the TP and TDP concentrations at this point in the river using linear regression in StatFi in Excel 2007, it was found that there is no significant increasing or decreasing trend in TP concentrations over time (data not shown; p > 0.05).

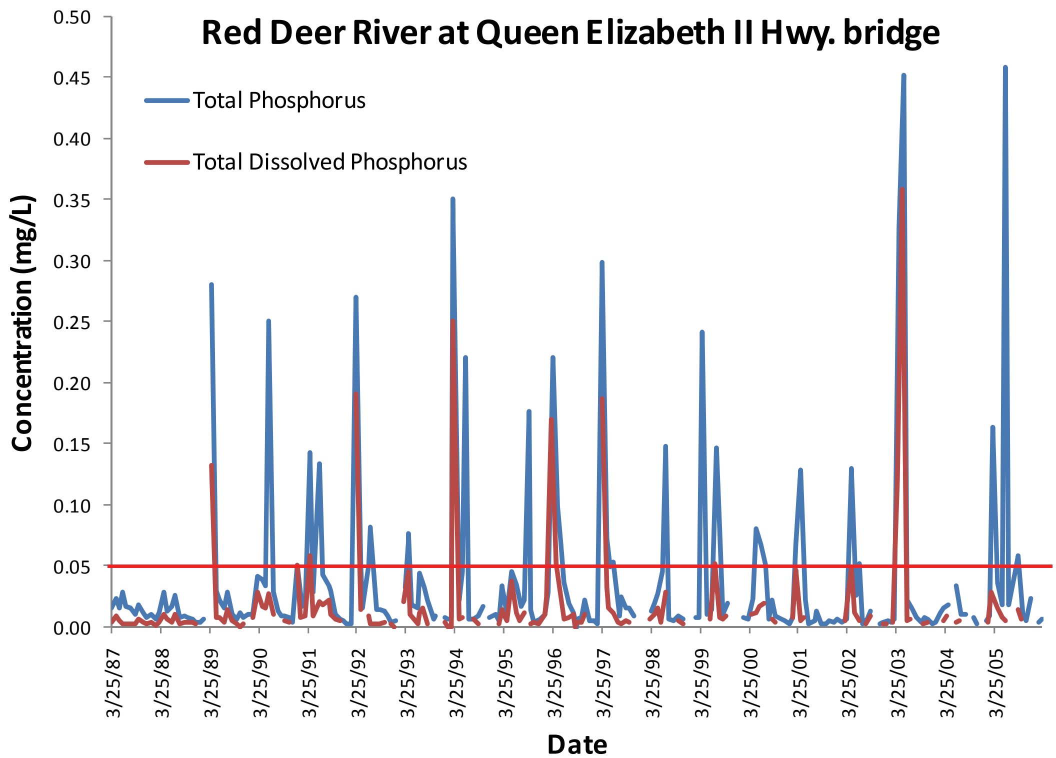


Figure 13. Total phosphorus (TP) and total dissolved phosphorus (TDP) concentrations in the Red Deer River at the Queen Elizabeth II Highway bridge (data from Alberta Environment, 2008). The ASWQG PAL for TP (0.05 mg/L) is indicated by the red line.

The Red Deer River at the Queen Elizabeth II Highway bridge experiences peaks in TN concentrations predominantly during the months of April through July (Figure 14), which is concomitant with spring runoff and precipitation events. Sources of nitrogen may include surface application of manure and/or fertilizer by agricultural producers (Carpenter et al., 1998; Chambers et al., 2001), municipal wastewater effluents (Servos et al., 2001) and urban run-off (Marsalek et al., 2001), all of which have been demonstrated to be a source of excess nutrients to surface waterbodies. Following a statistical analysis of the TN concentrations at this point in the river using linear regression in StatFi in Excel 2007, it was found that there is no significant increasing or decreasing trend in TN concentrations over time (p > 0.05); however, there is a significant relationship between TP and TN (p = 0.027), indicating that TN and TP concentrations were positively correlated at this point in the river.

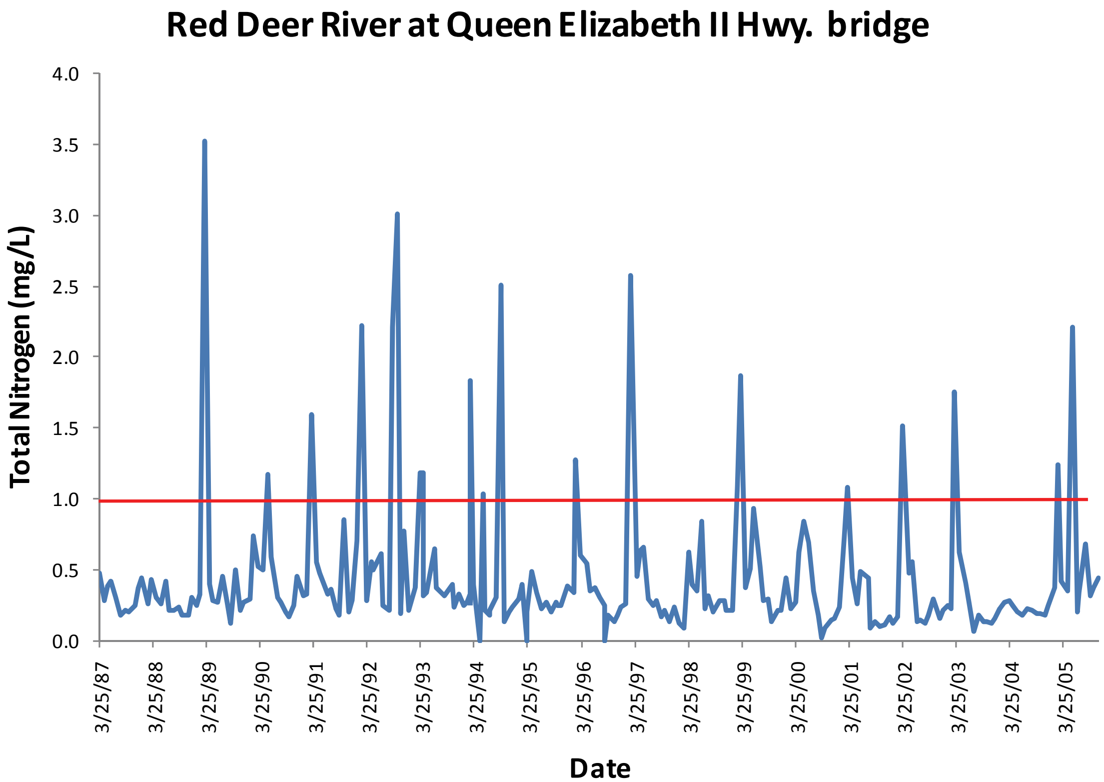


Figure 14. Total nitrogen (TN) concentrations in the Red Deer River at the Queen Elizabeth II Highway bridge (data from Alberta Environment, 2008). The ASWQG PAL for TN (1.0 mg/L) is indicated by the red line.

The Red Deer River at the Queen Elizabeth II Highway bridge experiences peaks in NO_2^--NO_3^- concentrations during the winter and early spring months (Figure 15), which is concomitant with ice cover and the buildup of waste products from decomposition and fish wastes. Higher levels of NH_3 will lead to higher levels of NO_2^--NO_3^- due to the conversion of nitrogen forms by bacteria in the nitrogen cycle. Following a statistical analysis of the NO_2^--NO_3^- concentrations at this point in the river using linear regression in StatFi in Excel 2007, it was found that there is no significant increasing or decreasing trend in NO_2^--NO_3^- concentrations over time ($p > 0.05$); however, there appears to be a positive relationship between NO_2^--NO_3^- and NO_3 levels in this point of the river ($p = 0.05$).

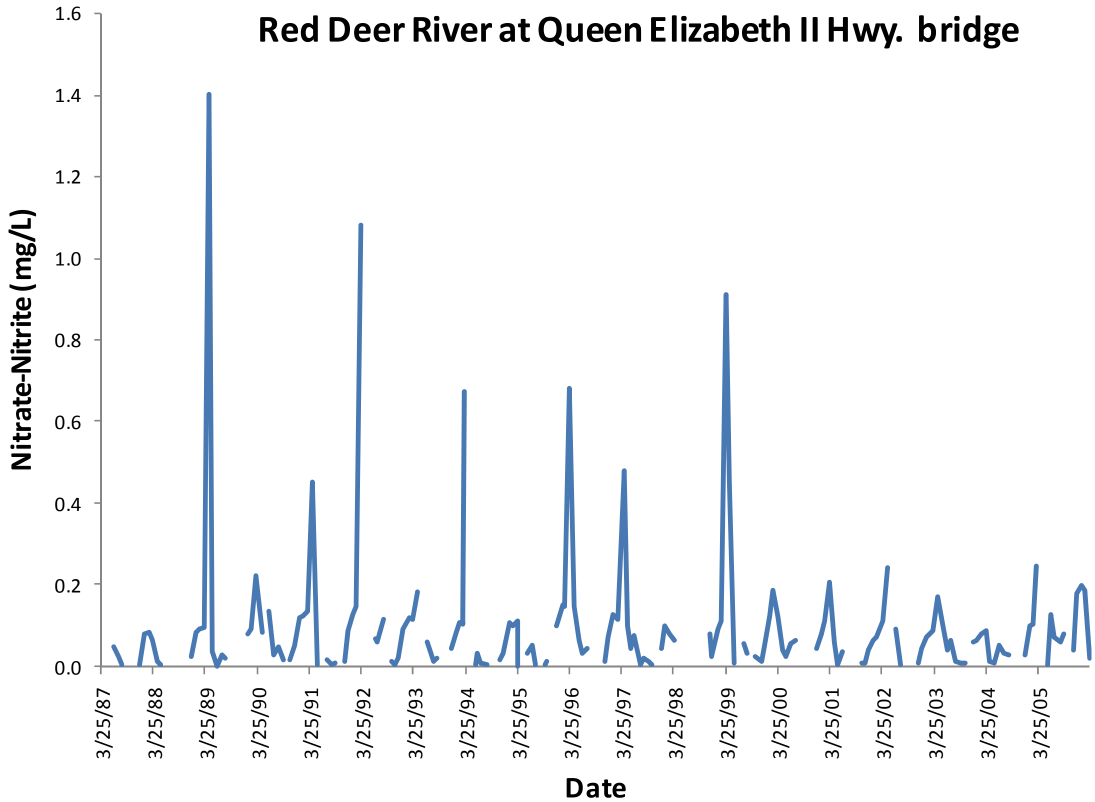


Figure 15. Nitrate-nitrite concentrations in the Red Deer River at the Queen Elizabeth II Highway bridge (data from Alberta Environment, 2008).

A spring survey conducted in 1997 indicated that inputs of nutrients from tributary streams during the freshet significantly affect water quality in the Red Deer River (Anderson, 1998). The frequency of ASWQG PAL non-compliance and the overall nutrient concentrations increased between the Dickson Dam and Innisfail. Although concentrations of water quality parameters were similar between Innisfail and Red Deer, the lowest ASWQ PAL guideline compliance rate for TP was observed at Red Deer (0% compliance). Several metals/metalloids exceeded CCME PAL WQGs on occasion (Al, Cu, Fe, Pb and Zn), while others exceeded guidelines consistently (Cd, Cr and Ag) (Table 11) (Alberta Environment, 2007b).

Table 11. Summary statistics for selected water quality parameters and total metals/metalloids (1999-2003) in the Red Deer River at Queen Elizabeth II Highway upstream of Red Deer (Alberta Environment, 2007b). n = sample size. All concentrations in mg/L unless otherwise indicated.

Parameter	Mean	Median	Minimum	Maximum	n	% ASWQG PAL compliance *
DO	10.9	11.05	7.67	14.22	60	100
TSS	17.3	2.4	< 0.4	221	60	---
Chl. *a* **	2.5	1.2	0.4	17.8	59	---
pH	8.03	8.06	7.07	8.72	60	93
TDS	216	219	138	282	60	---
TP	0.037	0.008	< 0.003	0.451	60	78
TDP	0.016	0.004	< 0.003	0.358	60	---

TN	0.39	0.24	< 0.053	1.86	60	100
NO_3^-	0.071	0.04	< 0.003	0.91	60	100
NH_3	0.02	< 0.01	< 01	0.26	60	100
Al	0.24	0.041	< 0.01	1.81	20	74
As	0.0006	0.0005	< 0.0002	0.0019	17	100
Cd	0.0005	< 0.0002	< 0.0002	0.003	19	0
Cr	0.0031	0.0025	< 0.001	0.01	20	0
Cu	0.0042	0.0033	0.0004	0.023	20	55
Fe	0.55	0.1	0.04	3.1	17	71
Pb	0.003	0.0003	< 0.0003	0.02	20	88
Mn	0.027	0.014	0.002	0.103	20	---
Hg **	0.021	< 0.005	< 0.0006	< 0.005	19	100
Mo	0.0012	0.001	0.0006	0.003	17	100
Ni	0.0043	0.0035	< 0.0005	0.0166	20	100
Se	0.0001	< 0.0001	< 0.0002	0.0002	17	100
Ag	0.0002	< 0.0001	< 0.0001	< 0.002	20	0
Zn	0.0159	0.0106	< 0.001	0.0871	20	89

* Abbreviations as in Table 10; ** in µg/L.

3.1.2.3 Reach 3: City of Red Deer to Drumheller

For the Nevis bridge site, downstream of Red Deer, concentrations of metals, nutrients, pesticides and bacteria were reflective of 'good' conditions from 1999-2003 based on ASWQG guidelines; however, there was considerable interannual variability for some sub-indices, notably nutrients and pesticides. ASWQG PAL values for the Morrin bridge site were similar to the other upstream LTRN monitoring sites. Although the nutrient and pesticide sub-indices rated 'fair' from 1999-2003, the absolute index values were similar to upstream sites. Like the other LTRN sites, sub-indices for nutrients and pesticides were quite variable among years.

The Red Deer River at Joffre experiences peaks in TP concentrations annually from April-May (Figure 16), coinciding with the period of peak runoff. Values during these times are well in excess of the ASWQG PAL limit of 0.05 mg/L; however, concentrations are typically closer to or below the limit throughout the remainder of the year. For example, Golder (2008) reported TP concentrations ranging from 0.017-0.044 mg/L in late October 2007, with the highest concentration 60 m downstream of the NOVA Chemicals Corporation effluent outfall (0.044 mg/L). TP concentrations returned to background levels within about 1.5 km downstream of the outfall location. The same trend was apparent for dissolved phosphorus, TN, NO_3^-, and NH_3 concentrations (Golder, 2008). Phenol concentrations have been measured at this location as well (Table 12), the only location anywhere in the Red Deer River watershed. Concentrations were below detection limits and CCME PAL guidelines (0.004 mg/L). Hydrocarbon concentrations (benzene, ethylbenzene, toluene, xylenes) were below detection limits and CCME PAL guidelines. TDS concentrations were similar to those seen in Reach 2, and metal concentrations were lower than in Reach 2 (Table 12).

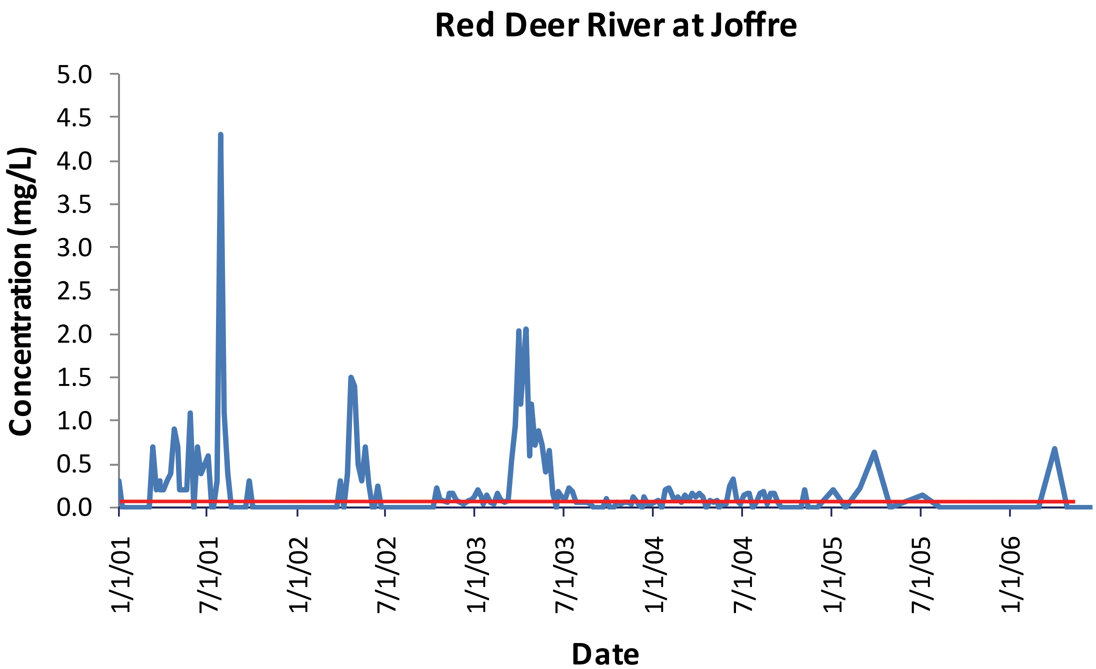


Figure 16. Total phosphorus (TP) concentrations in the Red Deer River at Joffre (data from NOVA Chemicals Corporation; Golder, 2008). The ASWQG PAL for TP (0.05 mg/L) is indicated by the red line.

Table 12. Summary statistics for selected water quality parameters in the Red Deer River at Joffre in 2007 (data from NOVA Chemicals Corporation; Golder, 2008). n = sample size. All concentrations in mg/L unless otherwise indicated.

Parameter	Mean	Minimum	Maximum	n
TP *	0.061-0.124	< 0.100	0.164	11
TDS	275	236	323	11
Total phenols	0.000-0.002	< 0.002	0.002	11
As	0.000-0.002	< 0.002	0.002	11
Hg	< 0.0001	---	---	11

* Abbreviations as in Table 10.

The Red Deer River remained well oxygenated at the Nevis bridge site, with all measurements collected from 1999-2003 in compliance with water quality guidelines (Table 13). Conversely, there was some oxygen depletion evident at Morrin for this time period (Table 14), although 98% of measurements were in compliance with the chronic ASWQ PAL guideline (6.5 mg/L). Saffran and Anderson (1997) reported a lower rate of compliance with the acute DO ASWQ PAL guideline at Morrin (95% compliance) from 1977-1995. All of the non-compliance events occurred during winter months prior to 1990. Historically, low DO levels have occurred naturally at the lower reaches of the Red Deer River (e.g., Cross, 1991), but the conditions have improved since the early 1980s, when the Dickson Dam was constructed. Depletion of DO under ice is not uncommon due to the lack of aeration, and depletion in lower reaches of streams is a reflection of oxygen consumption due to organic matter decay in the absence of aeration. "Natural" inputs of organic matter were identified as significant with respect to winter oxygen depletion in the Red

Deer River (Cross, 1991). Cross (1991) also reported that diurnal fluctuations of DO downstream of Red Deer were strong; however, values remained consistently above 5 mg/L in July and September 1983.

The Red Deer River at Nevis experiences peaks in TP concentrations during the months of April through July (Figure 17), which is concomitant with spring runoff and precipitation events. Sources of phosphorus may include surface application of manure and/or fertilizer by agricultural producers (Carpenter et al., 1998; Chambers et al., 2001), municipal wastewater effluents (Servos et al., 2001) and urban run-off (Marsalek et al., 2001), all of which have been demonstrated to be a source of excess nutrients to surface waterbodies. TDP, as expected, followed the same trend as TP, with peaks in the spring and summer (Figure 17). This form of TP is readily biologically available to plants and algae and is usually rapidly taken up. Following a statistical analysis of the TP and TDP concentrations at this point in the river using linear regression in StatFi in Excel 2007, it was found that there is no significant increasing or decreasing trend in TP concentrations over time (data not shown; $p > 0.05$).

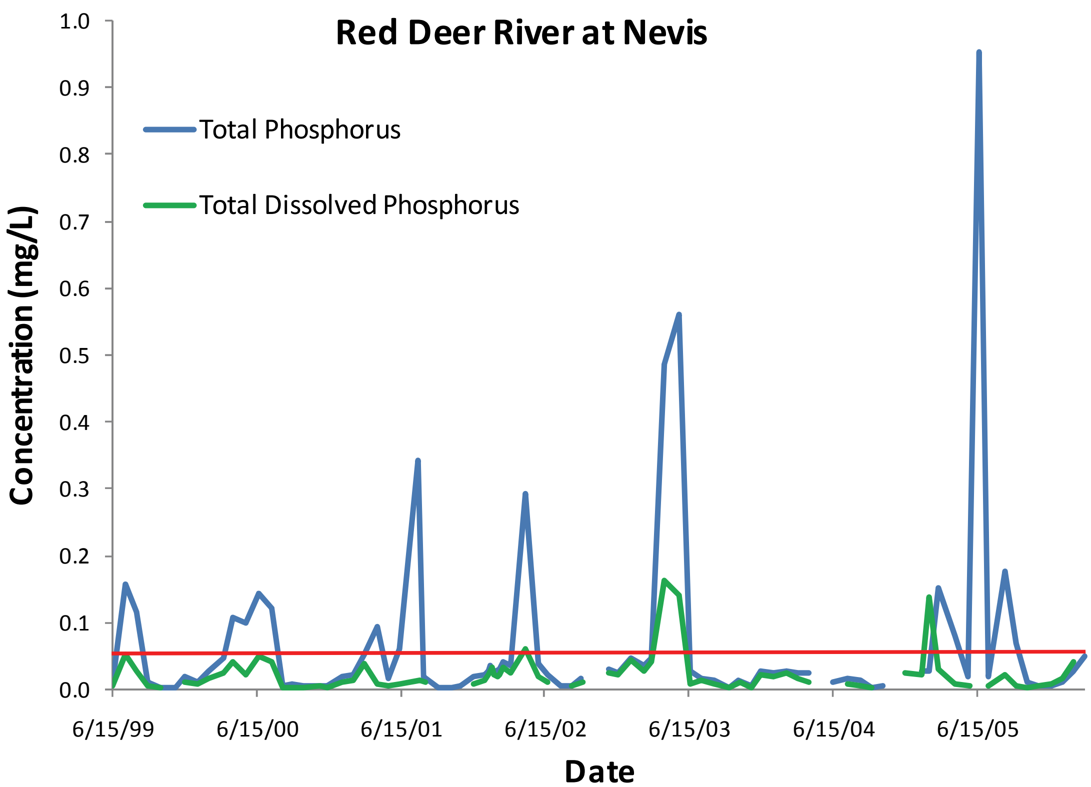


Figure 17. Total phosphorus (TP) and total dissolved phosphorus (TDP) concentrations in the Red Deer River at Nevis (data from Alberta Environment, 2008). The ASWQG PAL for TP (0.05 mg/L) is indicated by the red line.

The Red Deer River at Morrin bridge experiences peaks in TP concentrations during the months of April through July (Figure 18) concomitant with spring runoff and precipitation events. Sources of phosphorus may include surface application of manure and/or fertilizer by agricultural producers (Carpenter et al., 1998; Chambers et al., 2001), municipal wastewater effluents (Servos et al., 2001) and urban run-off (Marsalek et al., 2001), all of which have been demonstrated to be a source of excess nutrients to surface waterbodies. TDP, as expected, follows the same trend as TP, with peaks in the spring and summer. This form of total phosphorus is readily biologically available to plants and algae and is usually taken up quite quickly. Following a statistical analysis of TP and TDP concentrations at this point in the river using linear regression in StatFi in Excel 2007, it was found that TDP concentrations have increased significantly ($p < 0.05$) over time.

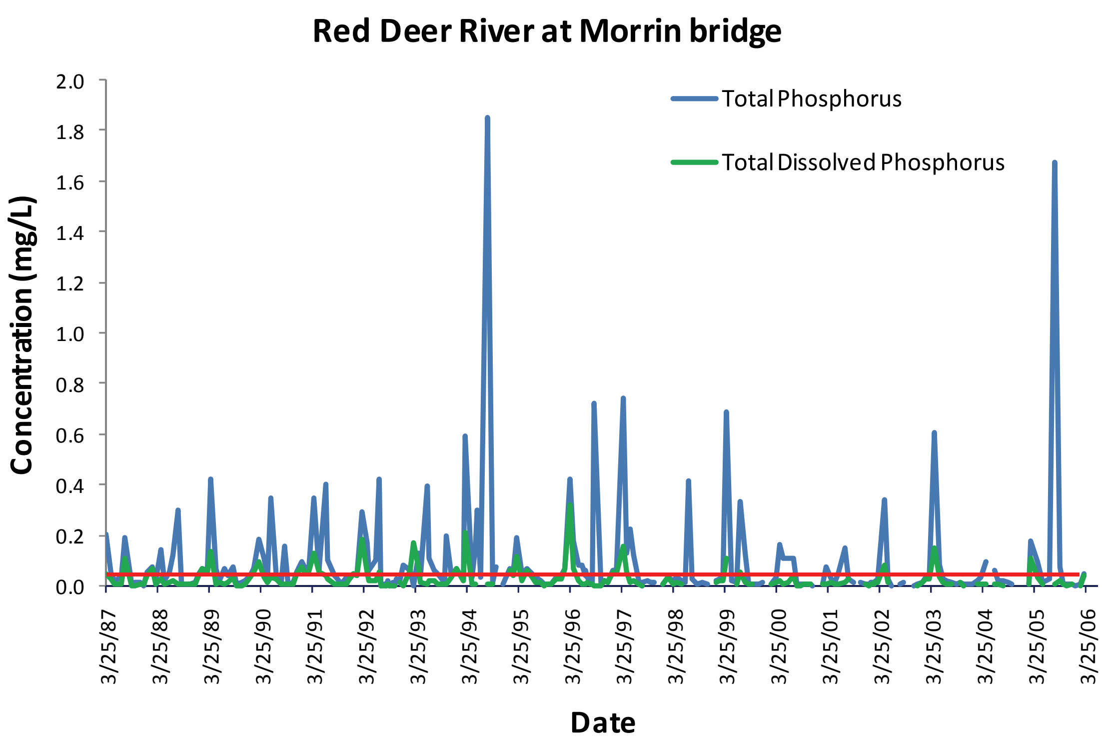


Figure 18. Total phosphorus (TP) and total dissolved phosphorus (TDP) concentrations in the Red Deer River at the Morrin bridge (data from Alberta Environment, 2008). The ASWQG PAL for TP (0.05 mg/L) is indicated by the red line.

The Red Deer River at Nevis experiences peaks in TN predominantly during the months of April through July (Figure 19), which is concomitant with spring runoff and precipitation events. Sources of nitrogen may include surface application of manure and/or fertilizer by agricultural producers (Carpenter et al., 1998; Chambers et al., 2001), municipal wastewater effluents (Servos et al., 2001) and urban run-off (Marsalek et al., 2001), all of which have been demonstrated to be a source of excess nutrients to surface waterbodies. Following a statistical analysis of the total nitrogen concentrations at this point in the river using linear regression in StatFi in Excel 2007, it was found that there is no significant increasing or decreasing trend in TN concentrations over time (data not shown; $p > 0.05$).

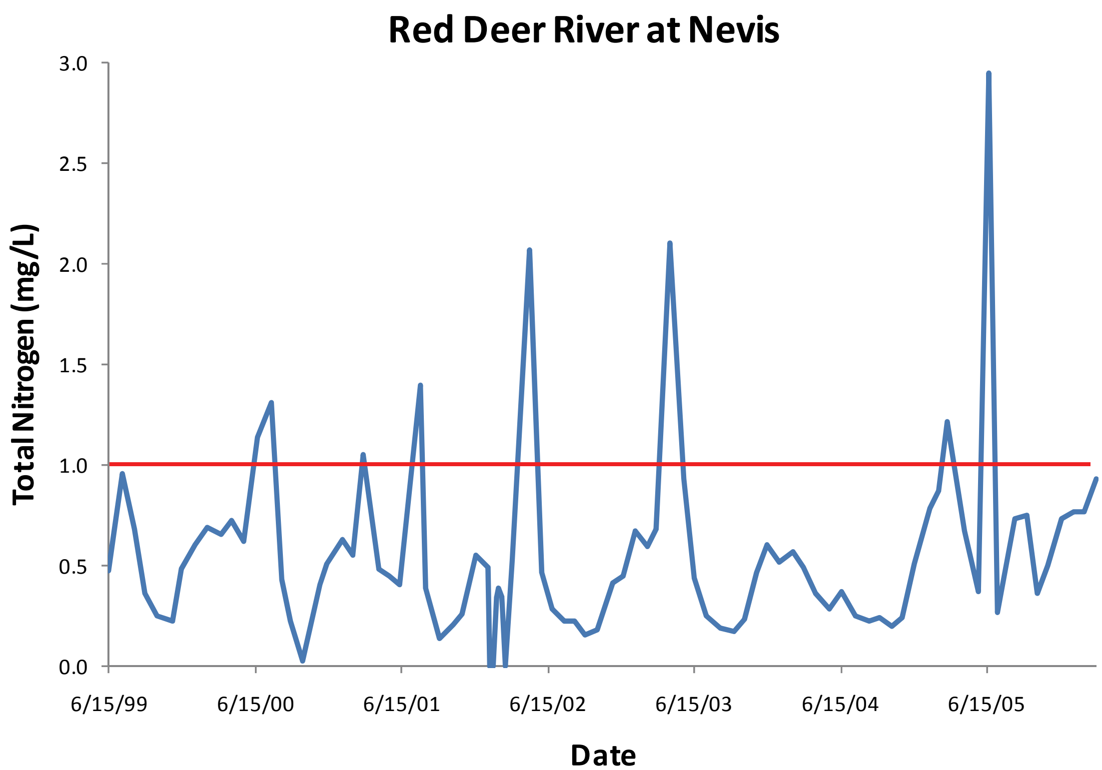


Figure 19. Total nitrogen (TN) concentrations in the Red Deer River at Nevis (data from Alberta Environment, 2008). The ASWQG PAL for TN (1.0 mg/L) is indicated by the red line.

The Red Deer River at Morrin bridge experiences peaks in total nitrogen (TN) concentrations predominantly during the months of April through July (Figure 20), concomitant with spring runoff and precipitation events. Sources of nitrogen may include surface application of manure and/or fertilizer by agricultural producers (Carpenter et al., 1998; Chambers et al., 2001), municipal wastewater effluents (Servos et al., 2001) and urban run-off (Marsalek et al., 2001), all of which have been demonstrated to be a source of excess nutrients to surface waterbodies. Following a statistical analysis of TN concentrations at this point in the river using linear regression in StatFi in Excel 2007, it was found that there is no significant positive or negative trend in TN concentrations over time ($p > 0.05$). There was a significant relationship between TP and TN ($p = 0.0007$), indicating that at this point in the TN concentrations are closely linked with TP levels. *E. coli* counts and TP were also correlated ($p = 0.01$) indicating that an increase in TP will result in an increase in *E. coli* counts in this particular section of the river. This suggests an input of manure and / or sewage to the river.

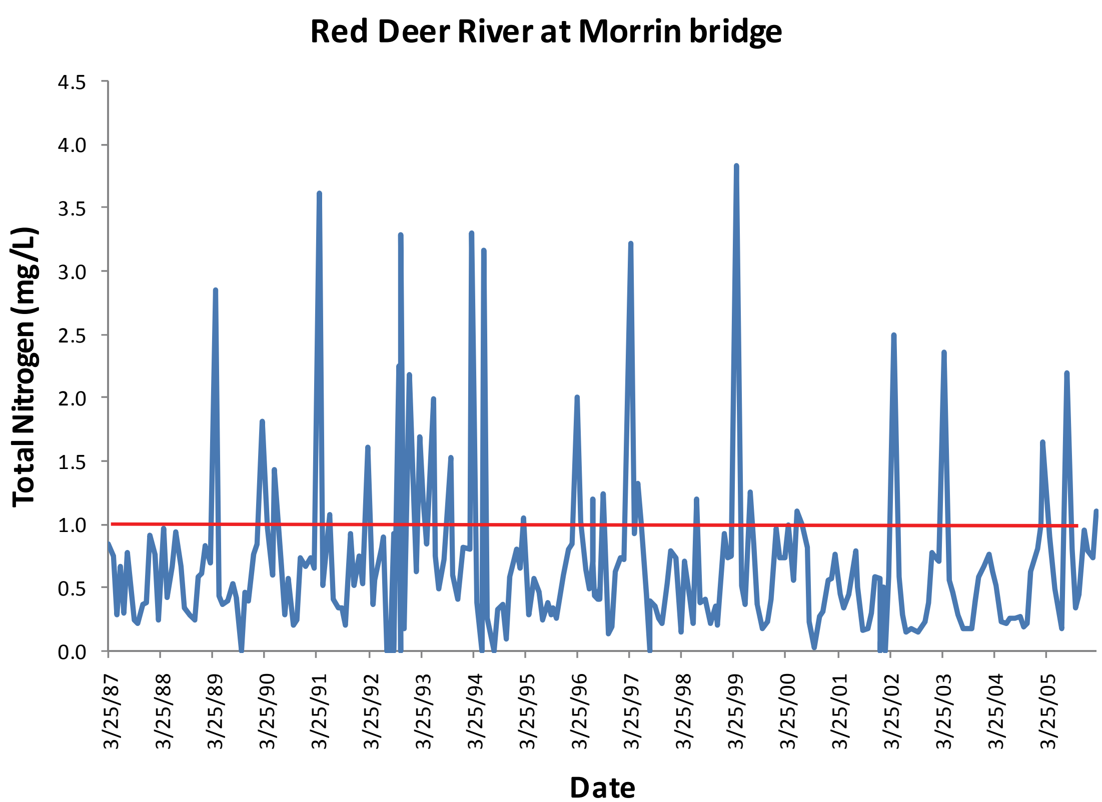


Figure 20. Total nitrogen (TN) concentrations in the Red Deer River at the Morrin bridge (data from Alberta Environment, 2008). The ASWQG PAL for TN (1.0 mg/L) is indicated by the red line.

The Red Deer River at Nevis experiences peaks in NH_3 concentrations predominantly during the winter months (Figure 21), which is concomitant with ice cover and the associated depletion of oxygen levels within the water column. Following a statistical analysis of NH_3concentrations at this point in the river using linear regression in StatFi in Excel 2007, it was found that there is no significant increasing or decreasing trend in NH_3 concentrations over time (data not shown; $p > 0.05$).

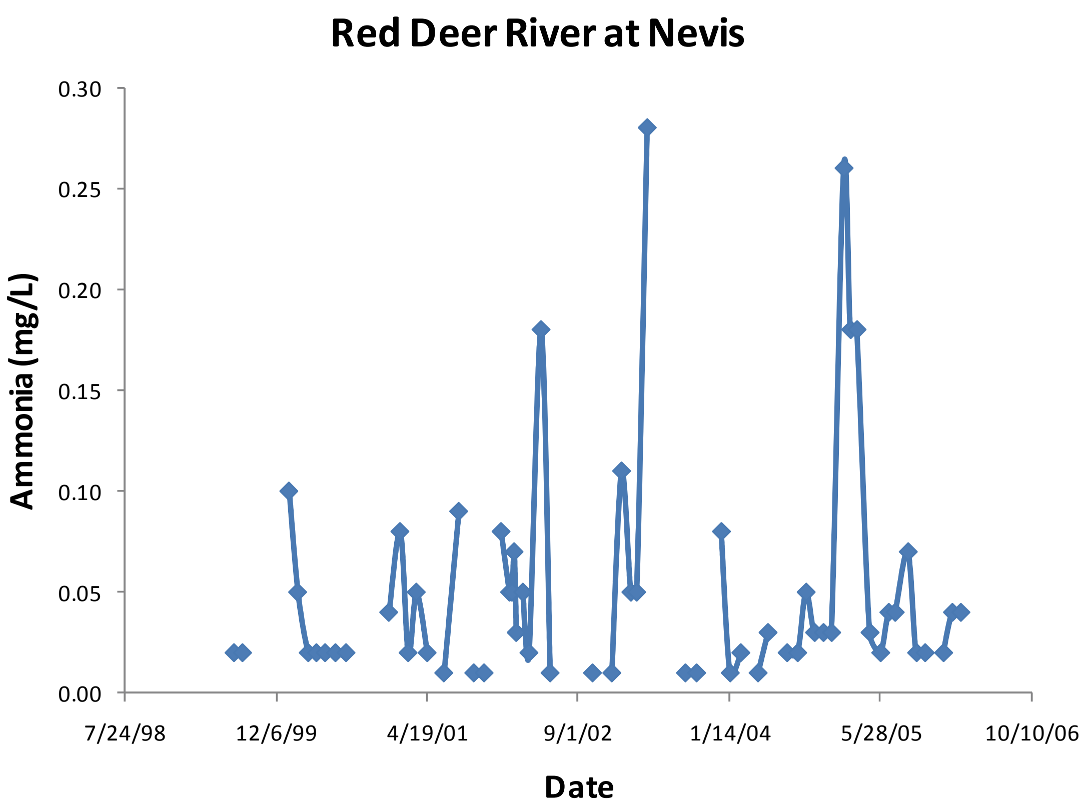


Figure 21. Ammonia concentrations in the Red Deer River at Nevis (data from Alberta Environment, 2008).

The Red Deer River at the Morrin bridge experiences peaks in NH_3 concentrations predominantly during the winter months (Figure 22), which is concomitant with ice cover and the associated depletion of oxygen levels within the water column; however, occasional peaks are seen in summer and early fall, which may prove harmful for fish populations and may indicate an external loading problem. Following a statistical analysis of NH_3 concentrations at this point in the river using linear regression in StatFi in Excel 2007, it was found that there is no significant increasing or decreasing trend in ammonia concentrations over time ($p > 0.05$).

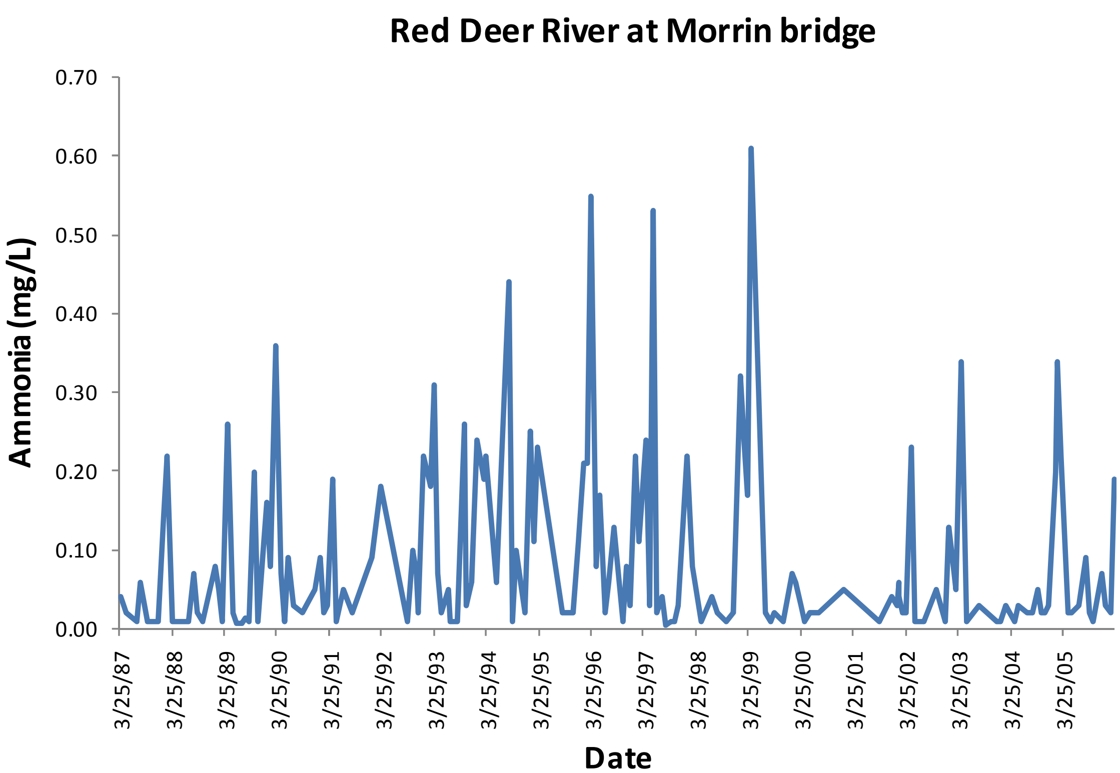


Figure 22. Ammonia concentrations in the Red Deer River at the Morrin bridge (data from Alberta Environment, 2008).

The Red Deer River at Nevis experiences peaks in NO_2^--NO_3^- concentrations predominantly during the winter and early spring months (Figure 23), concomitant with ice cover and the buildup of waste products from decomposition and fish wastes. Higher levels of NH_3 will lead to higher levels of NO_2^--NO_3^- due to the conversion of nitrogen forms by bacteria. Following a statistical analysis of the NO_2^--NO_3^- concentrations at this point in the river using linear regression in StatFi in Excel 2007, it was found that there is no significant increasing or decreasing trend in NO_2^--NO_3^- concentrations over time (data not shown; $p > 0.05$).

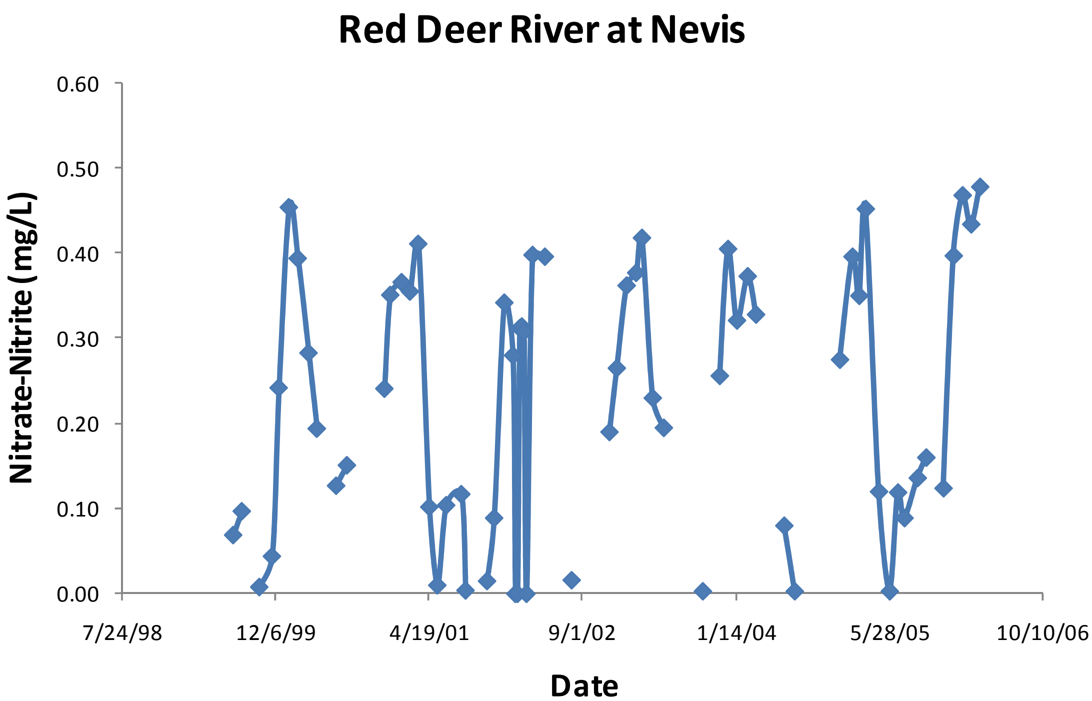


Figure 23. Nitrate-nitrite concentrations in the Red Deer River at Nevis (data from Alberta Environment, 2008).

The Red Deer River at the Morrin bridge experiences peaks in NO_2^--NO_3^- concentrations during the winter and early spring months (Figure 24) concomitant with ice cover and the buildup of waste products from decomposition and fish wastes. Higher levels of NH_3 will lead to higher levels of NO_2^--NO_3^- due to the conversion of nitrogen forms by bacteria in the nitrogen cycle. Following a statistical analysis of the NO_2^--NO_3^- concentrations at this point in the river using linear regression in StatFi in Excel 2007, it was found that there is no significant increasing or decreasing trend in NO_2^--NO_3^- concentrations over time ($p > 0.05$).

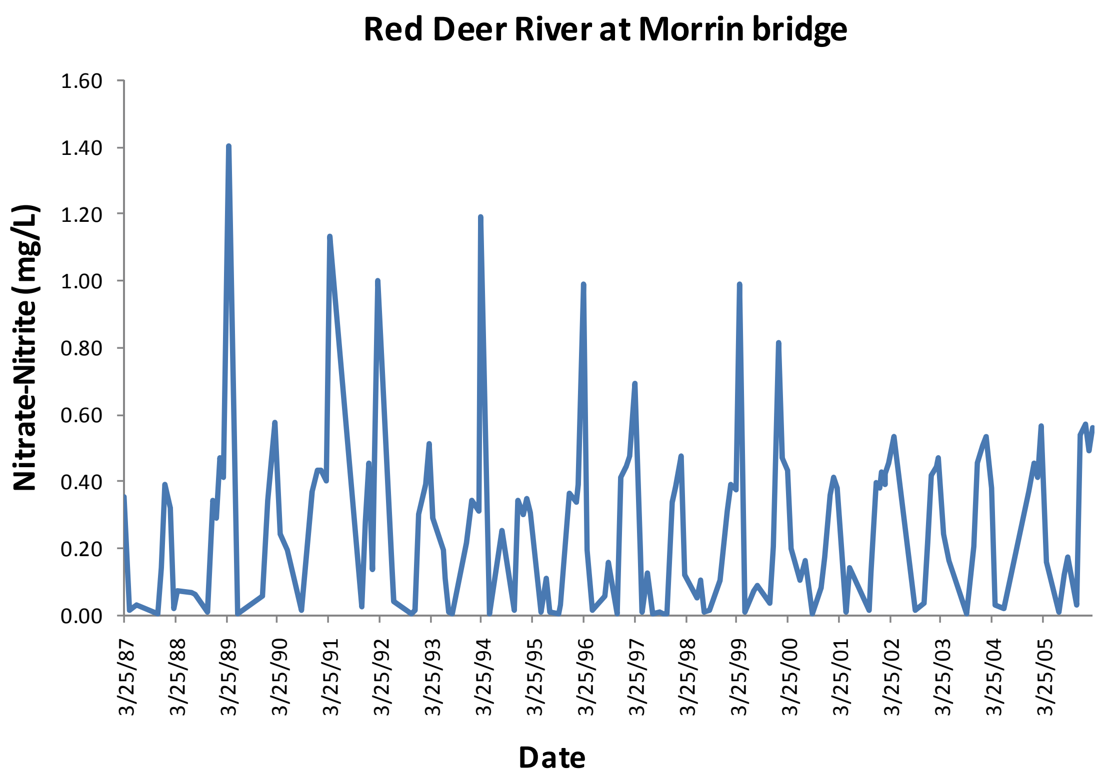


Figure 24. Nitrate-nitrite concentrations in the Red Deer River at the Morrin bridge (data from Alberta Environment, 2008).

Other parameters indicated cumulative effects of non-point and point sources. Most notable was the increase in TP and TN relative to Queen Elizabeth II Highway upstream of Red Deer (Tables 11, 13), likely reflecting agricultural and municipal nutrient inputs. TN increased somewhat more by Morrin, although there was no indication that TP increased between Nevis and Morrin. TN, TP and pH occasionally exceeded the ASWQ PAL guideline, further reflecting that water quality declined downstream of Red Deer. In Reach 3, the river remained mesotrophic on the basis of TP, oligotrophic on the basis of TN and planktonic chl. *a* but eutrophic on the basis of epilithic chl. *a*. Epilithic chl. *a*, a measure of periphyton biomass, did not increase from Reach 2 to 3 (Queen Elizabeth II Highway to Nevis). Previously, Carr and Chambers (1998) have reported that both epilithic and planktonic chl. *a* increased immediately downstream of Red Deer from 1983-1987 based on Alberta Environment monitoring data; however, that study was conducted before significant upgrades conducted in the late 1990s at the sewage treatment plant for the City of Red Deer.

Table 13. Summary statistics for selected water quality parameters and total metals/metalloids (1999-2003) in the Red Deer River at Nevis downstream of Red Deer (Alberta Environment, 2007b). n = sample size. All concentrations in mg/L unless otherwise indicated.

Parameter	Mean	Median	Minimum	Maximum	n	% ASWQG PAL compliance *
DO	10.80	10.33	7.7o	16.68	65	100
TSS	20	2	< 0.4	276	65	---
Chl. *a* **	3.0	1.2	0.3	0.3	55	---
pH	8.24	8.23	7.52	9.07	66	73
TDS	230	225	132	376	55	---
TP	0.055	0.02	< 0.003	0.561	65	80
TDP	0.0202	0.011	0.001	0.163	65	---
TN	0.55	0.48	< 0.053	2.1o	60	94
NO_3^-	0.171	0.135	< 0.003	0.453	60	100
NH_3	0.03	0.01	< 0.005	0.28	65	100
Al	0.274	0.051	0.002	1.82	18	72
As	0.0007	0.0004	< 0.0002	0.003	18	100
Cd	< 0.0002	< 0.0002	< 0002	0.0012	17	0
Cr	0.003	0.003	< 0.001	0.008	18	0
Cu	0.0025	0.0017	0.0005	0.0067	18	72
Fe	0.60	0.07	< 0.01	3.44	18	65
Pb	0.00106	0.00045	0.000117	0.00464	20	85
Mn	0.037	0.006	< 0.001	0.243	18	---
Hg **	0.023	0.025	0.0003	0.06	18	67
Mo	0.0012	0.0012	0.0006	0.0021	18	100
Ni	0.0044	0.0031	< 0.0005	0.018	18	100
Se	0.0001	0.0001	0.0001	0.0004	18	100
Ag	< 0.0001	< 0.0001	< 0.0001	0.0005	18	0
Zn	0.0135	0.0135	0.0008	0.0284	18	100

* Abbreviations as in Table 10; ** in µg/L.

Data collected from 1999-2003 indicated that a number of metals occasionally or frequently exceeded CCME PAL WQGs at Nevis and Morrin (Tables 13, 14) (Alberta Environment, 2007b). Additionally, As, Ni and Zn occasionally exceeded CCME PAL WQGs at Morrin bridge. A qualitative spatial comparison indicated that mean concentrations of Al, Fe, Mn, Cr and Ni notably increased at Morrin relative to the two upstream sites.

Table 14. Summary statistics for selected water quality parameters and total metals/metalloids (1999-2003) in the Red Deer River at Morrin upstream of Drumheller (Alberta Environment, 2007b). n = sample size. All concentrations in mg/L unless otherwise indicated.

Parameter	Mean	Median	Minimum	Maximum	n	% ASWQG PAL compliance *
DO	10.34	9.99	4.83	18.65	65	98
TSS	40	5.1	< 0.4	549	66	---
Chl. *a* **	2.6	1.0	0.2	16.5	60	---
pH	8.14	8.24	7.10	8.96	65	76
TDS	230	232	127	325	60	---
TP	0.055	0.016	< 0.003	0.687	66	80
TDP	0.014	0.006	< 0.003	0.149	66	---
TN	0.62	0.55	0.53	3.81	65	97
NO_3^-	0.201	0.137	< 0.003	0.9725	65	100
NH_3	0.05	0.01	< 0.005	0.61	66	100
Al	0.85	0.083	< 0.001	10.4	20	56
As	0.0009	0.0005	< 0.0002	0.0051	17	94
Cd	0.0004	<0.0002	< 0.0002	< 0.003	19	0
Cr	0.035	0.003	< 0.001	0.632	20	0
Cu	0.005	0.002	< 0.001	0.0314	20	61
Fe	1.44	0.17	< 0.01	10.30	17	50
Pb	0.0027	0.0006	0.000135	< 0.02	20	67
Mn	0.059	0.007	< 0.001	0.338	20	---
Hg **	0.019	0.025	< 0.0006	0.034	20	67
Mo	0.0033	0.0012	0.0003	0.0375	17	100
Ni	0.0514	0.0057	< 0.0005	0.905	20	95
Se	< 0.0002	<0.0002	< 0.0002	0.0003	17	100
Ag	0.0003	<0.0001	< 0.0001	0.001	20	0
Zn	0.0136	0.0101	< 0.001	0.0564	20	89

* Abbreviations as in Table 10; ** in µg/L.

There were limited recent (i.e., within the past 10 years) published data describing concentrations of metals in the Red Deer River from the City of Red Deer to Drumheller. Cross (1991) presented data collected in 1983-84, but the data have not been compared to current ASWQ PAL guidelines. Conversely to the results from 1999-2003, Golder (2001b) reported that no metals exceeded CCME PAL guidelines at several sites monitored downstream of Red Deer in September 2000 (near the NOVA chemical processing facility effluent outfall); however, a study conducted about 2 weeks later in relation to the Union Carbide chemical processing facility just upstream of the NOVA study area indicated that Al and Zn consistently exceeded CCME PAL guidelines at all sites (Golder, 2001a). The reason for the difference between the two studies is unknown, but it could be related to changes in Red Deer River discharge rates.

Sub-indices for nutrient, metal and pesticide concentrations in the Red Deer River in Reaches 2 (at the Queen Elizabeth II Highway) and 3 (at the Nevis and Morrin bridges) are highly variable over time (Figure 25) (Alberta Environment, 2007b). Overall, it appears that water quality in the Red Deer River has improved since 1996; however, the substantial interannual variability resulting from a variety of factors (including variable river discharge rates, climatic conditions, discharge quantities of wastewaters from municipalities and agricultural run-off) may obscure true trends in water quality.

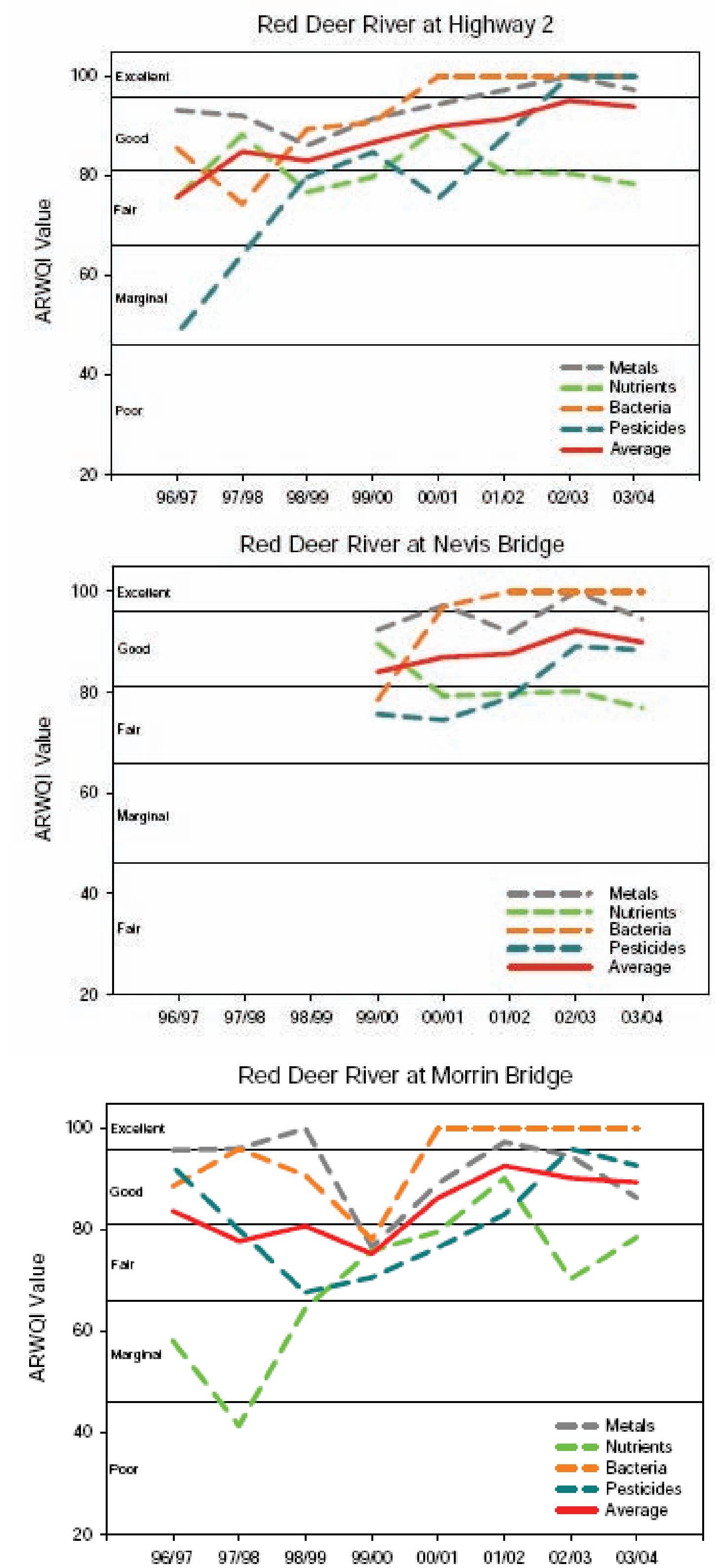


Figure 25. Annual Alberta River Water Quality Index (ARWQI) Values and sub-index values from 1996-2004 for three Red Deer River LTRN sites (Alberta Environment, 2007b).

3.1.2.4 Reach 4: Drumheller to the Provincial Border

Concentrations of TN and TP were higher at Bindloss than at upstream reaches (Table 15), causing a shift from mesotrophic to eutrophic on the basis of TP and from oligotrophic to mesotrophic on the basis of TN; however, there were no data available describing plant or algal production, and it is not known how these increases in nutrients affected overall productivity. Lower rates of compliance for TN (83%) and TP (53%) were also observed at this site relative to upstream (Table 15) (Alberta Environment, 2007b). This appeared to reflect elevations in particulates (TSS) at Bindloss, and the dissolved fractions of P and N were actually lower than those observed at Morrin.

Table 15. Summary statistics for selected water quality parameters and total metals/metalloids (1999-2003) in the Red Deer River at Bindloss near the Alberta-Saskatchewan border (Alberta Environment, 2007b). n = sample size. All concentrations in mg/L unless otherwise indicated.

Parameter	Mean	Median	Minimum	Maximum	n	% ASWQG PAL compliance *
DO	9.33	9.00	3.22	13.60	57	88
TSS	262.7	43.0	2.2	3,892	60	---
Chl. *a* **	---	---	---	---	---	---
pH	8.29	8.35	7.35	8.7	59	71
TDS	305	307	228	407	22	---
TP	0.146	0.046	0.006	1.85	60	53
TDP	0.008	0.006	< 0.002	0.046	59	---
TN	0.835	0.575	0.182	6.46	60	83
NO_3^-	0.166	0.04	< 0.01	0.689	60	100
NH_3	0.034	0.015	0.005	0.518	60	100
Al	3.33	0.48	0.038	40.5	57	14
As	0.0005	0.0003	0.0001	0.0015	41	100
Cd	0.0005	0.0001	< 0.0001	0.0065	57	0
Cr	0.004	0.001	< 0.0002	0.038	57	25
Cu	0.0067	0.0021	0.0006	0.0812	57	67
Fe	4.36	0.67	0.0589	56.1	55	31
Pb	0.0035	0.0004	< 0.0002	0.0486	57	68
Mn	0.104	0.0281	0.0041	0.924	55	---
Hg **	0.0033	0.0025	0.0025	0.005	3	100
Mo	0.0012	0.0012	0.0003	0.0023	55	100
Ni	0.0057	0.0019	< 0.0002	0.0638	57	100
S	0.0002	0.0002	0.00005	0.0005	41	100
Ag	0.0001	<0.0001	< 0.0001	0.001	55	0
Zn	0.0178	0.0029	0.0008	0.267	57	88

* Abbreviations as in Table 10; ** in µg/L.

Dissolved oxygen (DO) levels were relatively high at Bindloss but occasional low winter levels occurred from 1999-2003, with 12% of the measurements below the chronic ASWQG PAL (6.5 mg/L) and 5% below the acute ASWQG PAL (5.0 mg/L) (Table 15) (Alberta Environment, 2007b). Based on historical data (1978-1995), Saffran and Anderson (1997) reported similar compliance levels: 6% of samples collected from 1978-1995 did not comply with the acute ASWQG PAL (5.0 mg/L) at Bindloss, and the low levels occurred during winter; however, all non-compliant samples were collected prior to 1990. A similar situation was observed at the Morrin bridge over the same period. Cross (1991) reported that diurnal fluctuations in DO downstream of Drumheller in 1983-1984 were strong; however, values consistently remained above 5.0 mg/L in February, April, June, August and September. Oxygen demand also increased with increasing distance downstream in the Red Deer River in 1983-84, with peak biological oxygen demand (BOD, the amount of oxygen required by organisms to sustain life) and chemical oxygen demand (COD, an indirect measure of the amount of organic compounds in water) occurring in Reach 4 (Cross, 1991). Increased winter flow due to the construction of the Dickson Dam has improved DO levels in the Red Deer River, although some low levels were still detected even after the increased flow (Shaw and Anderson, 1994). Increased flow can augment the DO levels only to a degree, and if the point source loading continues to increase in the Red Deer River, low DO concentrations may become more frequent (Clipperton et al., 2003).

Several parameters appeared to change notably in Reach 4 relative to upstream of Drumheller. For example, Cross (1991) reported that total suspended solids (TSS), turbidity and TDS increased in this reach in 1983-84 compared to the lower reaches. This spatial trend was also reflected in tributary streams, with higher TDS and TSS observed in streams located in the lower portion of the sub-basin. Similarly, comparison of means for the period of 1999-2003 indicated that TSS, TP, TDS and TN were higher at Bindloss than in the upper reaches. Reach 4 of the Red Deer River flows through highly erodible grassland region, which may contribute to the TSS loading.

Several metals (Fe, Mn and Al) were also substantially higher at Bindloss relative to the three upstream stations, and Al and Fe frequently exceed the CCME PAL WQGs at this site (PPWB, 2005; Alberta Environment, 2007b). Previous provincial and federal studies have concluded that elevated Mn concentrations are largely natural in origin, e.g., originating from groundwater sources (PPWB, 2005; Alberta Environment, 2007b). Other metals that occasionally did not meet CCME PAL guidelines included Cd, Cr, Cu, Pb, Ag and Zn (Table 15). These exceedances generally occurred in April, June, and August and are associated with 2-3 fold increases in suspended sediment concentrations, likely as a result of high discharge events (PPWB, 2005).

Compared to other major rivers crossing western continental provincial borders, the Red Deer River water quality was among the lowest in 2005, having the 4th-lowest adherence rate (89.9%) (Figure 26) (PPWB, 2005); however, adherence rates of major rivers to PPWB water quality standards vary considerably from year to year. For example, the Red Deer River had an adherence rate of 97.7% in 2004. The PPWB indicated that variations to adherence rates were primarily due to exceedances of total metal concentrations, e.g., Mn and Cu, between 2004 and 2005.

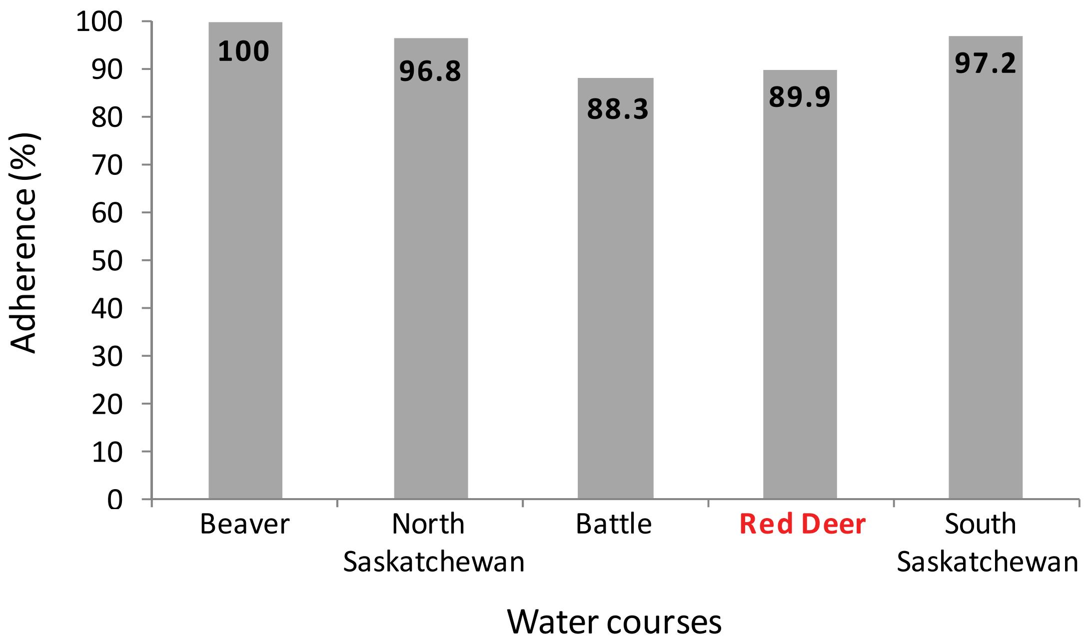


Figure 26. Adherence to water quality standards of the Prairie Province Water Board (PPWB) objectives in various water courses in Alberta and Saskatchewan (adopted from PPWB, 2005).

3.1.2.5 Spatial Trends

A number of parameters exhibited spatial trends, based on the results of intensive historical and longitudinal studies (e.g., Cross, 1991; Alberta Environment, 2007b) and the analyses of recent data (1999-2003) (Table 16). TSS and turbidity decreased below the Dickson Dam, likely a reflection of settling in Gleniffer Lake Reservoir, and increased with increasing distance downstream (Cross, 1991). Mean TSS was highest at Bindloss from 1999-2003. TDS and conductivity also increased downstream, most notably downstream of Drumheller (Cross, 1991). Median DO levels were similar throughout the length of the river from 1999-2003 (Table 16), although Bindloss had lower ASWQG PAL compliance than the upstream sites.

Concentrations of several metals (Fe, Mn and Al) were also substantially higher at Bindloss relative to the three upstream stations (Table 16) (Alberta Environment, 2007b). Increases in metals and other parameters at the Bindloss site are believed to reflect the combined effects of local geology and sediment resuspension in the reach between Drumheller and the Saskatchewan border (Anderson, 1996). Metals were correlated to stream flow and TSS, and much of the trace element presence in the lower reach of the Red Deer River originated from passage through the Bearpaw formation and the highly erodible 'badlands'. Evaluation of data from 1999-2003 indicated that the frequency of compliance of total metal concentrations with CCME PAL guidelines decreased with increasing distance downstream in the Red Deer River; however, there were no recent data for metals in the headwaters reach. Detection frequencies were greatest at Bindloss relative to the upstream sites. Cross (1991) theorized that exceedances of some of the metal guidelines in the Red Deer River may result from natural conditions (i.e., a reflection of the local geology), most notably Fe and Mn, which might originate from weathering of rocks and soils.

Table 16. Comparison of means of selected water quality parameters and total metals/metalloids (1999-2003) in the Red Deer River at five sampling sites along the Red Deer River (Alberta Environment, 2007b). All concentrations in mg/L unless otherwise indicated.

Parameter	Sundre	Queen Elizabeth II Highway	Nevis Bridge	Morrin Bridge	Bindloss
DO	9.71	10.90	10.80	10.34	9.33
TSS	37.0	17.3	20.0	40.0	262.7
Chl. *a* **	---	2.5	3.0	2.6	---
pH	8.17	8.03	8.24	8.14	8.29
TDS	216	216	230	230	305
TP	0.018	0.037	0.055	0.055	0.146
TDP	0.007	0.016	0.0202	0.014	0.008
TN	0.196	0.39	0.55	0.62	0.835
NO_3^-	0.105	0.071	0.171	0.201	0.182
NH_3	0.01	0.02	0.03	0.05	0.034
Al	---	0.240	0.274	0.850	3.460
As	---	0.0006	0.0007	0.0009	0.0004
Cd	---	0.0005	< 0.0002	0.0004	0.0005
Cr	---	0.0031	0.003	0.035	0.004
Cu	---	0.0042	0.0025	0.005	0.0067
Fe	---	0.55	0.60	1.44	4.59
Pb	---	0.003	0.00106	0.0027	0.00375
Mn	---	0.027	0.037	0.059	0.1079
Hg **	---	0.021	0.023	0.019	0.0033
Mo	---	0.0012	0.0012	0.0033	0.0012
Ni	---	0.0043	0.0044	0.0514	0.0059
Se	---	0.0001	0.0001	< 0.0002	0.0002
Ag	---	0.000238	< 0.0001	0.0003	0.0001
Zn	---	0.0159	0.0135	0.0136	0.014

* Abbreviations as in Table 10; ** in µg/L.

The overall water quality index reflects the generally deteriorating water quality along the Red Deer River towards the Saskatchewan border. Nutrient, metal, pesticide and bacterial concentrations increase considerably from the Alberta Environmental water quality sampling station at Queen Elizabeth II Highway to Nevis bridge and then Morrin bridge (Table 17). Of particular concern are marginal ratings for bacterial concentrations, which indicate the frequent and often considerable exceedances from ASWQ guidelines. Similarly, nutrient and metal concentrations substantially increase in the Red Deer River from Queen Elizabeth II Highway to the Morrin bridge and cause a deterioration in water quality (from "excellent" or "good" to "fair", indicating an infrequent and moderate exceedance of ASWQ PAL guidelines). Alberta Environment's ratings are as follows: "excellent" – 96-100 points, "good" – 81-95 points, "fair" – 66-80 points, "marginal" – 46-65 points and "poor" – 0-45 points (Alberta Environment, 2008a). Overall, Alberta Environment (2007b) provided a rating of "good" for the first three reaches of the Red Deer River, deteriorating slightly to a rank of "fair" in the most downstream reach of the river (Table 18).

Table 17. Assessment of different water quality components at three locations in the Red Deer River (Alberta Environment, 2008a).

Southern Rivers: 2006-2007				
River Location	Sub-Index Values (0-100)			
	Metals	Nutrients	Bacteria	Pesticides
Red Deer R. upstream of Red Deer (Hwy 2)	100	100	48	93
Red Deer R. at Nevis Bridge	100	80	58	90
Red Deer R. at Morrin Bridge	92	71	50	79

Table 18. Assessment of aquatic ecosystem health in the Red Deer River (Alberta Environment, 2007b).

Reach	Water Quality	Sediment Quality	Non-fish Biota	
Reach 1: Headwaters to Glennifer Lake	G	ID	ID	
Reach 2: Glennifer Lake to the City of Red Deer	G	ID	BI ID	PP F
Reach 3: City of Red Deer to Drumheller	G	ID	BI ID	PP F
Reach 4: Drumheller to Provincial border	F	ID	BI ID	PP F

Legend: Excellent, Good, Fair, Marginal, Poor, Insufficient data

BI = Benthic Invertebrates. PP = Primary Producers.

3.1.2.6 Temporal Trends

There was limited qualitative information regarding potential temporal trends in water quality conditions of the Red Deer River (Table 19) (Alberta Environment, 2007b). On a purely qualitative level, it appears that a number of variables had improved over time in the reach above Red Deer and the reach from Red Deer to Drumheller, most notably TP, TN, TSS and TDS (Table 19). Conversely, only TN and ammonia (NH_3) appeared to have declined notably at Bindloss. Cross (1991) also reported that metals had generally declined in each of the reaches between the 1973-1982 and 1983-1984 time frames.

The index of overall water quality has varied considerably from 1996-2007 (Figure 27). Upgrades in the municipal wastewater treatment facility in the City of Red Deer in 1999/2000 have generally resulted in an improvement in the overall water quality at the Queen Elizabeth II and Morrin bridge water quality sampling stations; however, indices at both stations have declined since 2003 (Alberta Environment, 2008b), likely in response to increased pesticide detections and recent exceedances for bacteria, metals and nitrogen and phosphorus in the Red Deer River. Their sources are currently being investigated by Alberta Environment.

Table 19. Comparison of selected water quality parameters in 1973-1984 and 1999-2003 for the Red Deer River reaches (Alberta Environment, 2007b). All concentrations in mg/L unless otherwise indicated.

	Reach above Red Deer			**Red Deer to Drumheller reach**				**Drumheller to border**		
Parameters	**1973-1982**	**1983/1984**	**1999-2003** [1]	**1973-1982**	**1983/1984**	**1999-2003** [2]	**1999-2003** [3]	**1973-1982**	**1983/1984**	**1999-2003** [4]
DO *	9.9	10.9	11.1	8.4	9.7	10.3	10.0	9.0	9.4	9.0
TSS	9	10	2	10	10	2	5	49	26	53
Chl. *a* **	0.005	0.8	1.2	---	1.7	1.2	1	0.0055	2.6	---
pH	8.1	8.4	8.06	8.1	8.5	8.22	8.24	8.2	8.4	8.35
TDS	243	192	219	302	200	225	232	290	219	307
TP	0.058	0.018	0.008	0.246	0.036	0.020	0.016	0.061	0.054	0.0464
TDP	0.004	0.008	0.004	0.016	0.020	0.011	0.006	0.008	0.016	0.006
TN	0.490	214	0.240	0.610	0.320	0.480	0.550	0.720	0.445	0.575
NO_3^-	< 0.1	0.024	0.04	< 0.1	0.003	0.1355	0.137	0.02	0.005	0.04
NH_3	< 0.2	0.01	< 0.01	0.3	0.012	0.01	0.01	0.2	0.012	0.015

* Abbreviations as in Table 10; 1 = median values for 1999-2003 at Queen Elizabeth II Highway, 2 = median values for 1999-2003 at Nevis, 3 = median values for 1999-2003 at Morrin, 4 = median values for 1999-2003 at Bindloss; ** in µg/L.

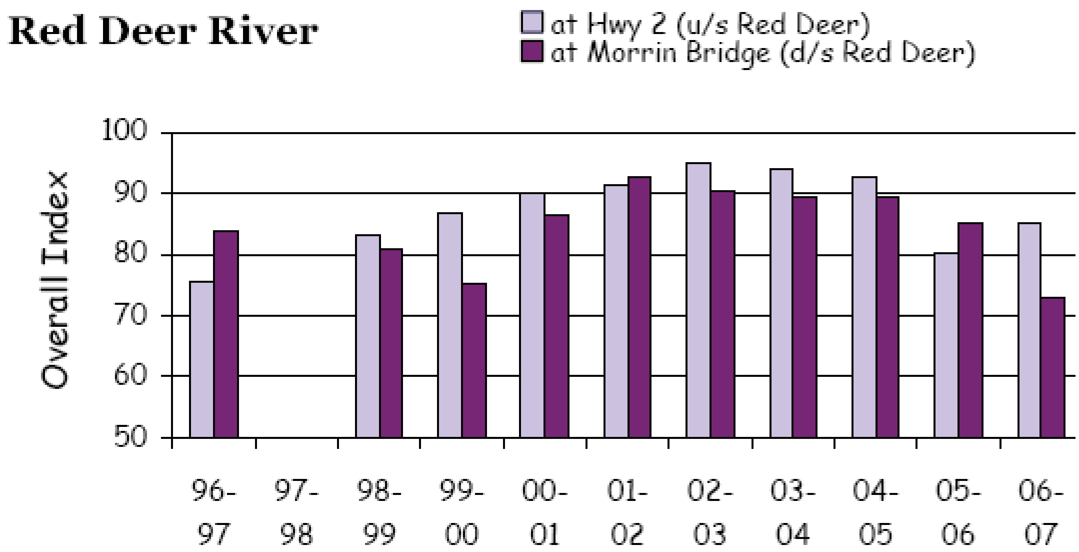


Figure 27. Overall water quality index comparison at the Alberta Environment water quality monitoring stations at Queen Elizabeth II Highway (Reach 2) and Morrin bridge (Reach 3) from 1996-2007 (Alberta Environment, 2008b).

3.1.2.7 Pesticides and Pharmaceuticals in the Red Deer River Watershed

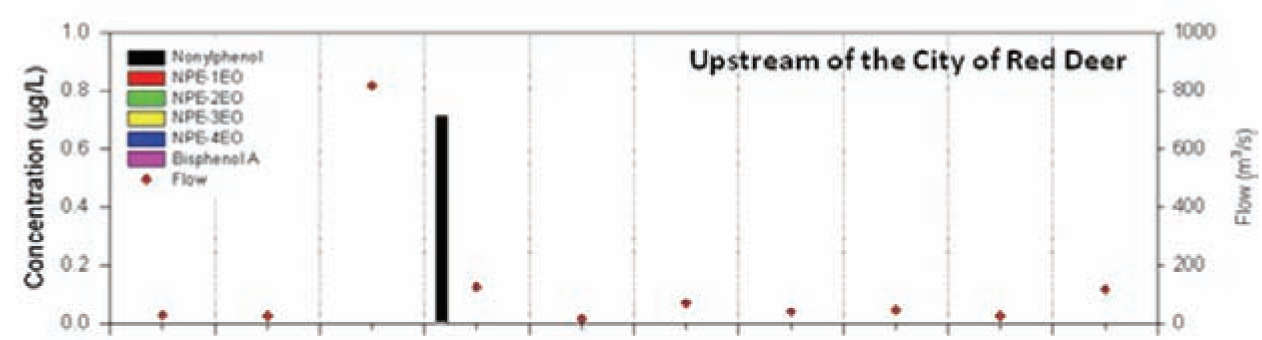
Pesticides were monitored at 49 sites from 1995-2002 in the Red Deer River watershed (Anderson, 2005). Only three pesticides (2,4-D, MCPA and lindane) exceeded CCME PAL WQGs in the entire Red Deer River watershed, including data from all sampled waterbodies; however, few of the tested pesticides have established water quality guidelines. Two LTRN sites along the Red Deer River were included in the analysis: Queen Elizabeth II Highway (Reach 2) and Morrin (Reach 3). The only variable that increased downstream of the City of Red Deer was the number of pesticides per sample. The increase is indicative of urban influence and possibly also non-urban pesticide use, since Morrin is located 150 km downstream of the city. Compared to other urban areas in Alberta, the upstream vs. downstream difference was small (Anderson, 2005). This could be due to the smaller size of Red Deer compared to larger urban centres, such as Edmonton and Calgary, or the more intensive use of pesticides in the upstream reaches.

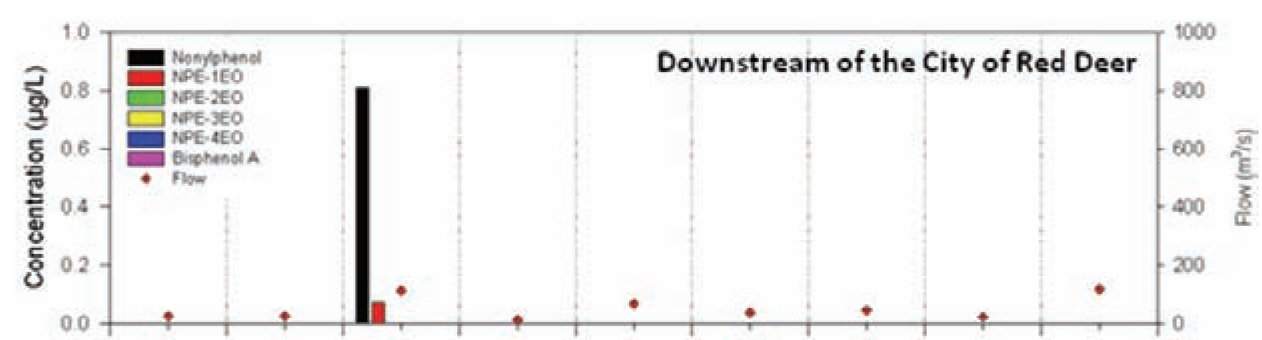
There were significant interannual differences in median total pesticide concentrations and the number of pesticide detections at Morrin over the period evaluated, with widest concentration ranges in 1998 and 1999. These differences may reflect changes in climatic conditions (Anderson, 2005). About 1% of the samples exceeded ASWQG PAL for lindane, and less than 1% of the samples exceeded ASWQG PAL for 2,4-D and MCPA. Detection frequency for pesticides in the Red Deer River sub-basin was about 72%, which was greater than the Hay, Slave, Athabasca, Beaver, Peace, North Saskatchewan, Milk and Bow River basins, but slightly less than the Oldman, Sounding, Battle and South Saskatchewan River basins. In addition to Anderson (2005), information on pesticide concentrations in the Red Deer River upstream of Haynes Creek had previously been summarized by Anderson et al. (1998). They reported that of the 18 pesticides analyzed in surface water from the Red Deer River upstream of Haynes Creek in 1995-1996, only three were detected (fenoxaprop-p-ethyl, 2,4-D and imazamethabenzmethyl, with only 2,4-D having an ASWQ PAL guideline). Overall, pesticides were detected very infrequently.

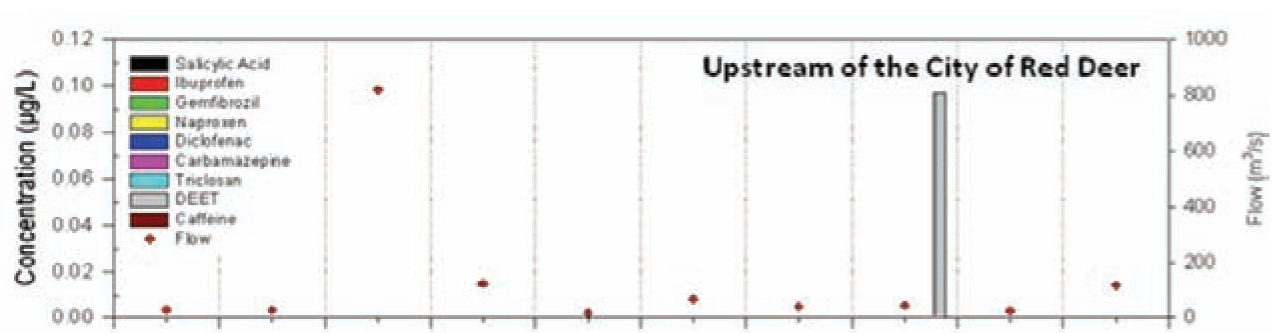
In response to increasing concentrations of herbicides-pesticides in Alberta waterbodies, herbicide-fertilizer combination products will no longer be sold in Alberta as of January 01, 2010, supporting Alberta's *Water for Life* Strategy. Herbicide-pesticide and herbicide-fertilizer combination products are highly mobile and commonly appear in water downstream of urban municipalities. The decision by the Alberta government to ban these combination products will not impact the agriculture sector or the landscaping industry, since these products are almost exclusively used on homeowners' lawns.

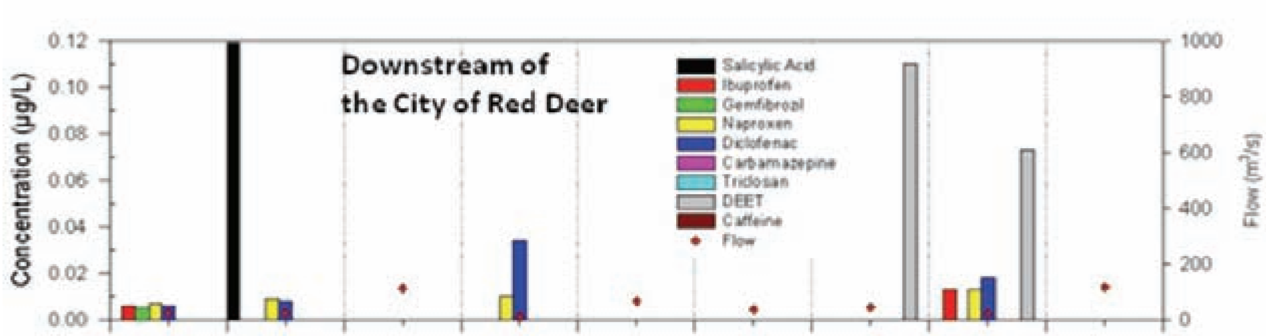
Pharmaceuticals are Organic Wastewater Contaminants (OWC) that have garnered increasing interest in surface water quality literature over the past two decades. Analytical methods and equipment are constantly being refined to detect these chemicals in water samples, and water quality guidelines are being developed in response to a better understanding of their activities and impacts in aquatic ecosystems. Current monitoring programs, e.g., Alberta Environment, examine a suite of pharmaceuticals, including non-steroidal anti-inflammatory drugs (NSAIDs), analgesics, antibiotics, antidepressants, antimaniacs and antilipemics (antihyperlipidemic/cholesterol-lowering).

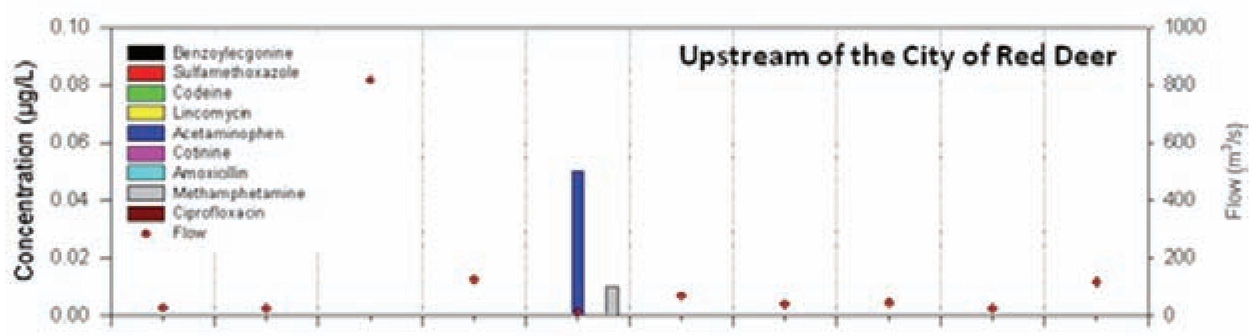
Pharmaceuticals were sampled quarterly upstream and downstream of the City of Red Deer from fall 2004 to spring 2007 (Alberta Environment, unpublished data). Sixteen pharmaceuticals, including musks (galaxolide), analgesics (codeine, acetaminophen), antibiotics (enrofloxacin, ofloxacin, lincomycin), an antilipemic (gemfibrozil), an insect repellant (DEET), and NSAIDs (naproxen, ibuprofen, diclofenac and salicylic acid), were detected at various times over this time period (Figure 28). All pharmaceuticals occurred in "trace concentrations", i.e., < 0.10 µg/L, and generally at greater concentrations and abundances immediately downstream from the City of Red Deer (Figure 28). Previous research has shown that some of these contaminants can accumulate in sediments and bioaccumulate in aquatic organisms, e.g., fish (Alberta Environment, unpublished data).

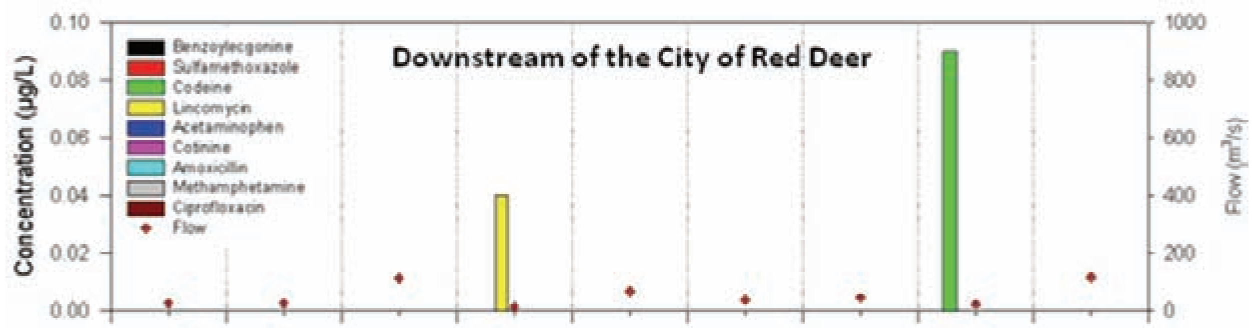

Upstream of the City of Red Deer
Concentration (µg/L)
Flow (m3/s)
Nonylphenol
NPE-1EO
NPE-2EO
NPE-3EO
NPE-4EO
Bisphenol A
Flow
0.0
0.2
0.4
0.6
0.8
1.0
0
200
400
600
800
1000

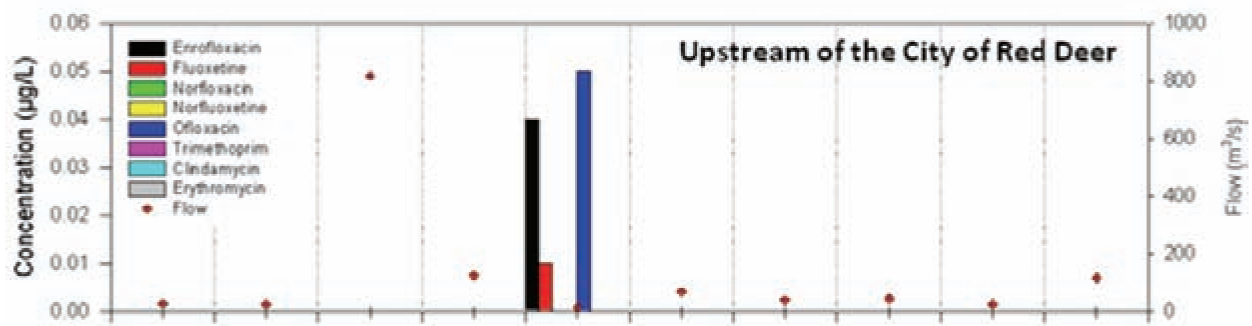

Downstream of the City of Red Deer
Concentration (µg/L)
Flow (m3/s)
Nonylphenol
NPE-1EO
NPE-2EO
NPE-3EO
NPE-4EO
Bisphenol A
Flow
0.0
0.2
0.4
0.6
0.8
1.0
0
200
400
600
800
1000

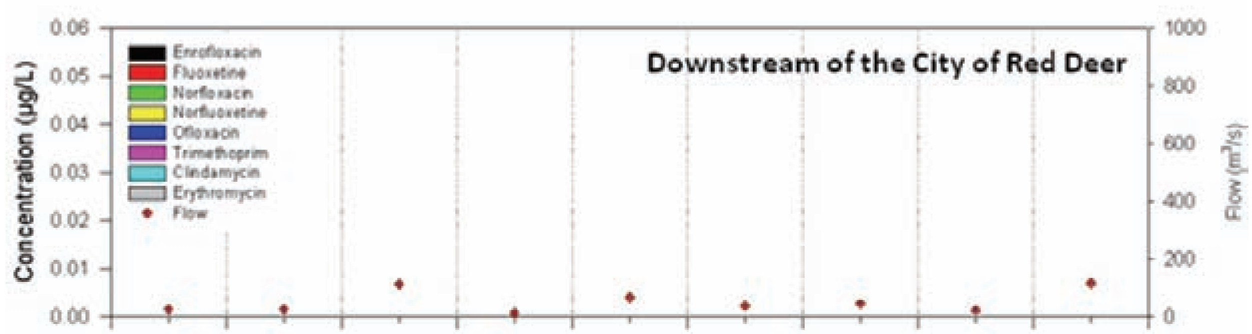

Upstream of the City of Red Deer
Concentration (µg/L)
Flow (m3/s)
Salicylic Acid
Ibuprofen
Gemfibrozil
Naproxen
Diclofenac
Carbamazepine
Triclosan
DEET
Caffeine
Flow
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0
200
400
600
800
1000

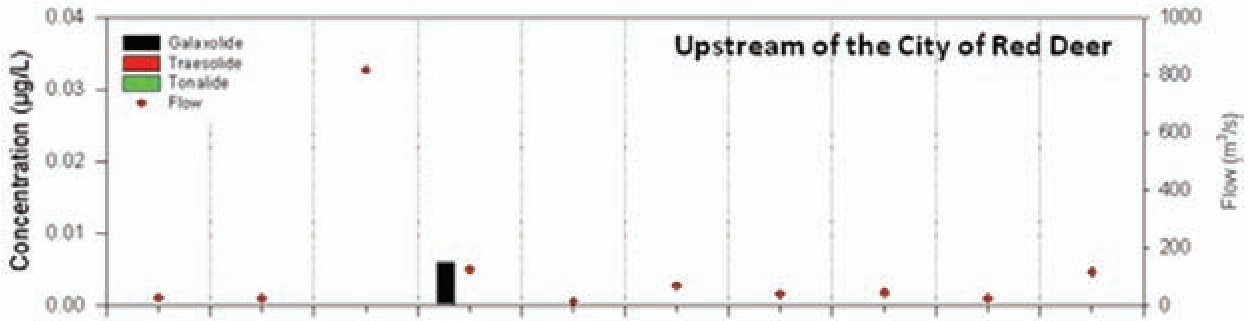

Downstream of
the City of Red Deer
Concentration (µg/L)
Flow (m3/s)
Salicylic Acid
Ibuprofen
Gemfibrozil
Naproxen
Diclofenac
Carbamazepine
Triclosan
DEET
Caffeine
Flow
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0
200
400
600
800
1000


Upstream of the City of Red Deer
Concentration (µg/L)
Flow (m3/s)
Benzoylecgonine
Sulfamethoxazole
Codeine
Lincomycin
Acetaminophen
Cotinine
Amoxicillin
Methamphetamine
Ciprofloxacin
Flow
0.10
0.08
0.06
0.04
0.02
0.00
1000
800
600
400
200
0


Downstream of the City of Red Deer
Concentration (µg/L)
Flow (m3/s)
Benzoylecgonine
Sulfamethoxazole
Codeine
Lincomycin
Acetaminophen
Cotinine
Amoxicillin
Methamphetamine
Ciprofloxacin
Flow
0.10
0.08
0.06
0.04
0.02
0.00
1000
800
600
400
200
0


Upstream of the City of Red Deer
Concentration (µg/L)
Flow (m3/s)
Enrofloxacin
Fluoxetine
Norfloxacin
Norfluoxetine
Ofloxacin
Trimethoprim
Clindamycin
Erythromycin
Flow
0.06
0.05
0.04
0.03
0.02
0.01
0.00
1000
800
600
400
200
0


Downstream of the City of Red Deer
Concentration (µg/L)
Flow (m3/s)
Enrofloxacin
Fluoxetine
Norfloxacin
Norfluoxetine
Ofloxacin
Trimethoprim
Clindamycin
Erythromycin
Flow
0.06
0.05
0.04
0.03
0.02
0.01
0.00
1000
800
600
400
200
0



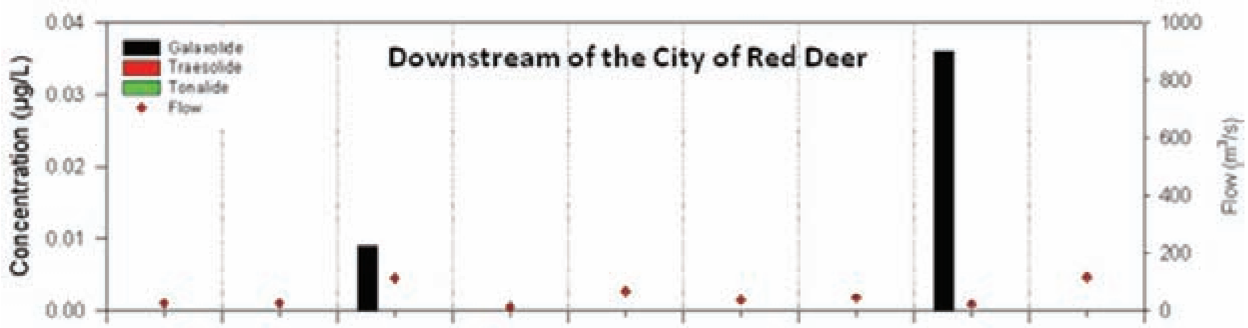


Figure 28. Pharmaceutical compounds in the Red Deer River from fall 2004 to spring 2007 upstream and downstream of the City of Red Deer (Alberta Environment, unpublished data).

3.1.3 Biologicals

3.1.3.1 Land cover

Land cover is the type of vegetation, or lack thereof, covering the landscape. Inventory of vegetation populations may show increases or declines through introductions or changes in environmental conditions. Indicator species that are sensitive to environmental pollution may show areas of concern with their absence, while others may show areas of concern with their presence. Changes in land cover can indicate a change in land use and identify areas that need restoration, are at risk of erosion and/or areas with rare plant species that need protection. Land cover is a separate measurement from land use even though these two terms are sometimes used interchangeably.

The majority of the land base of the Red Deer River watershed is covered by annual croplands, grasslands and perennial croplands/pastures (35%, 23% and 20%, respectively). Coniferous forests cover about 7% of the land base, while the remaining land cover types cover < 2.5% individually and are uncommon at the watershed scale (Figure 29, Table 20) (AAFC-PFRA, 2008).

There are several trends apparent in the land cover types within the 15 subwatersheds based on geographic position (Figure 30). The treed and forested landbase decreases along a west-east gradient, with cover values ranging from 40-70% in the western subwatersheds to cover values of 10-15% in the eastern subwatersheds. Conversely, the grassland and forage (perennial pastures) landbase generally increases from the western (about 20-40% land cover) to the eastern subwatersheds (about 55-75% land cover). Disturbed lands (annual croplands and developed lands) are most prominent in the central subwatersheds, i.e., in the Waskasoo Creek, Threehills Creek, Kneehills Creek and Rosebud River subwatersheds (Figure 30).

Table 20. Land cover in the Red Deer River watershed (AAFC-PFRA, 2008). The most prominent land cover types are highlighted.

Land cover type	**Area (ha)**	**Proportion of watershed area (%)**
Waterbodies	96,146	1.76
Exposed land	110,737	2.02
Developed land	40,854	0.75
Shrubland	104,033	1.90
Wetland	131,672	2.41
Grassland	1,250,984	22.86
Annual cropland	1,913,081	34.96
Perennial cropland/pastures	1,074,815	19.64
Coniferous forests	399,012	7.29
Deciduous forests	117,605	2.15
Mixed forests	12,808	0.23
No data	220,947	4.04
Total	**5,742,596**	

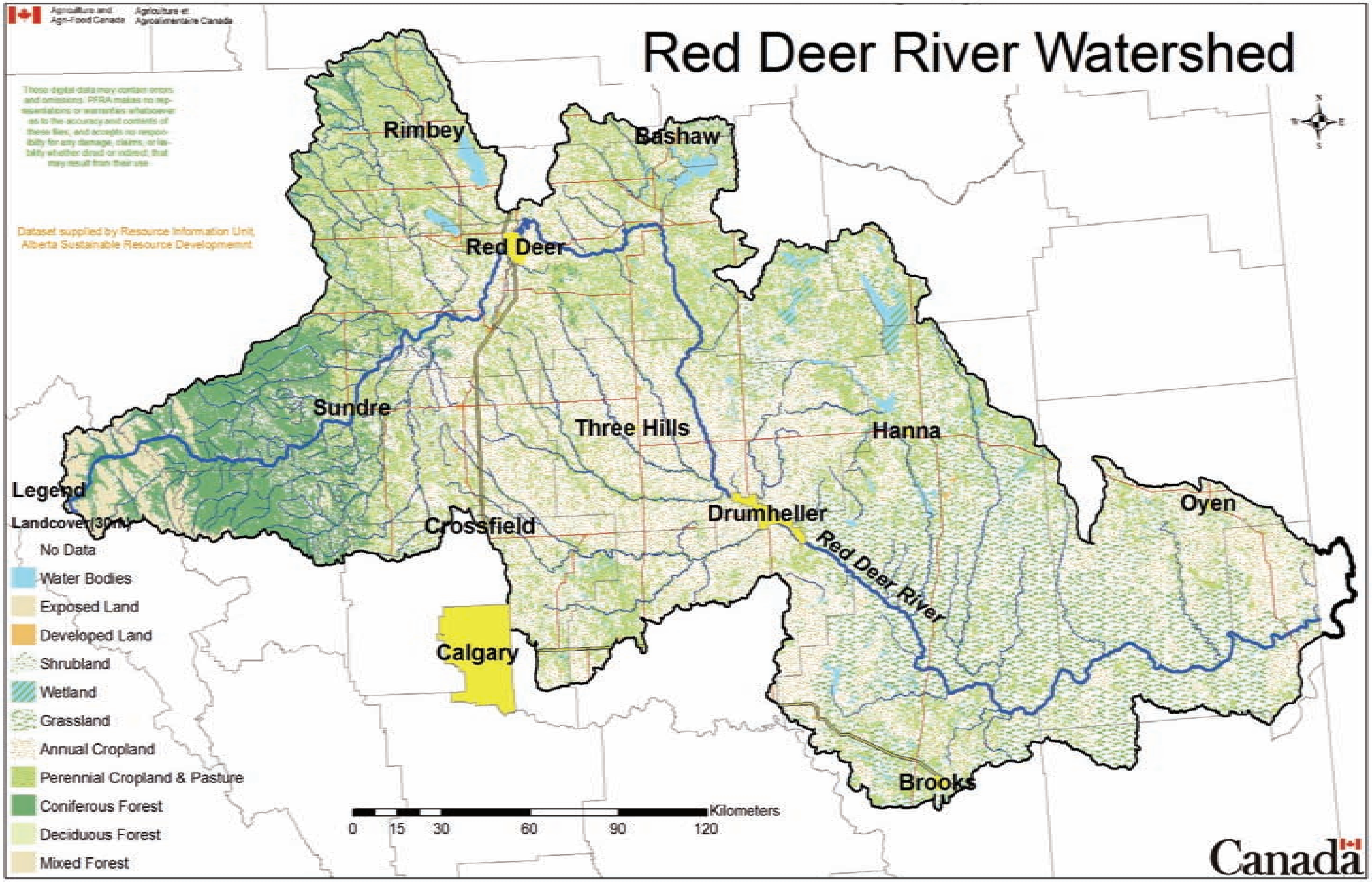


Figure 29. Land cover of the Red Deer River watershed (AAFC-PFRA, 2008).

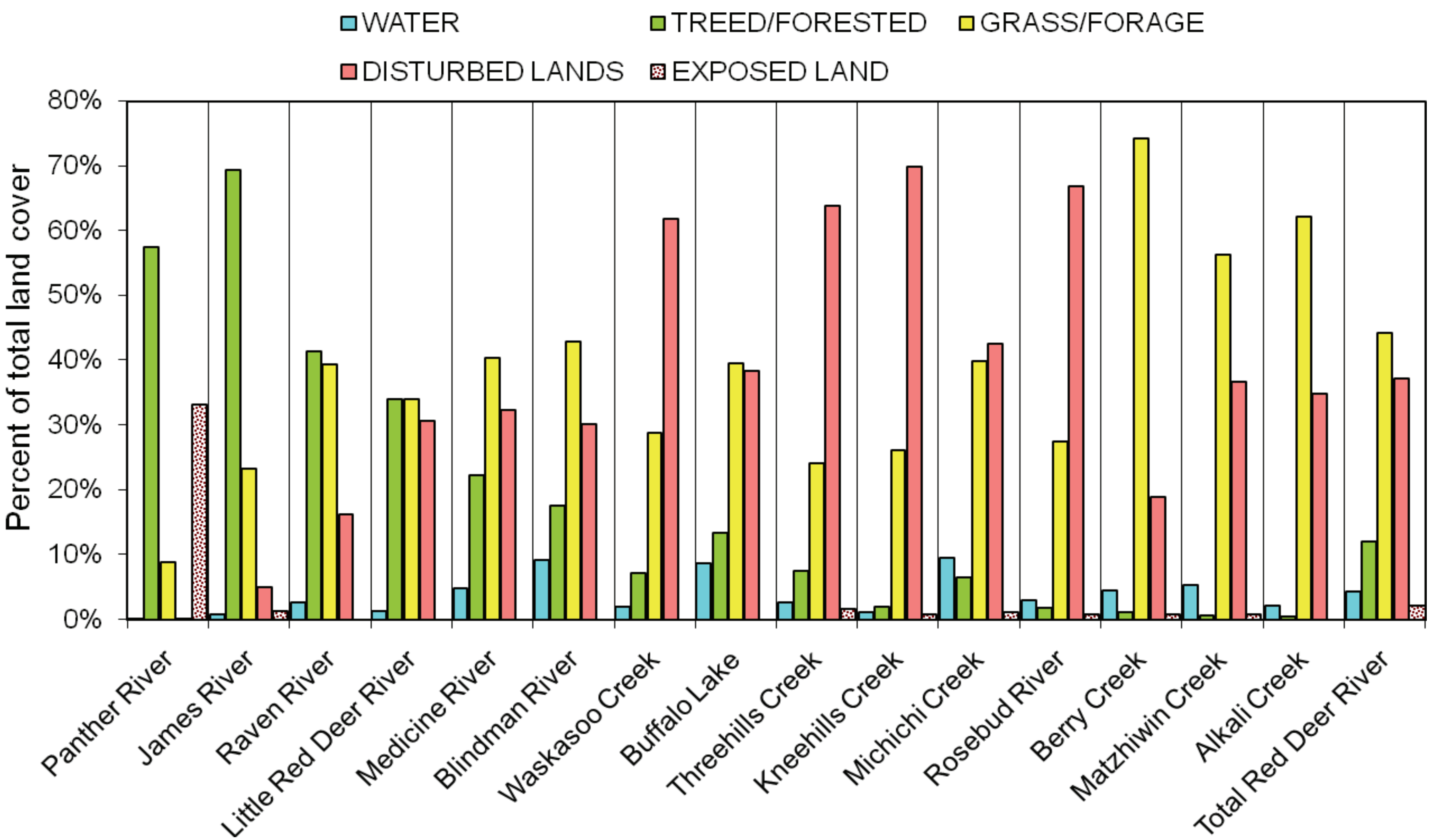


Figure 30. Land cover changes in the 15 subwatersheds of the Red Deer River watershed (based on data from AAFC-PFRA, 2008).

3.1.3.2 Riparian Health

Riparian areas are an important transition zone between uplands and aquatic systems. These areas act as buffer zones, protecting water quality, attenuating floods and providing habitat for a diverse community of aquatic, semi-aquatic and terrestrial organisms. Contaminants are adsorbed onto sediment particles, assimilated by vegetation and transformed by soil microbes into less harmful forms. They have long been proven effective in reducing nutrients, sediments and other anthropogenic pollutants that enter surface waters via overland and subsurface flow.

Riparian areas need to perform certain functions to be healthy, including trapping sediment to maintain and build streambanks, recharging groundwater supplies, providing stable flows, flood protection, habitat for fish and wildlife and shelter and forage for livestock. Riparian areas comprise a small percentage of the total land area and are critical to the long-term sustainability of a healthy landscape. Healthy riparian areas have the following components intact and functioning properly (Fitch et al., 2001):

- successful reproduction and establishment of seedling, sapling and mature trees and shrubs;
- lightly browsed trees and shrubs (by livestock or wildlife);
- floodplains and banks with abundant plant growth;
- banks with deep-rooted plant species (trees and shrubs);
- very few, if any, invasive weeds (e.g., Canada thistle);
- not many disturbance-caused plant species (e.g., Kentucky bluegrass, dandelions);
- very little bare ground or altered banks; and
- ability to frequently access a floodplain at least double the channel width (i.e., every few years).

Riparian health is evaluated by addressing a number of questions or parameters that help determine how the pieces of a riparian area are functioning. The result is an overall health category for the riparian area, identified by the health score. Riparian health ratings are broken down into three categories and score ranges (Table 21).

Table 21. Riparian health rating system (Fitch et al., 2001).

Health category	Score range (%)	Description
Healthy	80-100	Little to no impairment to any riparian functions
Healthy with problems	60-79	Some impairment to riparian functions due to management or natural causes
Unhealthy	< 60	Severe impairment to riparian functions due to management or natural causes

Riparian health has been assessed along the Red Deer River as part of an overview of riparian health for the South Saskatchewan River watershed (Cows and Fish, 2005a). Overall, the riparian areas in Reach 1 (headwaters to Gleniffer Lake Reservoir) and Reach 2 (Gleniffer Lake Reservoir-Red Deer) are considered healthy. In contrast, the riparian areas in Reach 3 (Red Deer-Drumheller) and Reach 4 (Drumheller to the Saskatchewan border) are considered healthy with problems. Riparian areas are primarily impaired due to the presence of disturbance-caused plant species and invasive plant species, poor regeneration of desired woody and native herbaceous plant species, grazing of woody plant species by livestock or wildlife, damming of the water course, excessive water withdrawals, impaired stream bank stability and stream bank alterations (Table 22).

Table 22. Riparian health assessments of the Red Deer River (Cows and Fish, 2005a).

Location	Primary health issues	Ranking
Banff National Park Boundary to upstream of Sundre gauging station (6.18 km)	Minor problems with grazing of desired woody plants, presence of invasive and noxious weeds	4 locations: 4 healthy, 0 healthy with problems, 0 unhealthy
Sundre gauging station to Dickson Dam (2.43 km)	Low cover of native graminoids, presence of invasive plants, impaired stream bank stability	2 locations: 2 healthy, 0 healthy with problems, 0 unhealthy
Dickson Dam to upstream of Blindman River confluence (3.17 km)	Low cover of native graminoids, presence of invasive and noxious plants	2 locations: 2 healthy, 0 healthy with problems, 0 unhealthy
Blindman River confluence to proposed Special Areas water supply project diversion site (2.14 km)	Presence of invasive and noxious plants, grazing of desired woody plants, low regeneration of woody plants, damming of water course	2 locations: 1 healthy, 1 healthy with problems, 0 unhealthy
Proposed Special Areas water supply project diversion site to the western boundary of Drumheller (upstream) (3.20 km)	Presence of invasive and noxious plants, low regeneration of desirable woody plants, grazing of woody plants, damming of water course, impaired stream bank stability	2 locations: 0 healthy, 2 healthy with problems, 0 unhealthy
Upstream of Drumheller to upstream of Dinosaur Provincial Park (includes Berry Creek) (6.92 km)	Presence of invasive and noxious plants, impaired regeneration of desirable woody plants, minor problems associated with stream bank instability, riverbank alterations, excessive water withdrawals, grazing of desired woody plants	3 locations: 1 healthy, 2 healthy with problems, 0 unhealthy
Western boundary of Dinosaur Provincial Park to upstream of Bindloss gauging station (3.70 km)	Presence of invasive and noxious plants, impaired regeneration of desirable woody plants, heavy grazing of woody plants, damming of water course, excessive water withdrawals	2 locations: 0 healthy, 2 healthy with problems, 0 unhealthy
Bindloss gauging station to Saskatchewan/Alberta border (3.59 km)	Presence of invasive and noxious plants, impaired regernation of desirable woody plants, impaired stream bank stability, damming of water course, excessive water withdrawals	2 locations: 0 healthy, 2 healthy with problems, 0 unhealthy

The riparian health along the Red Deer River in the Panther River subwatershed is rated as healthy (based on four sampling sites) (Alberta Environment, 2007c). Currently, preferred tree and shrub communities are abundant and are providing significant vegetative cover. Woody plant communities are also diverse, offering multiple species and layers, with good establishment and regeneration of *Populus* spp., as well as other trees species and shrubs. A significant positive attribute of the Red Deer River in the Panther River subwatershed are riparian areas with a moderately low presence of invasive plant communities. The herbaceous plant communities are diverse and consist primarily of native species. Disturbance-associated species are present at low to moderate levels. There is only one dam and no diversion impacts in the subwatershed. Consequently, the hydrology in the subwatershed is in a near natural state. There currently are no concerns with altered flow or timing, and the river readily accesses the floodplain (Golder, 2003; Cows and Fish, 2005a).

In addition, videography riparian health assessments have been done in Reach 2 (Gleniffer Lake Reservoir-Red Deer) by the Alberta Conservation Association in partnership with Alberta Sustainable Resource Development and the Department of Fisheries and Oceans in 2007. Using a different ranking system and in contrast to the assessment by Cows and Fish (2005a), the riparian areas of the Red Deer River from Gleniffer Lake Reservoir to the confluence of the Blindman River and the Red Deer River have been rated as primarily “poor”, with less than one third of the riparian areas being rated as “good” (29% good, 30% fair, 41% poor) (Alberta Conservation Association, 2006). The videography riparian health assessment did not extend to Reaches 1 (headwaters to Gleniffer Lake Reservoir), 3 (Red Deer-Drumheller) and 4 (Drumheller to the Saskatchewan border) of the Red Deer River.

3.1.3.3 Wetland Loss

The federal government has completed wetland habitat monitoring programs in 153 monitoring transects throughout Alberta within the Prairie Habitat Joint Venture area from 1985-2001, with many transects occurring in the Red Deer River watershed (Watmough and Schmoll, 2007; Watmough, 2008) (Figure 31). The Prairie Habitat Joint Venture is a partnership between federal and provincial governments, organizations and conservation groups in Manitoba, Saskatchewan and Alberta. The goal of the project was to provide an evaluation of habitat trends throughout the PHJV area and to provide the basis for a long term monitoring program.

Overall, in the Red Deer River watershed, 17 transects sampled baseline habitats for 23,439 ha of upland habitat and 1,837 ha (3,274 wetland basins) of wetlands, for a total sampled area in the Red Deer River watershed of 25,276 ha sampled in 1985. A summary of the program’s results in the watershed is as follows:

- From 1985-2001, 7% (134 ha) of the total sampled wetland area were considered lost or severely degraded as a result of targeted anthropogenic activities.
- Overall sampled transects in the Red Deer River Watershed had a mean wetland area loss of 7 % with a range of -36% to +2 %for the entire 17 transect sample.
- From 1985-2001, a total of 121 (4%) of sampled wetland basins were recorded as lost or severely degraded.

An additional 8% (139 ha) of the total wetland area sampled in 2001 was considered impacted/degraded by drainage or infilling impacts.

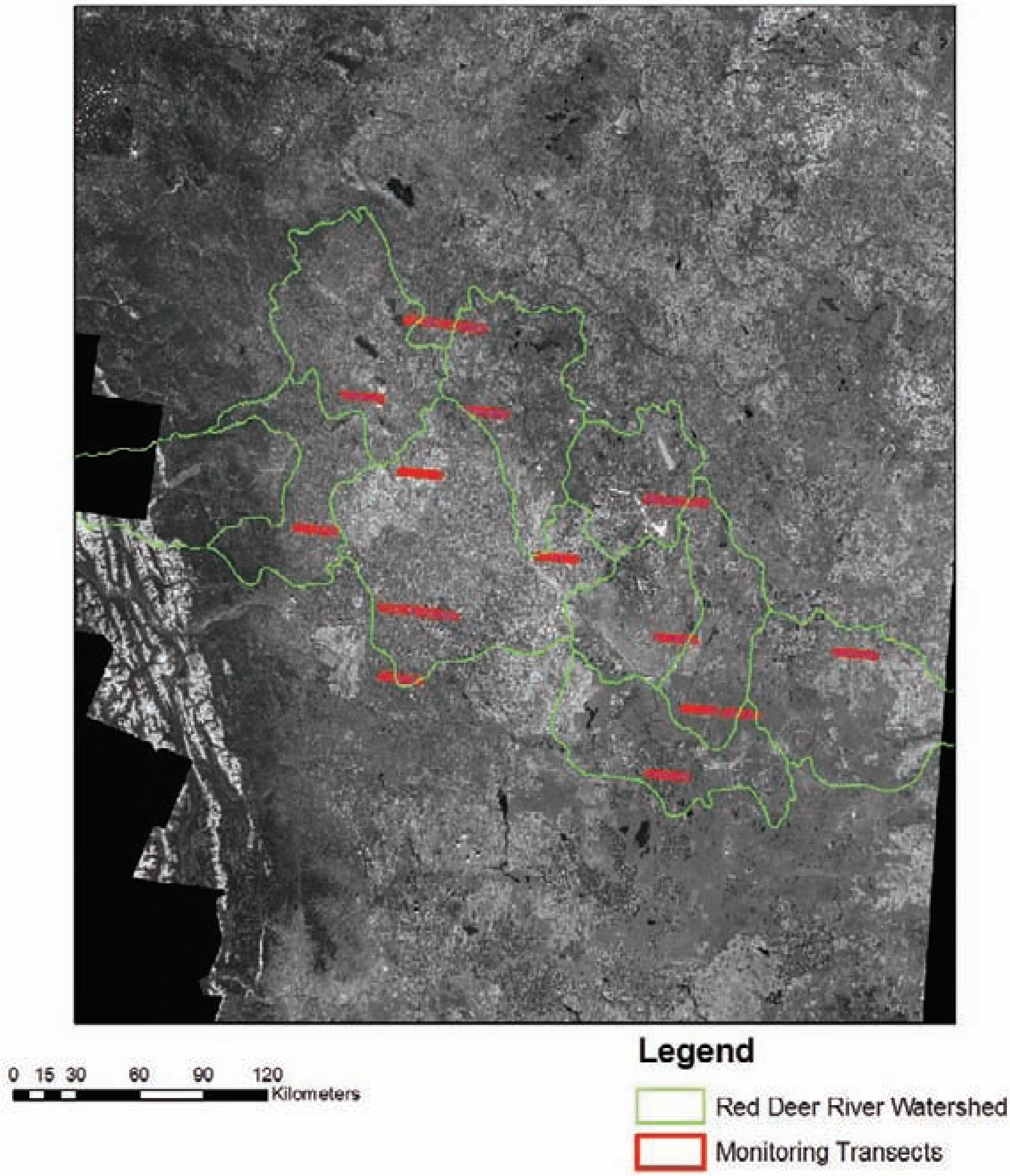


Figure 31. Prairie Habitat Joint Venture Monitoring transects in the Red Deer River watershed (Watmough, 2008).

Various wetland cover types were seen in the watershed (Figure 32), with 63% of the cover being grasses/sedges and 17% being open water.

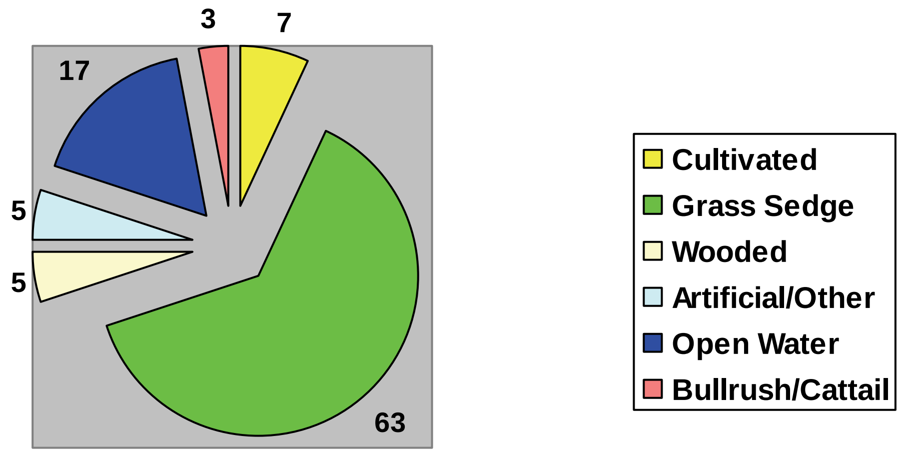


Figure 32. Wetland cover types in the Red Deer River watershed (Watmough, 2008).

3.1.3.4 Fish

About 30 different fish species live in the Red Deer River (Table 23). The most predominant species are mountain whitefish, longnose dace, longnose sucker and brown trout (Figure 33). There have been no significant changes in the population numbers of these fish over the time period of the sampling ($p > 0.1$, 0.3, 0.4 and 0.1 respectively). The northern pike and walleye populations also have not changed appreciably over time ($p > 0.1$ and 0.6, respectively). Cooper and Council (2004) reviewed sport fish and non-sport fish species, river access sites, water flow rates and optimal fish survey periods in the lower reaches of the Red Deer River (Joffre to the Saskatchewan border).

Table 23. Fish species in the Red Deer River (Alberta Sustainable Resource Development).

Common name	Latin name	Abbreviation
Brook stickleback	*Gasterosteus microcephalus* Girard	BRST
Brook trout	*Salvelinus fontinalis* Mitchill	BKTR
Brown trout	*Salmo trutta* L.	BNTR
Bull trout	*Salvelinus confluentus* Suckley	BLTR
Burbot	*Lota lota* L.	BURB
Cutthroat trout	*Oncorhynchus clarki* Richardson	CTTR
Emerald shiner	*Notropis atherinoides* Rafinesque	EMSH
Finescale dace	*Phoxinus neogaeus* Cope	FNDC
Flathead chub	*Hybopsis gracilis* Richardson	FLCH
Goldeye	*Hiodon alosoides* Rafinesque	GOLD
Lake chub	*Couesius plumbeus* Agassiz	LKCH
Lake sturgeon	*Acipenser fulvescens* Rafinesque	LKST
Lake Whitefish	*Coregonus clupeaformis* Mitchill	LKWH
Longnose dace	*Rhinichthys cataractae* Valenciennes	LNDC

Longnose sucker	*Catostomus catostomus* Forster	LNSC
Mooneye	*Hiodon tergisus* Lesueur	MOON
Mountain sucker	*Catostomus platyrhynchus* Cope	MNSC
Mountain whitefish	*Prosopium williamsoni* Girard	MNWH
Northern pike	*Esox lucius* L.	NRPK
Quillback	*Carpiodes cyprinus* Lesueur	QUIL
Rainbow trout	*Oncorhynchus mykiss* Walbaum	RNTR
River shiner	*Notropis blennius* Girard	RVSH
Sauger	*Sander canadensis* Griffith & Smith	SAUG
Shorthead redhorse	*Moxostoma macrolepidotum* Lesueur	SHRD
Spoonhead sculpin	*Cottus ricei* Nelson	SPSC
Spottail shiner	*Notropis hudsonius* Clinton	SPSH
Trout-perch	*Percopsis omiscomaycus* Walbaum	TRPR
Walleye	*Sander vitreus* Mitchill	WALL
White sucker	*Catostomus commersonii* Lacépède	WHSC
Yellow perch	*Perca flavescens* Mitchill	YLPR

Mountain whitefish live in mountain streams and lakes, favoring clear cold water and large deep pools at least 1 m deep. They are bottom feeders, stirring up the substrate with pectoral and tail fins to expose insect larvae and other invertebrates, including snails, crayfish and amphipods. Their main feeding time is in the evening, but they will also take drifting prey during the day. The mountain whitefish frequently feeds in the lower strata of streams, but populations may rise to the surface to prey on hatching insects, including mayflies. Their spawning season is from October to early December, when water temperatures are 2-6 °C. The fish seek out areas of coarse gravels or cobbles at depths of at least 75 cm, and scatter the non-adhesive eggs so that they sink into the interstices. The eggs then develop slowly through the winter (6-10 weeks), hatching in the early spring. They are considered to be a barometer of good water quality (Nelson and Paetz, 1992; Scott and Crossman, 1998).

The longnose dace are found in muddy and warm, clear and cold, streams and lakes. The largest longnose dace are about 15 cm long. They are well-adapted for living on the bottom of fast-flowing streams among the stones. Longnose dace eat mostly immature aquatic insects, and they are important forage minnows for larger predatory fish (Nelson and Paetz, 1992; Scott and Crossman, 1998).

The longnose sucker inhabits cold, clear waters. It is a bottom-feeding fish, eating aquatic plants, algae and small invertebrates. They are preyed upon by larger predatory fish, such as bass, walleye, trout, northern pike, muskellunge and burbot. They are fished for game and food and also used as bait to catch the larger predators (Nelson and Paetz, 1992; Scott and Crossman, 1998).

Brown trout prefer cold, well-oxygenated upland waters, especially large streams in mountainous areas. Cover is important to them, and they are more likely to be found where there are submerged rocks, undercut banks and overhanging vegetation. Brown trout are active both by day and by night and are opportunistic feeders. While in fresh water, the diet will frequently include invertebrates from the streambed, small fish, frogs and insects trapped in or flying near the water's surface. The high dietary reliance upon insect larvae, pupae, nymphs and adults is what allows trout to be a favoured target for fly fishing (Nelson and Paetz, 1992; Scott and Crossman, 1998).

Instream flow needs to maintain adequate water quality for the protection of mainstem fisheries have been determined for most of the Red Deer River (Clipperton et al., 2003). Generally, flow rates should not drop below 16-18 m^3/sec during the winter months and below 17-40 m^3/sec during the summer months, depending on location. These flow rates were determined by examining temperature and dissolved oxygen concentration requirements for fish species, potential impacts of waterwater additions to the river and the frequency of scouring flows in the Red Deer River. Table 24 summarizes the minimum flow needs in various reaches along the Red Deer River.

Table 24. Minimum inflow needs to maintain adequate water quality for local fisheries in the Red Deer River (Clipperton et al., 2003).

Reach	**Minimum inflow needs (m^3/sec)**			
	Winter (weeks 1-11, 51-52)	**Spring** (weeks 12-24)	**Summer** (weeks 25-37)	**Fall** (weeks 38-50)
Dickson Dam to Medicine River	16	16-23	18-33	17-22
Medicine River to Blindman River	16	16-23	18-33	17-22
Blindman River to the Special Areas Water Supply Project	16-17	17-23	17-33	17-21
Special Areas Water Supply Project to Drumheller	16-17	12-22	18-35	18-22
Drumheller to Dinosaur Provincial Park	16-18	17-23	22-40	18-25
Dinosaur Provincial Park to Bindloss	16-18	17-22	21-39	18-25
Bindloss to Saskatchewan border	16-18	17-22	21-39	18-25

Note: Ranges refer to weekly values.

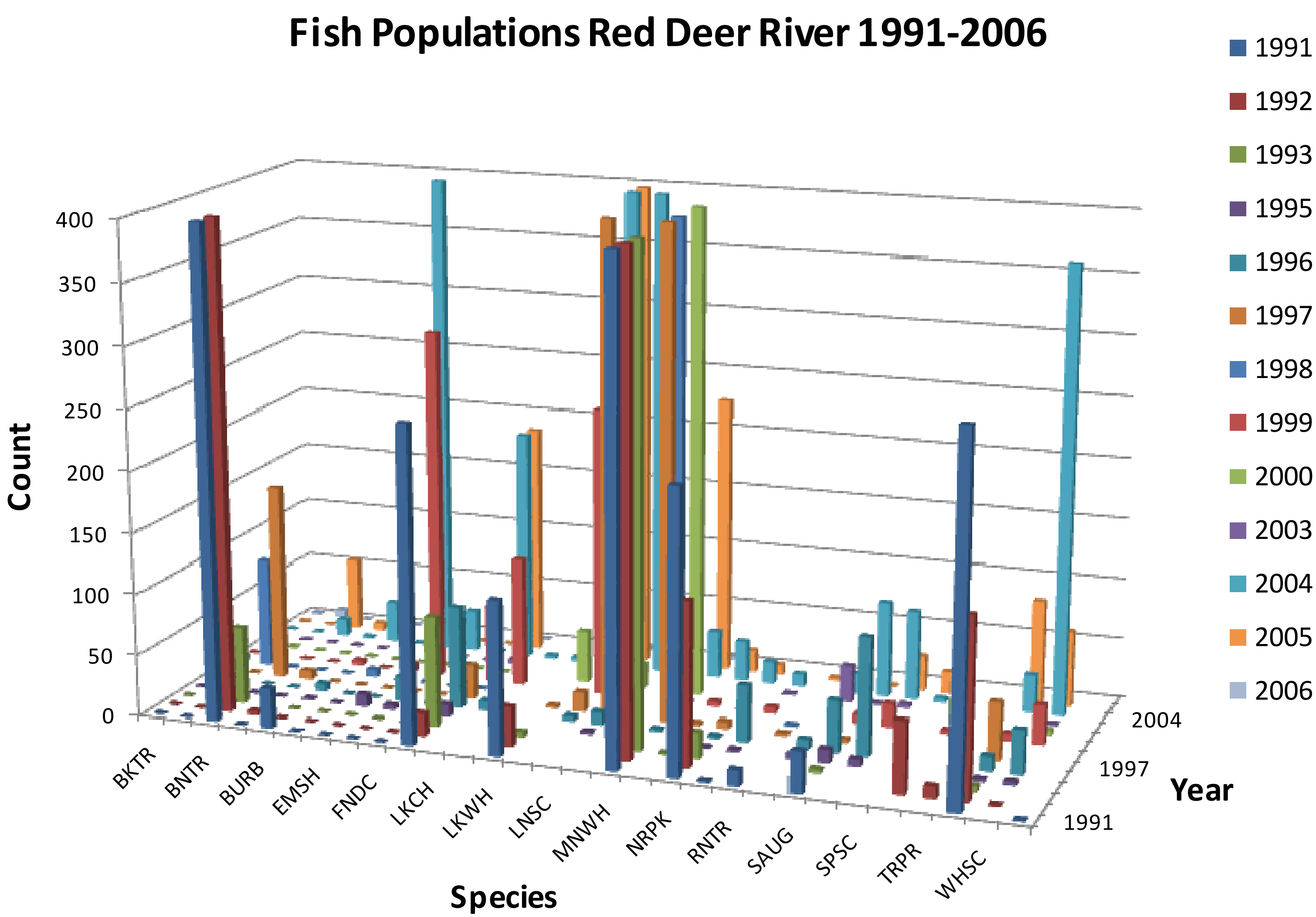


Figure 33. Fish populations in the Red Deer River from 1991-2006 (data from Alberta Sustainable Resource Development, 2008). The y-axis has been modified for better data representation. For full species names, please refer to Table 23.

3.1.3.4 Phytoplankton

Cross (1991) examined phytoplankton chl. *a* in an intensive survey of the Red Deer River in 1983-1984. Mean planktonic chl. *a* concentrations increased in a downstream direction, beginning from a site upstream of the Dickson Dam and ending at the provincial border; however, concentrations remained relatively low at all sites (i.e., < 6 µg/L), indicating oligotrophic conditions. The 1999-2003 results were similar, although concentrations did not increase downstream. Mean planktonic chl. *a* concentrations were 2.5, 3.0 and 2.6 µg/L at Queen Elizabeth II Highway bridge, Nevis and Morrin stations, respectively. According to Cross (1991), planktonic chl. *a* was notably higher in spring in the Red Deer River, declining thereafter. Spring peak in the planktonic chl. *a* levels may be caused by seasonal flow patterns and the resulting scouring effect, which would increase the amount of chl. *a* in the water column from epilithic sources. Most of the chl. *a* measured in the water column in the South Saskatchewan River Basin originates from scouring of periphyton rather than from true phytoplankton (Charlton et al., 1986). Consequently, periphyton functions as a better indicator of trophic status in rivers, which do not support a significant phytoplankton community.

Periphyton (epilithic algae) has been monitored at Queen Elizabeth II Highway, Nevis and Morrin stations by Alberta Environment. Mean epilithic chl. *a* levels, which provide a measure of periphyton biomass, were similar among sites from 1999-2003. The highest biomass occurred at Queen Elizabeth II Highway upstream of Red Deer (Figure 34). Using the classification scheme of Dodds et al. (1998), all three sites were considered eutrophic based on median epilithic chl. *a* levels; however, on the basis of maximum epilithic chl. *a* concentrations, each site would be classified as mesotrophic. Cross (1991) reported that benthic algal biomass increased sharply downstream of the City of Red Deer (at Joffre) and then progressively declined to the border, possibly due to increased turbidity. Similar results were reported by Yonge (1988). As there were no long-term data for the site at Joffre, it is not known if this spatial pattern is currently maintained, after significant upgrades in the sewage treatment process during the 1990s.

Golder (2001a, b, 2005, 2006, 2008) presented information on epilithic chl. *a* concentrations from several sites in the Red Deer River downstream of Red Deer in relation to monitoring for effects of the NOVA ('NOVA effluent') and Union Carbide ('UC effluent') chemical processing facility effluents. Moderate algal growth was observed in the study area, which was interpreted to indicate "moderately enriched" conditions with respect to nutrients. Filamentous algae were predominant at all sampling locations. It was further indicated that the cause of this enrichment was the City of Red Deer Municipal Wastewater Treatment Facility effluent and non-point agricultural nutrient inputs to the Red Deer River (Shaw and Anderson, 1994). Epilithic chl. *a* levels reported in the UC study area were notably higher than those observed at Alberta Environment monitoring sites upstream of Red Deer and at Nevis and Morrin, which are much further downstream than sites sampled by Golder. It should be noted that only a single water sample was collected at each of the sampling locations in the fall of 2004, 2005 and 2007, and any possible impacts of NOVA effluent on the benthic algal community may have been obscured due to the late sampling time. Moreover, benthic algal communities change seasonally, and a single sampling event would not be able to ascertain any potential impacts on their community composition at other times during the year.

Lastly, Carr and Chambers (1998) evaluated relationships between nutrients and epilithic chl. *a* as well as spatial trends for periphyton in the Red Deer River using Alberta Environment data collected from 1983-1991. Epilithic chl. *a* increased immediately downstream of Red Deer in spring, summer and fall (1983-1987), but the effect was only evident for about 100 km.

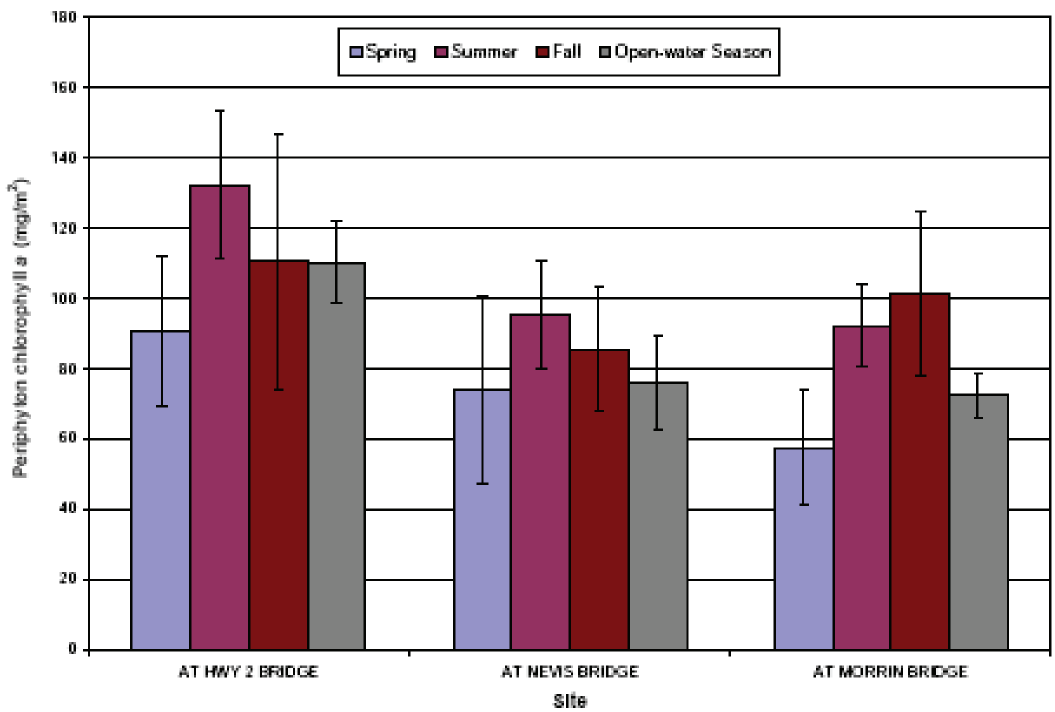


Figure 34. Mean of periphyton chl. *a* densities measured at three sites on the Red Deer River in 1999-2003 (Alberta Environment, 2007b). Error bars indicate standard deviations, an indicator of variability in the data.

3.1.3.5 Benthic Invertebrates

Smith (2003) evaluated the relationship between land use and benthic invertebrate communities in Reach 1 of the Red Deer River in 2002-2003. Ephemeroptera/Plecoptera/Trichoptera taxa (mayflies/stoneflies/caddisflies, respectively) were more abundant in the headwaters of the Red Deer River than the Bow River, that the sampled sites in the Red Deer River were quite homogenous within the studied reach and that the communities were indicative of "good" water quality. Benthic invertebrate community metrics were not significantly correlated with calculated indices of cumulative activity within Reach 1 in the Red Deer River watershed.

Historically, the Red Deer River has had uniform benthic community composition and diversity through the whole length of the river, with only a minimal impact of discharges from the City of Red Deer (Reynoldson, 1973). Since the 1970s, Red Deer has had an increasing impact on the benthic communities. For example, an increase in benthic abundance downstream of Red Deer, indicating nutrient enrichment caused by municipal wastewater discharges, has been evident in later studies (Cross, 1991; Shaw and Anderson, 1994). According to these studies, the benthic invertebrate abundance was generally low upstream of Red Deer, and, after the peak at Joffre, declined again downstream. Benthic invertebrate communities were altered by the Dickson Dam, based on data collected from 1983-1987 (Anderson, 1991; Cross, 1991; Shaw and Anderson, 1994). Prior to water flow regulation, invertebrate communities were similar upstream and downstream of the dam site. Following regulation, the downstream community shifted to resemble the peak values recorded at a site downstream of Red Deer.

According to Anderson (1991), the benthic invertebrate community near the provincial border (at Empress) was notably different than all other sites (densities were lower due to the unstable nature of the sandy substrate at this location). Overall, the invertebrate community of the Red Deer River was more diverse and abundant than in other rivers in the South Saskatchewan River basin (Reynoldson, 1973; Anderson, 1991) and North Saskatchewan, Athabasca and Beaver Rivers (Anderson, 1991).

Cross (1991) also examined the benthic invertebrate community along the length of the Red Deer River in 1983-1984. Wet weight, diversity and number of taxa increased at the City of Red Deer site and, to a lesser extent, above Drumheller. Relative abundance of Chironomidae (chironomids, or non-biting midges) was highest at most sites in fall; however, the relative abundance of Ephemeroptera (mayflies) increased in the downstream reach of the Red Deer River. The Shannon-Weiner Diversity Index (an index of biodiversity) was highest at sites upstream of Red Deer and Drumheller and near the provincial border in fall, indicating a potential effect related to development. Overall, Cross (1991) indicated that the longitudinal zonation of benthic invertebrate communities in spring was similar to that seen in other rivers that cross different ecoregions in Alberta. The observed increase above Drumheller was believed to reflect the influence of local tributaries, while the observed decrease downstream of Drumheller was suggested to be a reflection of historical coal mining activities.

Golder (2001a, b, 2005, 2006, 2008) examined benthic invertebrate communities in the Red Deer River in Reach 3 as part of monitoring programs for the UC and NOVA chemical processing facilities effluent, which discharge to the river. Overall, the Golder studies indicated that invertebrates found were similar to those of other large rivers in southern Alberta. Furthermore, the community was indicative of a nutrient-enriched aquatic ecosystem on the basis of the dominance of taxa that are tolerant of mild enrichment and the very low abundance of more sensitive taxa, such as Plecoptera (stoneflies). Golder (2001a) concluded that there was a small localized effect of the UC effluent on the benthic invertebrate community of the Red Deer River. Effects of the NOVA effluent on benthic invertebrates were reportedly more notable. Increasing abundance of Oligochaeta (earthworms), reductions in pollution-sensitive taxa and a small reduction in taxonomic richness of the community were observed to about 600 m downstream of the outfall (Golder, 2001b). These effects were attributed to organic enrichment. Members of the orders Ephemeroptera/Plecoptera/Trichoptera accounted for about 50% of the mean number of taxa. In 2007, Golder (2008) reported similar results, i.e., the benthic invertebrate community is characteristics of large rivers in southern Alberta and the result of "mild nutrient enrichment" downstream of the NOVA effluent outfall. In contrast with previous years, overall species richness was lower in 2007 (33 taxa) than in 2005 (42 taxa; Golder, 2006) and 2004 (59 taxa; Golder, 2005), which Golder attributed to scouring of the river bed during flooding events in the summer 2005 and the use of a different sampling device. Overall, Golder concluded that NOVA effluent had no significant impact on the benthic invertebrate community; however, this conclusion should be taken with caution. Only a single water sample was collected at each of the seven sampling locations in late October 2007, and any possible impacts of NOVA effluent on the benthic invertebrate community may have been obscured due to the late sampling time. Moreover, benthic invertebrate communities change seasonally, and a single sampling event would not be able to ascertain any potential impacts on their community composition at other times during the year.

3.1.3.6 Bacteria

There are no data on bacterial concentrations in Reach 1 (Red Deer River headwater to Gleniffer Lake Reservoir) and Reach 4 (Drumheller to Saskatchewan border). The Red Deer River at Bowden and at the Queen Elizabeth II Highway bridge (both Reach 2) experiences peaks in fecal coliform and *E. coli* concentrations, respectively, predominantly during the months of May through August (Figures 35, 36), concomitant with spring runoff and precipitation events. Following statistical analyses, it was found that there is no significant increasing or decreasing trend in fecal coliform or *E. coli* concentrations over time ($p > 0.05$). In addition, there is no relationship between fecal coliforms and total phosphorus concentrations ($p > 0.05$).

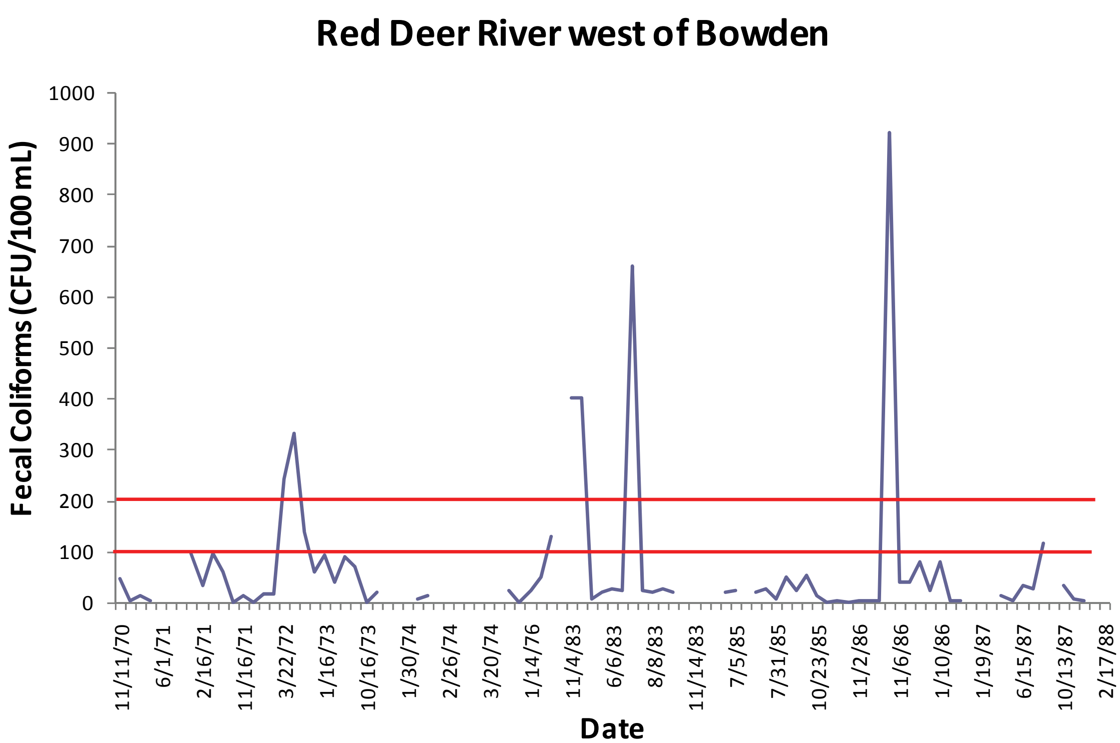


Figure 35. Fecal coliform concentrations in the Red Deer River west of Bowden (data from Alberta Environment, 2008). The red lines indicate the Health Canada Guidelines for Contact Recreation (200 CFU/100 mL) and the ASWQG for Irrigation (100 CFU/100 mL).

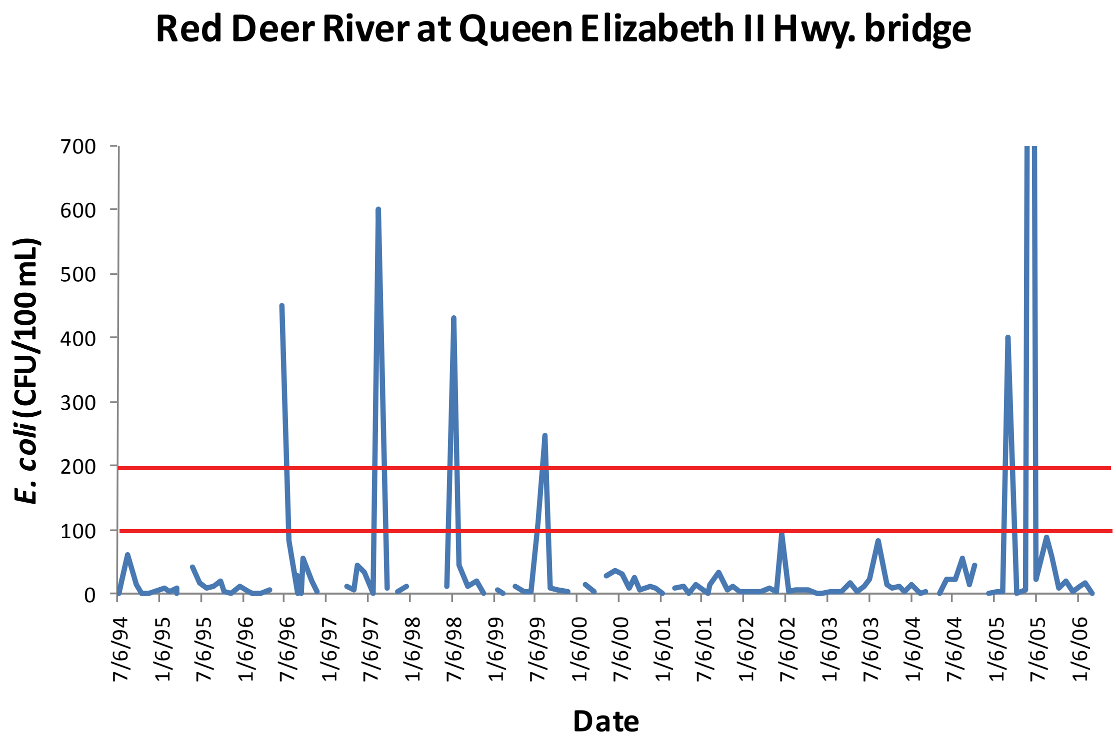


Figure 36. *E. coli* concentrations in the Red Deer River at the Queen Elizabeth II Highway bridge (data from Alberta Environment, 2008). The red lines indicate the Health Canada Guidelines for Contact Recreation (200 CFU/100 mL) and the ASWQG for Irrigation (100 CFU/100 mL).

Similarly, the Red Deer River at Nevis and the Morrin bridge (both Reach 3) experiences peaks in *E. coli* concentrations predominantly during the months of April/May through July/August (Figures 37, 38), concomitant with spring runoff and precipitation events. Following statistical analyses, it was found that there is no significant increasing or decreasing trend in *E. coli* concentrations over time (data not shown; $p > 0.05$).

Sources of bacteria in the Red Deer River include surface application of manure by agricultural producers, septic fields or byproducts from wastewater treatment plants without tertiary treatment.

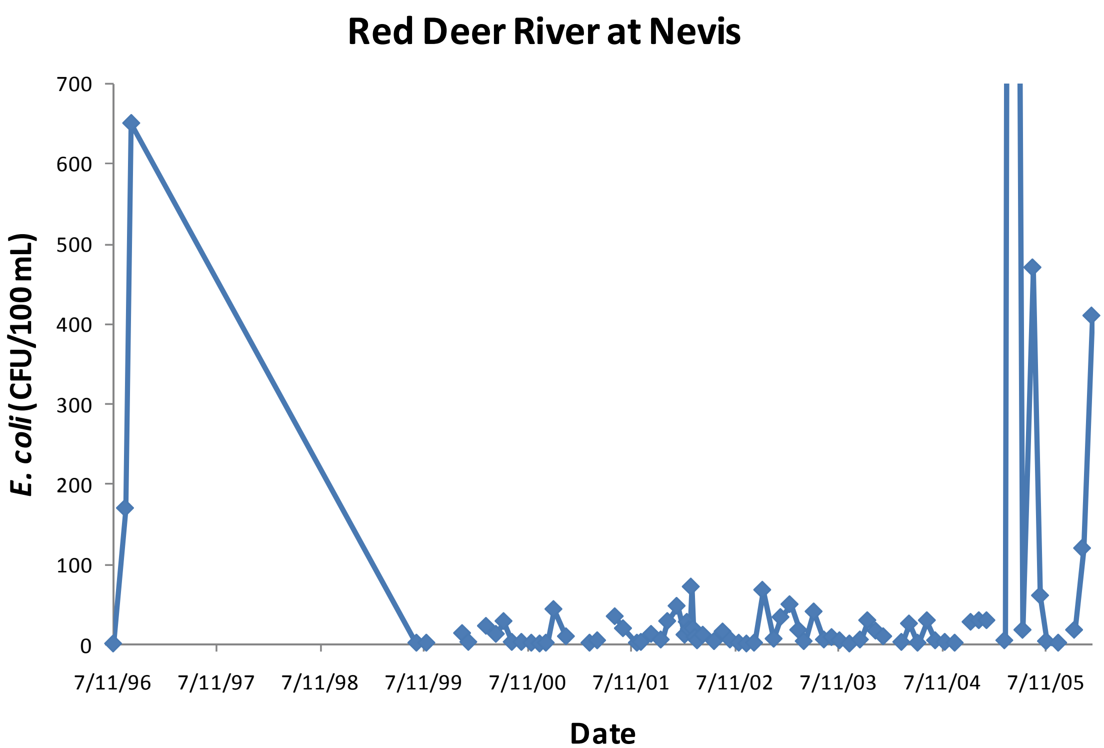


Figure 37. *E. coli* concentrations in the Red Deer River at Nevis (data from Alberta Environment, 2008). The red lines indicate the Health Canada Guidelines for Contact Recreation (200 CFU/100 mL) and the ASWQG for Irrigation of 100 CFU/100 mL.

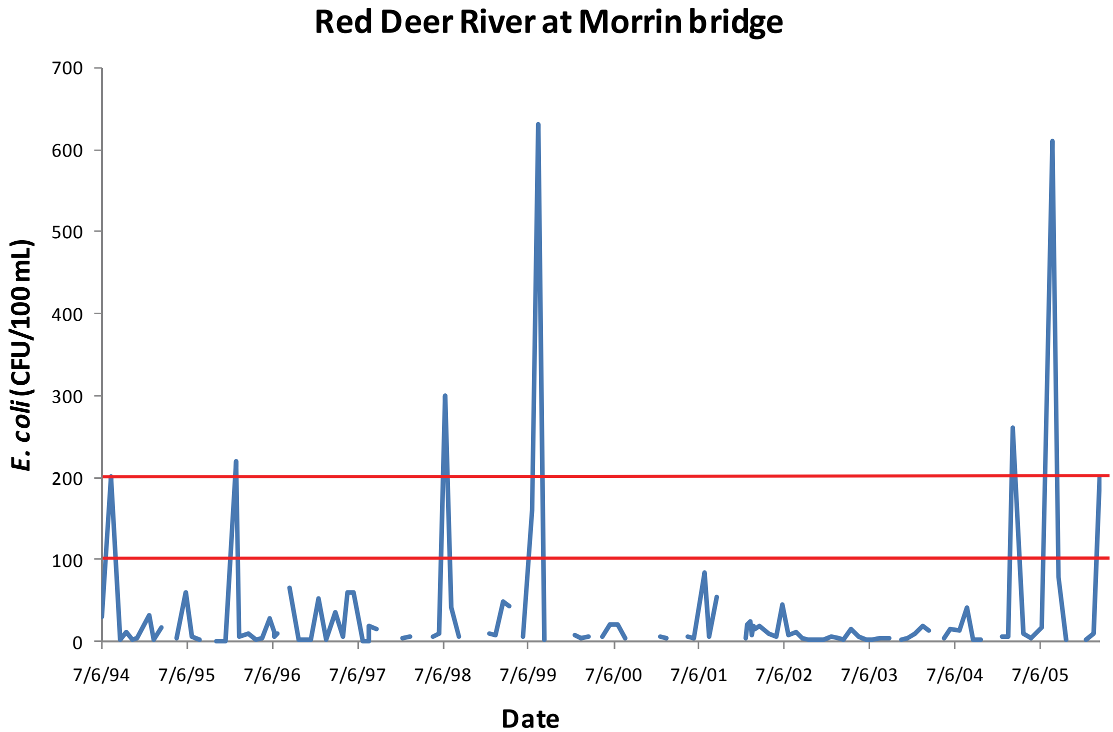


Figure 38. *E. coli* concentrations in the Red Deer River at the Morrin bridge (data from Alberta Environment, 2008). The red lines indicate the Health Canada Guidelines for Contact Recreation (200 CFU/100 mL) and the ASWQG for Irrigation of 100 CFU/100 mL.

3.1.3.7 Species at Risk

Identifying species at risk and their habitat requirements will help to determine sensitive areas and level of protection required. The *Species at Risk Act* (*SARA*) was introduced in June 2003 to provide legal protection of wildlife species and conservation of biological diversity. The Act aims to prevent Canadian indigenous species, subspecies and distinct populations from becoming extinct or extirpated (locally extinct), to provide for the recovery of endangered or threatened species and encourage the management of other species to prevent them from becoming at risk. Currently, there are 363 species listed as either endangered (169 species), threatened (110 species) or of special concern (84 species) (Species at Risk, 2008).

“Endangered species” are those species that face imminent extirpation or extinction, while “threatened species” are those that are likely to become an endangered species if nothing is done to reverse the factors leading to its extirpation or extinction. “Species of special concern” are those species that warrant special attention to ensure their conservation.

The Red Deer River watershed is home to 14 species that are listed under the *Species at Risk Act*. These are eight birds, two plants, one mammal, one amphibian and one insect, of which four are threatened, five are endangered, and five are of special concern (Table 25).

Table 25. Endangered (E), threatened (T) and species of special concern (SC) in the 15 subwatersheds of the Red Deer River watershed (Species at Risk, 2008).

Species	**Subwatersheds**														
	Panther River	**James River**	**Raven River**	**Little Red Deer River**	**Medicine River**	**Blindman River**	**Waskasoo Creek**	**Buffalo Lake**	**Threehills Creek**	**Kneehills Creek**	**Michichi Creek**	**Rosebud River**	**Berry Creek**	**Matzhiwin Creek**	**Alkali Creek**
Anthus spragueii Audubon (Sprague's pipit)				T			T	T	T	T	T	T	T	T	T
Athene cunicularia Molina (burrowing owl)											E	E	E	E	E
Bufo boreas Baird & Girard (western toad)	SC	SC	SC	SC	SC	SC									
Bufo cognatus Say (great plains toad)														SC	SC
Charadrius melodus circumcinctus Ord. (piping plover)				E			E	E	E	E	E	E	E	E	E
Coturnicops noveboracensis Gmelin (yellow rail)	SC	SC	SC	SC	SC	SC	SC	SC	SC	SC	SC	SC	SC	SC	SC
Cryptantha minima Rydb. (tiny cryptanthe)															E
Danaus plexippus L. (monarch butterfly)	SC	SC	SC	SC	SC	SC	SC	SC	SC	SC	SC	SC	SC	SC	SC
Falco peregrinus anatum Bonaparte (peregrine falcon)							T	T	T	T	T	T			
Halimolobos virgata (Nutt.) O.E. Schulz (slender mouse-ear-cress)														T	
Lanius ludovicianus excubitorides L. (loggerhead shrike)				T			T	T	T	T	T	T	T	T	T
Numenius americanus Bechstein (long-billed curlew)									SC	SC	SC	SC	SC	SC	SC
Oreoscoptes montanus Townsend (sage thrasher)														E	
Vulpes velox Say (swift fox)														E	

Mammals

The swift fox is and endangered species that prefers open, sparsely vegetated short-grass and mixed-grass prairie, where visibility and mobility are unimpeded. Native vegetation common in such grasslands includes buffalo grass, bluestem and wire grass. The conversion of native prairie grasslands to farmland has reduced both the quantity and quality of habitat available to the swift fox over much of its former range. The swift fox is very vulnerable to shooting and trapping since it is not wary of humans, and poison used to kill coyotes has been detrimental to the species. Predation by coyotes, eagles and red-tailed and rough-legged hawks is a potential threat to the swift fox (Species at Risk, 2008).

Birds

The loggerhead shrike is a threatened species that inhabits a wide variety of open habitats, including grasslands, sagebrush stands, pastures, agricultural areas and thinly wooded areas with small trees and shrubs where it can nest and forage. This shrike has a preference for small bushy trees and dense or thorny bushes. Its habitat choices are still poorly understood, as many apparently suitable sites are left unused. Suitable habitats for breeding, migration and wintering have declined and continue to decline. Habitat loss is primarily due to the conversion of native grasslands to agricultural land and the degradation of the remaining grasslands. Pesticides are one of the major factors that have contributed to population declines. Sharp declines of the loggerhead shrike *excubitorides* subspecies population have been shown to coincide with the period during which organochlorine pesticides (e.g., DDT) were used in Canada and the United States, in part to combat grasshoppers, which are a key source of food for loggerhead shrikes nesting in the Prairie Provinces. Since this bird is a predator at the top of the food chain, pesticides accumulate in its body every time it eats prey that has itself absorbed pesticides. These chemicals may be the cause of developmental delays in juveniles, the thinning of eggshells and smaller clutch sizes. Although organochlorines are no longer used, they remain in the environment and the effects of new pesticides are unknown. Moreover, the decline of the prey base related to the use of pesticides and habitat fragmentation may also be major factors. Collisions with automobiles are believed to be another major cause of mortality of both juvenile and adult loggerhead shrikes that build their nests and hunt near roadways. The predation rate on adults, eggs and nestlings also appears to be higher near roads and hedges, which attract predators. Finally, juvenile birds are also vulnerable to cold temperatures and heavy precipitation (Species at Risk, 2008).

Sprague's pipit is a threatened bird that prefers native grassland and is rarely found in cultivated lands, or in areas where native grasses have been replaced with introduced forages. In general, pipits prefer native vegetation of intermediate height and density, with moderate amounts of litter. Such areas tend to occur where habitats are lightly to moderately grazed, or where fires periodically remove vegetation. Areas of suitable habitat must be >150 ha to be attractive as breeding sites for this species. Current information suggests that at least 75% of native grasslands on the Canadian prairies have been lost to cultivation. This has greatly reduced the availability of suitable habitat for Sprague's pipit. Among the other factors which may also reduce habitat suitability are (1) intensive grazing, which removes vegetation and may cause reproductive failure due to disturbance and trampling of nests, (2) haying, (3) fragmentation of habitat and (4) reduction in fire frequency, which encourages encroachment of woody vegetation and promotes excessive growth of vegetation and accumulation of litter. The use of pesticides to control grasshoppers may also impact Sprague's pipit populations, since grasshoppers are an important food item for the adults and nestlings during the breeding season. The most significant 'natural' limiting factor for the species is probably drought, which affects nesting habitat and possibly food supply at the local level (Species at Risk, 2008).

Peregrine falcon *anatum* subspecies is a threatened bird. The habitat requirements of the peregrine falcon can be divided into three components: (1) the nest site: nests are usually scrapes made on cliff ledges on steep cliffs, usually near wetlands, including artificial cliffs such as quarries and buildings; (2) the nesting territory: the area defended around the nest prevents other pairs from nesting within 1 km or more, ensuring adequate food for all nesting pairs and their young; the density of nests tends to be related to food availability; (3) the home range: the extended, non-defended area in which the peregrines hunt for additional food and which can extend to 27 km from the nest; peregrines prefer open habitats such as wetlands, tundra, savanna, sea coasts and mountain meadows, but will also hunt over open forest. The major cause of decline of peregrine falcon populations was the presence of agricultural pesticides, especially organochlorine compounds, in the environment. These compounds cause egg-shell thinning, egg breakage, reduced hatching success, reduced brood-size and reduced breeding success. Since peregrine falcons are at the top of the food chain, their tissues accumulate a great deal of these substances. Organochlorine contamination is no longer a major limiting factor for peregrines. Current threats include the small population size and the diminishing quality of habitat. Locally, peregrines may be affected by destruction of breeding sites and breeding areas, or by human intrusion near nest sites (Species at Risk, 2008).

The piping plover is an endangered bird that nests just above the normal high-water mark on exposed sandy or gravelly beaches. On the prairies, nesting occurs on gravel shores of shallow, saline lakes and on sandy shores of larger prairie lakes. Seeps also provide important foraging habitat on the Prairies. The most important limiting factor for the piping plover *circumcinctus* subspecies is loss of habitat due to human use of beaches and the consequent disturbance of nesting sites. Dogs and cats prey on the eggs and young, as do gulls and raccoons initially attracted to the nesting areas by picnickers' garbage. On the Prairies, cattle and horses trample nests, and chicks can be trapped in deep hoof prints. Changes in water levels due to recreational or building activities, dams and seasonal storms also threaten the nesting sites of this subspecies (Species at Risk, 2008).

The sage thrasher is an endangered bird that almost entirely depends on sagebrush habitat during the breeding season. Occasionally, the species has been seen in other shrub-steppe areas, such as greasewood and antelope brush. Shrub size is very important for nesting, with the birds requiring sagebrush about 1 m in height. In winter, the sage thrasher uses a variety of scrub, brush and thicker habitats. In general, areas with suitable sage thrasher habitat in Canada have been slowly decreasing over the last 50 years. All threats relate to habitat quality and quantity, primarily land conversion to intensive agriculture and residential complexes. Overgrazing is less of a problem now than it was in the past, but in some cases it does continue to affect private ranchlands (Species at Risk, 2008).

The burrowing owl is an endangered bird that requires treeless plains largely free of visual obstructions, such as grasslands grazed by livestock. It uses burrows abandoned by ground-dwelling mammals (e.g., badgers, gophers and prairie dogs) for nesting, roosting and caching food. Short or sparse vegetation and permanent cover are preferred around the burrows. Grasslands with thicker vegetation support the small mammals that they eat. Thus, the owls need a mosaic of grass densities to successfully breed. The species is sometimes found on roadsides and crop lands and in urban areas where mowing keeps expanses of grass short. The availability of suitable burrows, or some sort of hole in the ground, is essential to burrowing owl habitation. In addition to serving as nesting sites, burrows provide shelter from wind, rain, sun and predatory hawks. Cultivation of pastures, extermination of ground squirrels, and other agriculture techniques have combined to reduce the number of suitable burrows. The use of chemical pesticides to control grasshoppers and other insects reduces an important food supply. When shortage of food forces the birds to forage far from their nesting sites, they become more susceptible to predation. Other factors that can contribute to the decline of this species include inclement weather, illegal shooting and collisions with motor vehicles. During migration, they have difficulty finding burrows, since 99% of prairie dog colonies have been destroyed in the Great Plains. In winter, most of their habitat is cultivated, and burrows may be in short supply (Species at Risk, 2008).

The long-billed curlew is a bird species of special concern that nests in grassland, primarily native short-grass and mid-grass prairie. The birds show a preference for nesting in irregular clumps where they blend in well and perhaps can spot approaching predators more easily. Once the eggs have hatched, the curlews seem to prefer taller and denser grass, possibly because it offers better camouflage for the young and reduces heat stress. Although they are more numerous in native grassland, curlews appear to be able to use some agricultural areas for feeding and raising young. While migrating and on their wintering grounds, curlews prefer shallow inland and coastal waters. At the beginning of the 20th century, long-billed curlews were killed for market in large numbers. Sport hunters also killed many as they made easy targets. Cultivation of their native prairie nesting grounds contributed to the early declines as well; it continues to be a problem, now exacerbated by urban encroachment. Remaining grasslands are fragmented and disturbed by industry, livestock overuse, fire control and the invasion of exotic plants. While habitat loss is now the greatest threat to the long-billed curlew, there is also the problem of increasing risk from predators. Habitat fragmentation creates easier access to the Curlews for the increasing number of coyotes and other predators (Species at Risk, 2008).

The yellow rail is a bird of special concern that is typically found in marshes dominated by sedges, grasses and rushes, where there is little or no standing water (generally 0-12 cm water depth), and where the substrate remains saturated throughout the summer. They can be found in damp fields and meadows, on the floodplains of rivers and streams, in the herbaceous vegetation of bogs and at the upper levels (drier margins) of estuarine and salt marshes. Nesting habitats usually have a dry mat of dead vegetation from previous growing seasons. The loss and degradation of wetlands due to agricultural and human development is the greatest threat to this species throughout its breeding range. On the wintering grounds, habitat loss has been so extensive that the wintering range may no longer be contiguous, and the yellow rails are becoming largely restricted to a narrow band of coastline. Coastal marshes are threatened throughout the Gulf States (Species at Risk, 2008).

Amphibians
The great plains toad is an amphibian of special concern that breeds mainly in temporary wetlands that fill with water following heavy rains in late spring and early summer. During periods of extended drought in Alberta, the toads appear to rely upon irrigated areas for breeding habitat. Grassland habitat may be widely available for this species within its range, but many areas of grassland may not include depressions (such as sloughs) suitable for breeding when high spring runoff or heavy rains trigger breeding. Progressive conversion of grasslands to cropland, application of herbicides and pesticides and local impacts by grazing may be slowly reducing the quantity and quality of available habitat (Species at Risk, 2008).

The western toad is an amphibian of special concern that will breed in an impressive range of natural and artificial aquatic habitats, ranging from the shallow margins of lakes to roadside ditches. It does not seem to matter if the sites have tree or shrub canopy cover, coarse woody debris, or emergent vegetation. Adult females may lay their eggs at depths of 5 cm to 2 m (although depths over 1 m are rare) in the same location within sites each year. It appears that the absence of predators and warm spring water temperatures are desirable. Studies using radio tracking of western toad have shown that, outside the breeding season, toads spend up to 90% of their time in terrestrial habitats. Adult toads can be found in forested areas, wet shrublands, avalanche slopes and meadows. They appear to favour dense shrub cover, perhaps because it provides protection from desiccation and predators. Western toads are often found in clear cuts, and may prefer these habitats to closed canopy forests in coastal areas. The habitat requirements of hibernation sites for the western toad in Canada are not known. Radio-tracked individuals in Colorado often used the burrows of golden-mantled ground squirrels, which are deep enough to prevent freezing and moist enough to prevent desiccation. The practice of stocking lakes where fish do not occur naturally may be one of the biggest threats to the western toad. Fish generally do not eat this species, but they do carry diseases to which the tadpoles and toads are susceptible. The degradation and loss of habitat to development and agriculture is an issue. As the remaining populations become more fragmented, they are more vulnerable to chance events and are more likely to be wiped out by unfavourable climatic conditions. Other threats associated with development and agriculture include road traffic, pesticides and contaminants. Predation or competition with introduced species such as bullfrogs and stocked fish are also a concern (Species at Risk, 2008).

Insects
The monarch butterfly is an insect of special concern. In Canada, it exists primarily wherever milkweed (*Asclepius* spp.) and wildflowers (such as goldenrod, asters, and purple loosestrife) exist. This includes abandoned farmland, along roadsides and other open spaces where these plants grow. Environmental conditions and loss of breeding habitat pose threats to all monarch butterflies. In the Prairie provinces, habitat disturbances from agricultural practices and residential land conversions reduce suitable habitat for monarch butterflies. In addition, the widespread and increasing use of herbicides poses a significant threat to the caterpillars that require the milkweed and the adults that require nectar-producing wildflowers (Species at Risk, 2008).

Plants

Slender mouse-ear-cress is a threatened vascular plant that grows in open, short- to mid-grass prairie in sandy, alkaline soil that is dry for most of the year but may be moist in spring. It grows on flat areas or in low prairie depressions, but is inexplicably absent from great stretches of similar suitable habitat. The species is at the northern edge of its range where it is limited by climate. The main threat to the Canadian populations of slender mouse-ear-cress is loss of habitat as a result of urban and industrial development and agriculture. It appears to be unable to grow on previously turned soil. Other limiting factors include invasion of its habitat by non-native species and trampling by ATVs and other human activities (e.g., campgrounds) (Species at Risk, 2008).

Tiny cryptanthe is an endangered vascular plant that occurs in the Mixed Grassland Ecoregion on eroding areas and slopes in Alberta. The species occurs with a wide variety of weedy plants. The conversion of mixed-grass prairie to cropland directly threatens the tiny cryptanthe. Historically, urban development has decimated a few populations. Any changes to the South Saskatchewan River resulting in flooding or water diversion could seriously imperil the species in Canada (Species at Risk, 2008).

The provincial Endangered Species Conservation Committee under the auspice of Alberta Sustainable Resource Development's *Alberta's Species at Risk Program* recognizes a number of additional species that "may be at risk" or as "sensitive" within the Red Deer River watershed. Several of these species may be classified as "species of special concern", "endangered" or "threatened" in the future (Fish and Wildlife Division, 2008).

3.1.4 Water Quantity

3.1.4.1 *Master Agreement on Apportionment*

The need for cooperative management of shared waters was recognized by the provinces of Alberta, Saskatchewan and Manitoba and the federal government as early as 1948, with the signing of the PPWB Agreement. From 1948-1969, the Board recommended the best use of interprovincial waters and allocations of such waters between provinces.

On October 30, 1969, the Governments Alberta, Saskatchewan, Manitoba and Canada entered into the *Master Agreement on Apportionment*, which provided a formula for the sharing of the waters of eastward flowing inter-provincial streams. The sharing of waters of eastward flowing streams, including the South Saskatchewan River, between Alberta and Saskatchewan is governed *Schedule A* of the *Master Agreement on Apportionment*. The general principle of the agreement is outlined in Paragraph 3, *Schedule A*, which states:

> *"Alberta shall permit a quantity of water equal to one-half the natural flow of each watercourse to flow into the Province of Saskatchewan, and the actual flow into the Province of Saskatchewan shall be adjusted from time to time on an equitable basis during each calendar year, but this shall not restrict or prohibit Alberta from diverting or consuming any quantity of water from any watercourse provided that Alberta diverts water to which it is entitled of comparable quality from other streams or rivers into such watercourse to meet its commitments to Saskatchewan with respect to each watercourse."*

And by paragraph 2b which states:

> *"For the purpose of this agreement, the said natural flow shall be determined at a point as near as reasonably may be to the said common boundary."*

The *Agreement* listed a number of additional conditions for the South Saskatchewan River.

> **Paragraph 2C**; *"...the point at which the natural flow of the watercourses known as the South Saskatchewan and Red Deer Rivers is to be determined may be, at the option of Alberta, at a point at or as near as reasonably may be below the confluence of the said two rivers."*

This provision means that the waters of the South Saskatchewan and Red Deer Rivers, for apportionment purposes, may be treated as a single entity, i.e., Alberta's delivery of Saskatchewan's entitlements during a particular year may be made entirely from the Red Deer River or entirely from the South Saskatchewan River, or any combination thereof, at the discretion of Alberta.

> **Paragraph 4A**; *"Alberta shall be entitled in each year to consume, or to divert or store for its consumptive use a minimum of 2,100,000 acre-feet net depletion out of the flow of the watercourse known as the South Saskatchewan River even though its share for the said year, as calculated under paragraph 3, would be less than 2,100,000 acre-feet net depletion, provided however Alberta shall not be entitled to so consume or divert or store for its consumptive use, more than one-half the natural flow ... if the effect thereof at any time would be to reduce the actual flow ... at the common boundary ... to less than 1,500 cubic feet per second."*

This provision contains two conditions, one pertaining to the minimum flow rate and another to total annual volume. Based on Chen and Goodwin (1986), when the natural flow of the South Saskatchewan River at the boundary is > 85 m^3/sec, the minimum flow is to be 42.5 m^3/sec. When natural flow at the boundary is < 85 m^3/sec, the minimum flow has to be one-half of the natural flow at the boundary. In addition, Alberta is permitted to store or consume a minimum of 2,590,000 dam^3 of water, even though this may be more than 50% of the annual volume, provided that the minimum flow constraint is satisfied. Currently, Alberta maintains a minimum continuous flow of 42.5 m^3/sec.

> **Paragraph 4B**; *"The consumption or diversion by Alberta provided for under the preceding subparagraph [4A] shall be made equitably during each year, depending on the actual flow of water in the said watercourse and the requirements of each Province, from time to time."*

This provision indicates that the balancing period for the South Saskatchewan River is the calendar year; however, calculations of the apportionment status are carried out on a quarterly basis (more frequently if required) by the PPWB. Surplus deliveries by the upstream jurisdiction during a calendar year cannot be banked and cannot be used to offset short falls in subsequent years.

Stream flow is monitored at 14 locations along the Alberta-Saskatchewan and Saskatchewan-Manitoba borders; however, the *Master Agreement* covers all eastward flowing streams, including those where the water flow is currently not monitored. Other river basins may be added to the monitoring list when water uses in an upstream province become significant. In addition, hydrometric data that are needed to calculate natural flow are gathered at over 90 sites, located primarily in the South Saskatchewan and Qu'Appelle River basins in Alberta and Saskatchewan, respectively.

3.1.4.2 Red Deer River Flow rates

The Red Deer River watershed occupies 8% of Alberta's landbase. It flows into the South Saskatchewan River and forms part of the Nelson River Basin, which eventually drains into Hudson Bay. In 2006, the basin had a population of 267,863 people, or 8.14% of the provincial population, living in 74 municipalities (urban, rural and regional). This represents a population density of about 5 people/km^2 (Alberta Environment, 2007a).

The Drummond Glacier, which covers about 25 km^2 and lies at an altitude of 2,400-3,000 m above sea level (a.s.l.), is located in the headwaters of the Red Deer River in Banff National Park and contributes to the streamflow of the river from meltwater in Banff National Park. The glacier has retreated about 1850 m from 1884-1965 (Nelson et al., 1966; Brunger et al., 1967), as have most glaciers that feed into the South Saskatchewan River basin (Demuth et al., unpublished data). Moreover, Demuth et al. (unpublished data) showed that glacier cover contraction is evolving at an unprecedented pace towards a state not in evidence for several millennia. Both rising temperatures and a reduction in glacier replenishment in winter due to a persistent ocean-atmosphere regime shift has fuelled the drastic glacier contraction in evidence recently.

Rood et al. (2005) determined that streamflow from many eastern Rocky Mountain slope rivers and creeks has decreased at a mean rate of 0.22%/year over the past 100 years and will continue to decrease in the future. They postulated that the historic and continuing reductions in streamflows will impact aquatic and riparian ecosystems and diminish water supplies for irrigation, industrial and domestic use, and hydroelectric power generation, with effects extending from these headwaters downstream through other ecoregions. As a result of climate change, Rood et al. (2008) further determined that (1) winter flows (especially in March) will likely slightly increase, (2) spring run-off and peak flows will likely occur earlier and be more substantial and (3) summer and early autumn flows (July-October) will likely be considerably reduced in many of these eastern Rocky Mountain slope streams and creeks.

Water flow rates of the Red Deer River have varied considerably since 1961, ranging from 20-30 m^3/sec to over 100 m^3/sec (Figure 39) (Alberta Environment, 2007a). This variation in flow rates resulted from variability in water withdrawal rates by agricultural operations, municipalities, the petroleum industry, commercial and industrial sectors, water management activities and climatic variation. On average, flow rates are about 70 m^3/sec along the length of the river.

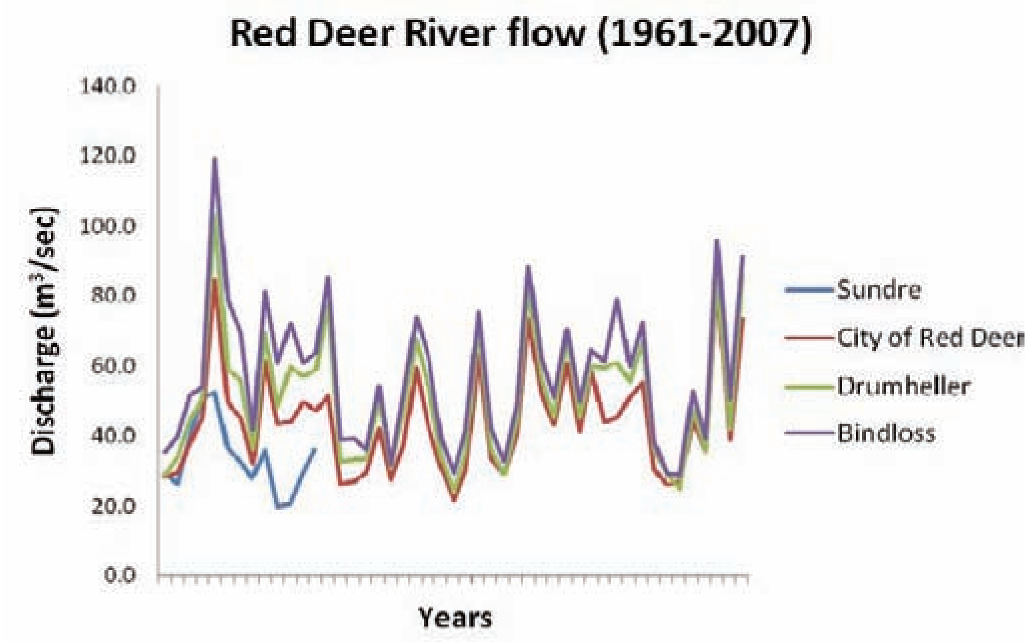


Figure 39. Red Deer River flow at various stations from 1961-2007 (Alberta Environment, 2007a).

There have been several high streamflow and flood watch/warning advisories in the Red Deer River since 2005 in response to snow melt early in the year and high precipitation events throughout the summer months (June-September) (Table 26). Most of these occur upstream of the Dickson Dam (i.e., Reach 1).

Table 26. Advisories and warnings in the Red Deer River since 2001 (Alberta Environment, 2008c).

Advisory	Location	Date
High streamflow	Upstream of Dickson Dam	April 25, 2003
	Upstream of Dickson Dam	May 04, 2003
	Upstream of Dickson Dam	April 28, 2003
	Sundre, Red Deer, Drumheller	June 06, 2005
	Upstream of Dickson Dam	August 25, 2005
	Upstream and downstream of Dickson Dam	September 10, 2005
	Upstream of Dickson Dam	June 15, 2006
	Upstream of Dickson Dam	May 27, 2008
	Upstream of Dickson Dam	June 10, 2008
Flood watch/warning	Upstream of Dickson Dam	June 17, 2005

There are 731 active licenses to divert water directly from the Red Deer River within a distance of 6,400 m from the river (Government of Alberta, 2008d). These licenses permit the removal of up to 222.66 dam^3/yr of water (cubic decameter, 1 dam^3 = 1,000 m^3) (Table 27), assuming that all licensees remove the maximum amount of water permitted on their license. The largest users of water from the Red Deer River are urban centres (62,435 dam^3/yr, or 28.3% of the total water use), crop producers (48,491 dam^3/yr, or 22.0% of the total water use), gas/petrochemicals industries (25,500 dam^3/yr, or 11.6% of the total water use). In addition, substantial quantities of water are used to cooling purposes (24,875 dam^3/yr, or 11.3% of the total water use) and water level stabilization endeavors (22,617 dam^3/yr, or

10.2% of the total water use). Together, these five users/uses divert 183,918 dam^3/yr of water from the Red Deer River, which represents 83.3% of the total amount of water permitted to be diverted. The western-most license to divert water from the Red Deer River was issued in the Williams Creek area in the James River subwatershed (Figure 40). The remaining licenses have been issued with greater concentrations near urban centres, e.g., Sundre, Red Deer and Drumheller, and in regions with low flow rates in streams and creeks, e.g., in the Matzhiwin and Alkali subwatersheds, or elevated agricultural intensities, e.g., in the Threehills and Kneehills subwatersheds (Government of Alberta, 2008d).

Table 27. Active licenses and surface water diversions from the Red Deer River (Government of Alberta, 2008d). The highest uses for water are highlighted.

Purpose	Active licenses	Surface water diversions (dam^3/yr)
Aggregate washing	1	50
Camps	2	1.1
Construction	15	150
Cooling	3	24,875
Co-operative, farmsteads, colonies	5	84
Crop (grain)	162	48,491
Drainage (gravel pits, mines)	2	68
Erosion	13	20,000
Feedlot	2	53
Fish, fish farms/hatcheries	1	123
Flood control	21	3,034
Gas/petrochemicals	7	25,500
Golf courses	7	444
Gardening, markets, gardens, greenhouses	4	40
Oilfield injection	12	5,032
Institutions (hospitals, etc.)	1	0.01
Drilling for well development	50	65
Other (abattoirs, dust control, etc.)	31	5,176
Parks	4	584
Recreation	7	268
Traditional agriculture	179	57
Specified by Director	3	5
Storage reservoir for wildlife	1	42
Stabilization	2	22,617
Stockwatering	153	885
Subdivisions	1	146
Urban	27	62,435
Crops-Deadfish Sheerness Agreements	1	261
Wetlands	5	174
Total	**731**	**220,660**

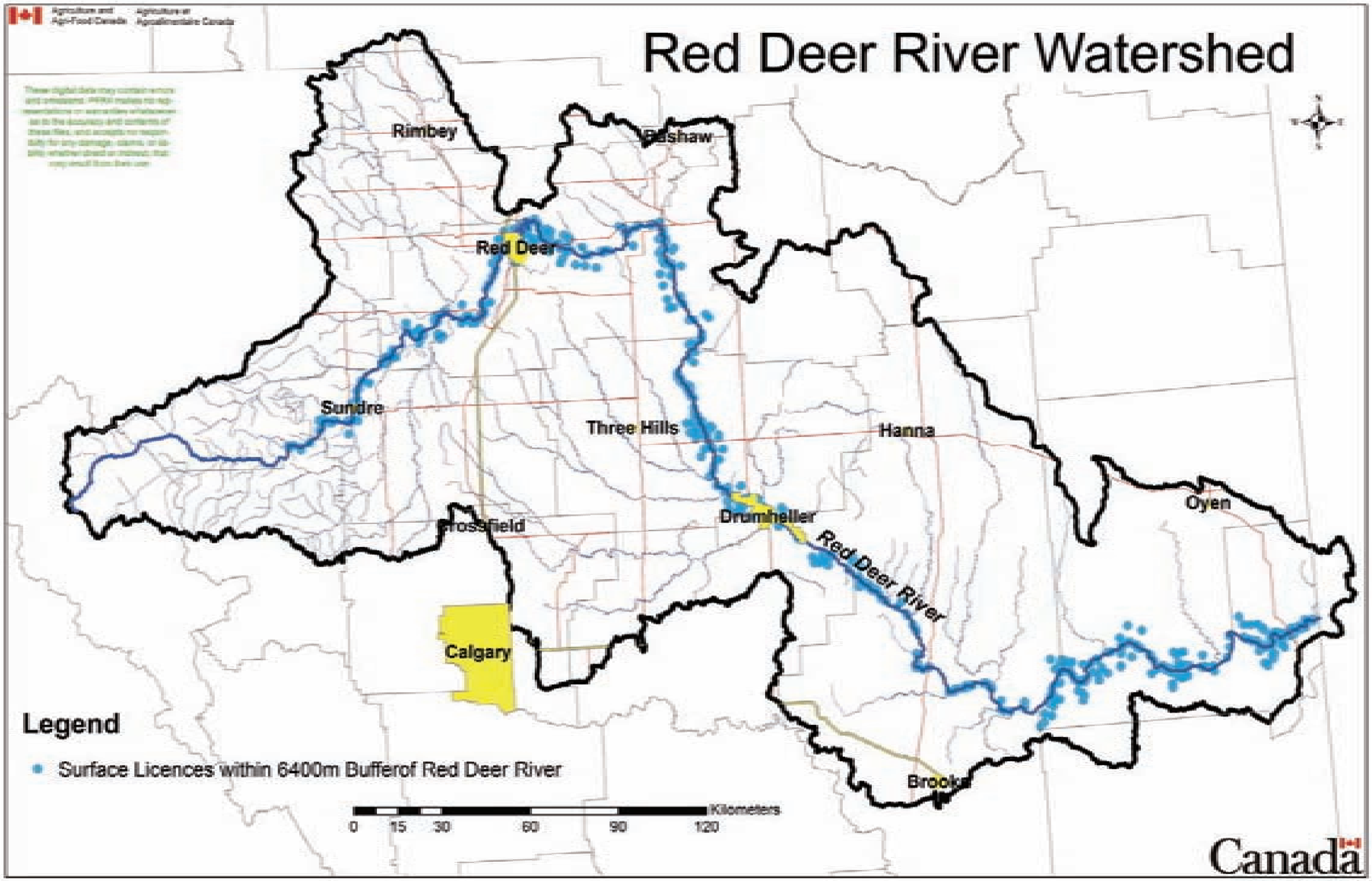


Figure 40. Active surface water licenses that permit water diversions from the Red Deer River (AAGC-PFRA, 2008).

An overview of current surface and groundwater allocations is shown in Figure 41. In 2005, the "Other" sector accounted for the largest percentage of water allocations in the watershed (30%, for use in water management, fish, wildlife and habitat enhancement and uses specified by a director of Alberta Environment). Allocations to the agricultural, municipal and petroleum sectors accounted for 24%, 19% and 13%, respectively. Total allocations in the Red Deer River watershed were 372,792 dam^3 in 2005 (Alberta Environment, 2007a).

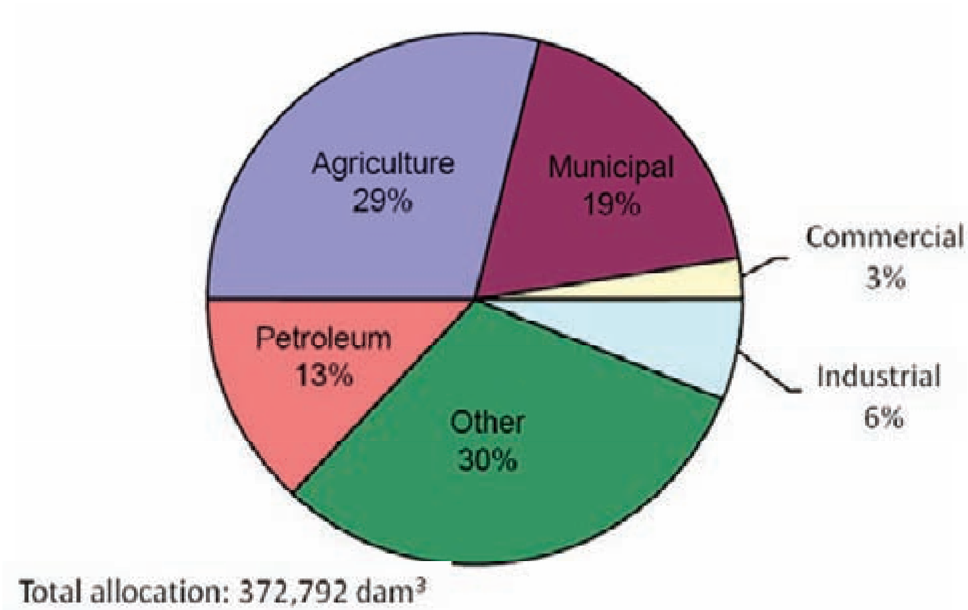


Figure 41. Distribution of active water allocations in the Red Deer River watershed (Alberta Environment, 2007a).

3.1.4.3 Municipal and Residential Sector

As of 2005, there were 342 active municipal surface and groundwater licenses for 133 licensees in the Red Deer River watershed. These licenses allow maximum withdrawals of 69,340 dam^3, which accounted for 19% of all licensed water allocations in the basin. Allocations to urban communities (cities, towns, villages, summer villages) accounted for 96% of total allocations. Rural users (subdivisions, cooperatives, farmsteads, single- and multi-family homes and colonies) accounted for 3% of total allocations, while other municipal uses (institutions, senior/correctional centres, nursing/children's homes, hospitals, schools and training centres) accounted for the remaining 1% (Alberta Environment, 2007a).

The municipal sector is allowed to withdraw up to 59,234 dam^3 of surface water from the Red Deer River watershed. Surface water licenses represent 85% of total municipal water allocations, and urban users have 21 licenses that allow total withdrawals of 58,588 dam^3 (99%). Surface water allocations to rural uses amount to only 616 dam^3 (14 licenses). For example, the City of Red Deer draws water from the Red Deer River to provide potable water to over 82,000 residents of the city. In addition, the Mountain View Regional Water Commission operates the Anthony Henday Water Treatment Plant, which provides potable water to 20,000 people in the towns of Innisfail, Bowden, Olds, Didsbury and Carstairs.

Municipal users are allowed to withdraw up to 10,105 dam^3 of groundwater. Groundwater licenses account for 15% of total municipal water allocations and urban users account for 79% of these allocations (8,023 dam^3 over 141 licenses). Another 1,628 dam^3 of groundwater has been allocated to rural users (over 124 licenses) (Alberta Environment, 2007a).

The combined allocations for large urban, rural and other municipal water licensees account for almost 97% of the total municipal allocation. It should be noted that the City of Brooks and the Town of Bassano draw their water from the Bow River watershed but are located in the Red Deer River watershed. Conversely, the Town of Stettler is located in the Battle River watershed but is drawing its water from the Red Deer River watershed (Alberta Environment, 2007a).

Most municipal allocations have been for urban surface water through time, with rapid growth in allocations occurring in the 1950's, 1970's and 1980's (Figure 42). Rural and urban groundwater allocations have grown steadily since 1990. Municipal water allocations have increased by 12% from 2000-2005 (Alberta Environment, 2007a).

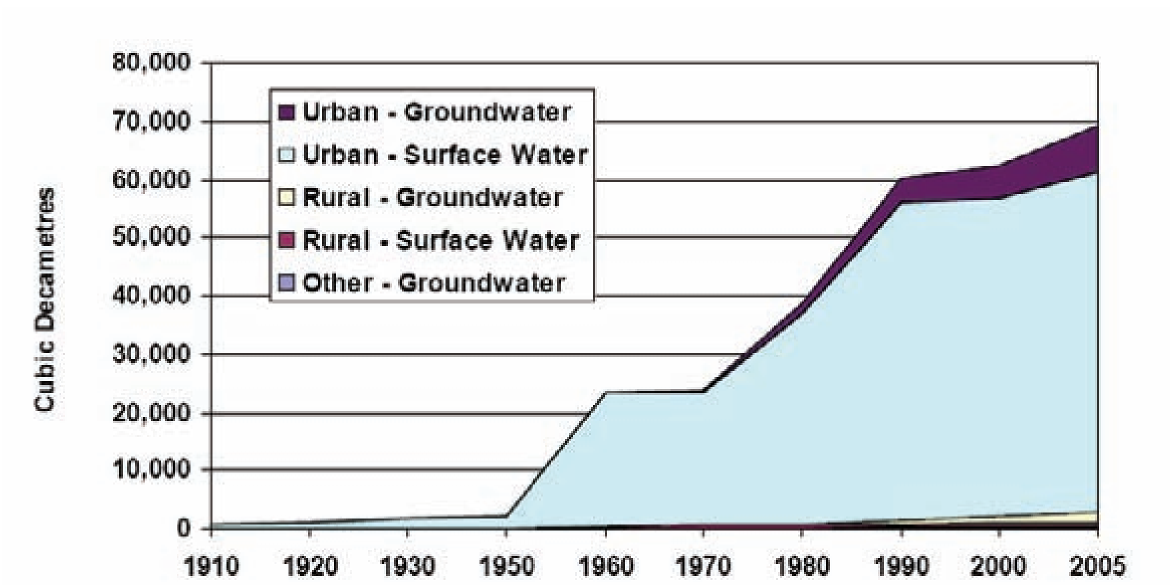


Figure 42. Red Deer River watershed historical water allocations for municipal purposes (Alberta Environment, 2007a).

Licenses for the municipal sector assume that a maximum of 33,733 dam^3 will be used (i.e., 49% of withdrawals can be consumed and/or lost) and the remainder (35,606 dam^3, or 51%) will be returned to surface water sources. The licenses issued to surface water users included 54% of diversions, but there were no return flow allowances for rural or other municipal users licensed to use surface water. Municipal users of groundwater are assumed to return 38% of their withdrawals, although this proportion ranges from 40% of the urban groundwater users to 26% for rural groundwater users. In 2005, only 5% of municipal licensees reported their water diversions to the provincial government through the Water Use Reporting System (WURS). These seven licensees were allowed to divert 28,374 dam^3, which represented 41% of total allocations for all municipal users in the basin. For 2005, they reported actual diversions of 21,367 dam^3, or 75% of their allocations. Only three of the seven licensees reported return flows in 2005, which totaled 1,506 dam^3, or about 7% of the actual diverted amounts Additional information on municipal water use is available from Environment Canada's Municipal Use Database (MUD) (Alberta Environment, 2007a) and from Associated Engineering Alberta Ltd. (2008).

Municipalities currently withdraw about 68% of their licensed allocations. This ranges from 74% for surface water users to 33% for groundwater users. Surface water use is 78% and groundwater use is about 22% of the licensed water use amounts. Overall, municipal water use is estimated to be 67% of the municipal use allocation within Red Deer River watershed (Alberta Environment, 2007a).

The *Water Act* allows water to be diverted for "household purposes" without a license. A household purpose means the water must be used for the purposes of human consumption, sanitation, fire prevention and watering animals, gardens, lawns and trees. The water cannot be used for commercial or agricultural purposes. The household user exemption applies to "riparian owners" or those whose land directly borders a watercourse or waterbody or to owners with groundwater underneath their land. A household user does not include persons who receive water from a municipality or another licensed water supply. The maximum amount that may be diverted is 1,250 m^3 per household per year; amounts over 1,250 m^3 per household per year require a water license. The quantity of water used in this manner in Alberta is unknown, since no licenses are required and this use of water cannot be registered.

3.1.4.4 Agricultural Sector

As of December 2005, a total of 107,448 dam^3 had been allocated to the agricultural sector in the Red Deer River watershed. This included 19,023 registrations representing 13,047 dam^3 and 4,243 licenses representing 94,400 dam^3 of water. Water allocated to agriculture accounted for 29% of all allocations in the Red Deer River watershed (Figure 41). Figure 43 shows how this water is distributed among the different agricultural uses in the watershed. The largest allocation is for private irrigation (65%). Stockwatering accounted for 21%, registration accounts for 12% and feedlot and district irrigation together account for 3% of the total allocation (Alberta Environment, 2007a).

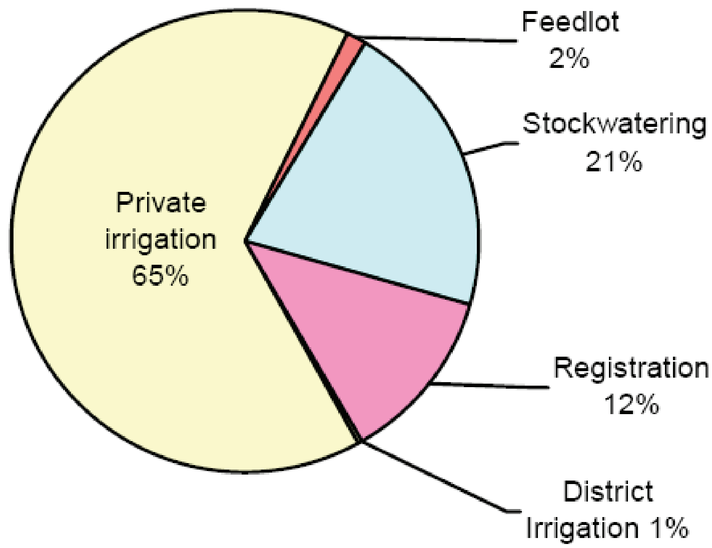


Figure 43. Water allocation for agricultural activities in the Red Deer River watershed (Alberta Environment, 2007a).

A total of 9,677 registrations and 2,222 licenses allow withdrawals of up to 87,369 dam^3 of surface water, which accounts for 81% of all water allocated to the agricultural sector. Groundwater accounts for 19% of allocations for agricultural purposes (2,021 licenses and 9,346 registrations have been issued to withdraw up to 20,078 dam^3 of groundwater) (Alberta Environment, 2007a). About 55% of the farms in the Red Deer Basin were classified as livestock operations, raising primarily cattle. Overall 22,766 licenses and registrations have been issued for livestock watering with total allocation amounting to 57,096 dam^3. In addition to these allocations, farmers are able to obtain up to 1,250 m^3 of water for household purposes and can also obtain water as "exempted agricultural" users. There is no information on either the numbers of such households or the amount of unlicensed water use in the watershed.

A historical perspective on water used for livestock is provided in Figure 44, showing that some registrations were issued with priority dates in the 1890s, while licenses for stockwatering began to be issued in the early 1900s (Alberta Environment, 2007a). Allocations for stockwatering have risen steadily since the 1920s, with substantial increases occurring in groundwater registrations, which now account for about 50% of all allocations. Since 1990, surface water and groundwater allocations have remained relatively steady at around 57,000 dam^3. Over the last few decades, there has been an increase in the number of intensive livestock operations in Alberta, including feedlots. In the Red Deer River watershed, the first allocations for feedlots were issued in the 1980s, currently accounting for about 3% of total livestock water allocation. The majority of licenses and registrations for stockwatering show no return flow allowances. There are allowances for return flows of 3.7 dam^3 from some surface water licenses, but this represents less than 0.01% of total water allocations for livestock. There is a projected increase in water requirements for livestock watering. Assuming a continued growth rate of livestock (2.2%/year from 1958-2001) (Alberta Environment, 2007a) and the same groundwater/surface water ratio, Associated Engineering Alberta Ltd. (2008) projected a nearly doubling of water requirements by 2031 and a nearly tripling of water requirements by 2056 to sustain livestock operations.

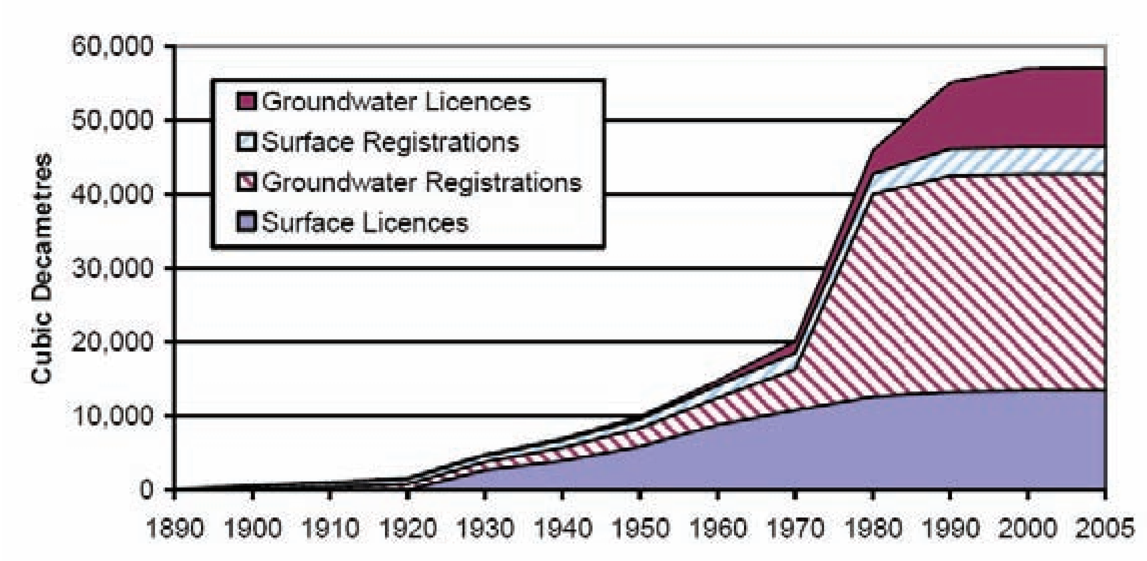


Figure 44. Historical trends in water allocation for livestock in the Red Deer River watershed (Alberta Environment, 2007a).

There is no information in Alberta Environment's WURS that indicates the extent to which water allocations are actually used in the Red Deer River watershed; however, a reasonable estimate of water use can be derived using the actual animal population in the watershed. Based on livestock populations in the Red Deer River watershed in 2001, the total water required for livestock was estimated to be 21,289 dam^3, or about 57% of the licensed allocation. In terms of water requirements by species, cattle account for about 85% of the total, about 9% is required by pigs, 1% is required by poultry and all other species accounted for the remaining 5% (Alberta Environment, 2007a). While the estimated actual consumption based on livestock populations (21,289 dam^3) appears to be less than the amount of water allocated (37,130 dam^3), the actual consumption figure does not include an allowance for the evaporative and seepage losses associated with storing water for livestock use. Typically, licensed consumption accounts for only 35% of surface water allocated for livestock use, while losses account for 65% (Watrecon Consulting, 2005). Since 54% of livestock water consumption comes from groundwater (no losses) and the balance comes from surface water with 65% losses, a total allocation of 26,562 dam^3 would be required to support the animal populations in the watershed. This water requirement is about is about 70% of the water allocation through licenses and registrations. While the analysis suggests that allocations exceed actual livestock requirements, this may not necessarily be the case, because many farmers have multiple registrations so that, in dry years, they will have sufficient water even if their dugouts are only half full (Alberta Environment, 2007a).

The other major use of water for agricultural purposes is irrigation or crop watering. Although some licenses have been issued for district irrigation in the Red Deer River watershed, the acres actually irrigated are located outside the basin; however, these allocations are very small (28 dam^3, or 0.04% of allocation for irrigation). Almost all of the irrigation in the Red Deer River watershed is done by private irrigators, who have their own water licenses and divert water using their own pumps and water distribution equipment. When aggregate information from the 2001 Census of Agriculture for individual counties and municipal districts is modified to reflect river watershed boundaries, the resulting estimates suggest that about 99,150 ha of land in the Red Deer River watershed were irrigated in 2001. This number could be incorrect though, because irrigation hectares are not evenly distributed throughout each of the counties that make up the watershed and because of likelihood of inaccuracy in the Census data. A better estimate of the irrigated hectares can be made based on water allocations and irrigation requirement of about 450 mm. Based on this requirement, it is estimated that water allocations are sufficient to support irrigation of about 23,470 ha (Alberta Environment, 2007a).

There are 495 private licenses that allocate about 70,288 dam^3 for irrigation purposes. Over 99% of irrigation allocations are for surface water. The Red Deer River watershed accounts for about 10% of water allocations for private irrigation and about 20% of the private irrigation licenses in Alberta. Historically, allocation for irrigation commenced in about 1910 (Figure 45) (Alberta Environment, 2007a). Water allocations began to increase in the 1920s and grew very rapidly in the 1960s and 1970s. Since the 1980s, allocations have remained stable (Alberta Environment, 2007a). Associated Engineering Alberta Ltd. (2008) projected a 2.4- and 2.6-fold increase in water requirements for irrigation purposes by 2031 and 2056, respectively.

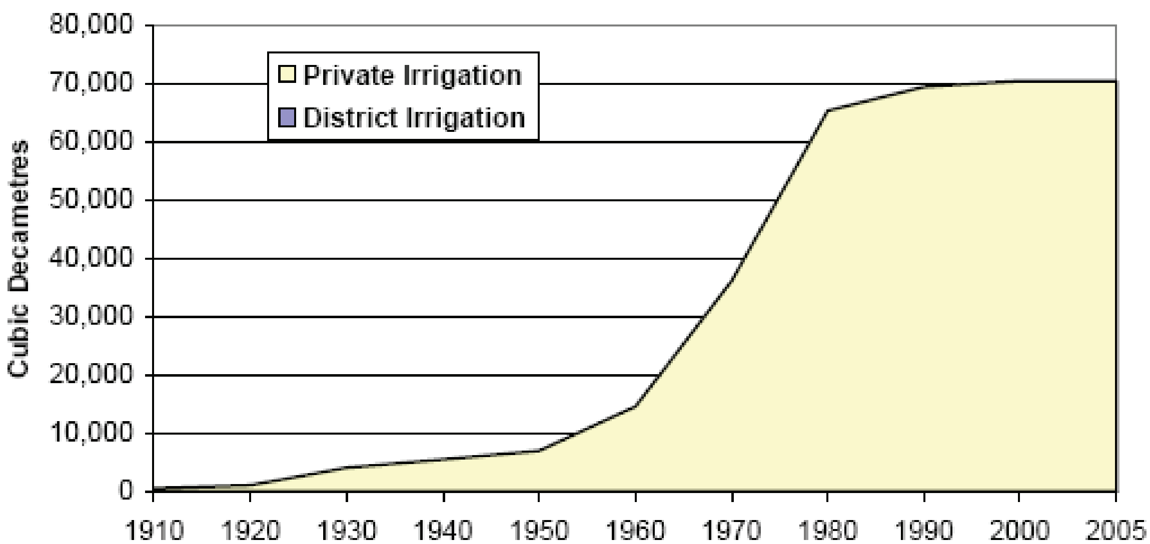


Figure 45. Historical trends in surface water allocation for irrigation in the Red Deer River watershed (Alberta Environment, 2007a).

Licenses issued for surface water assume that up to 97% of the total allocation will be used and that only 3% (1,951 dam^3) will be returned to surface sources. No return flow is associated with groundwater allocation. Neither AAFD nor AENV has any information on actual water use by private irrigators. It is assumed that actual use is equal to licensed water use; however, water use in any given year will depend on how much of the crop water demand can be satisfied by natural precipitation. Water allocated for crop watering use is 2.6 times the amount of water that can be used for stockwatering (Alberta Environment, 2007a). Additional information on agricultural water use can be found in Associated Engineering Alberta Ltd. (2008).

The *Water Act* allows water to be diverted for "agricultural use" without a license. Agricultural use means the water must be used for the purposes of raising animals or applying pesticides to crops as part of an agricultural operation on or before January 01, 1999. The agricultural use exemption applies to "riparian owners" or those whose land directly borders a watercourse or waterbody or to owners with groundwater underneath their land. The maximum amount that may be diverted is 6,250 m^3 per year or an amount specified in an "approved water management plan" for an area, whichever amount is greater. An agricultural user also has the right to divert water for household purposes without a license, for a total amount of 7,500 m^3 per year. An agricultural user could register this use with Alberta Environment until January 01, 2002, but not thereafter. Hence, it is unknown how much water is used under this exemption in the agricultural sector.

3.1.4.5 Commercial Sector

There are 248 licenses that allow diversion of about 9,948 dam^3 of water for use by the commercial sector in the Red Deer River watershed. This allocation accounts for 3% of total allocations in the watershed. More than 60% of the water allocations for commercial purposes are for parks and recreation (78 licenses with allocation of 6,032 dam^3) (Figure 46). Other important commercial activities include golf courses (52 licenses with allocation of 1,310 dam^3) and aggregate washing (21 licenses with allocation of 941 dam^3). Allocations for all other commercial activities are relatively minor, accounting for 16% of the total (Alberta Environment, 2007a).

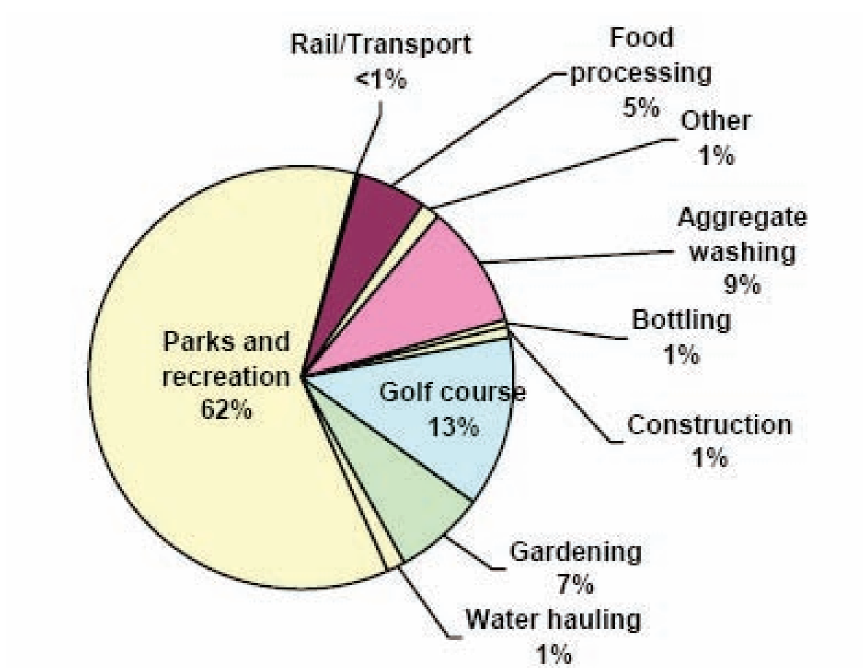


Figure 46. Water allocation for commercial activities in the Red Deer River watershed (Alberta Environment, 2007a).

Licenses issued for the commercial sector allow maximum withdrawals of about 8,696 dam^3 of surface water; surface water accounts for 86% of allocations for commercial purposes. The largest surface water allocation is for parks and recreation, which accounts for about 70% of the total surface water allocation. Fourteen % of commercial allocations are for groundwater with licenses for 1,251 dam^3. The largest groundwater allocation is for golf courses, which account for about 20% of total groundwater allocations (Alberta Environment, 2007a).

Historically, the earliest allocations began in the 1900s for groundwater, but the allocations remained relatively unchanged until the 1950s (Figure 47). Groundwater allocations increased gradually since then but have remained relatively constant since 2000. The first surface water allocations were issued in the 1900s and remained relatively unchanged until the 1920s. Since that time, there have been sharp increases in allocations related to parks and recreation and gardening activities, although there have been no additional allocations since 2000. Overall, groundwater allocations make up a small proportion of total water allocations for commercial purposes (Alberta Environment, 2007a). Alberta Environment (2007a) used a forecast of average long-term economic growth rates to project the growth in aggregate washing (2.2%). Assuming a similar growth rate for the food industry, projected increases in water requirements in these two commercial sectors suggests a doubling and tripling in water requirements by 2031 and 2056, respectively (Associated Engineering Alberta Ltd., 2008).

Return flow allowances in licenses specified a total of 3,256 dam^3 (33% of allocation) to be returned. Return flow allowances in licenses amount to 37% of surface water allocations, but only 2% of groundwater allocations. Return flow requirements ranged from 13% for aggregate washing to 36% for bottling to 52% for parks and recreation to 82% for construction (Alberta Environment, 2007a).

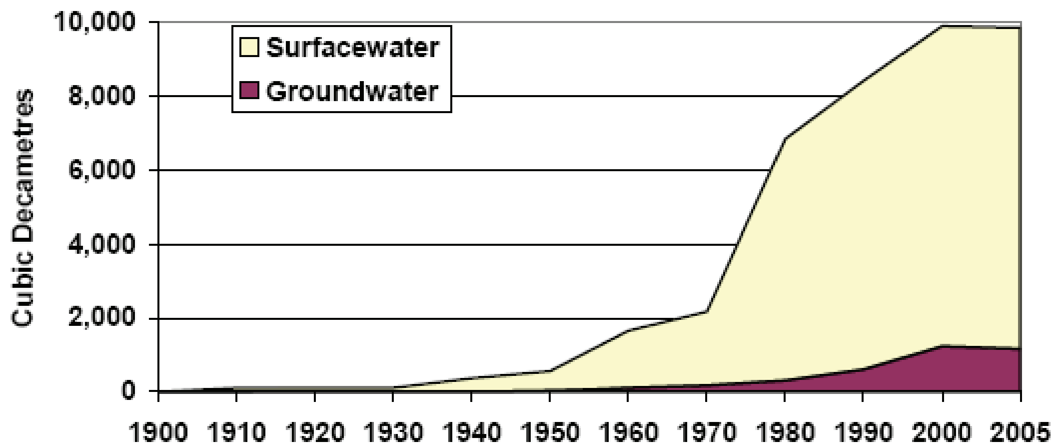


Figure 47. Historical trend in commercial sector water allocation in the Red Deer River watershed (Alberta Environment, 2007a).

Presently, Alberta Environment's WURS contains very little information on actual water use in 2005 by any of the licensees in commercial sector in the Red Deer River watershed. The data base contains only one report for parks and recreation and the reported use of 0.2 dam^3 represents less than 0.01% of total allocation for that activity. Given the lack of information on actual water use for commercial purposes, it is assumed that all licensees are withdrawing and using the full amounts of water to which they are entitled. While this assumption may overstate actual water use in the watershed, the commercial sector accounts for 3% of total allocations, so it will not appreciably affect overall water use estimate for the Red Deer River watershed (Alberta Environment, 2007a).

3.1.4.6 Petroleum Sector

In the Red Deer River watershed, there are 126 active licenses, which allocate 49,021 dam^3 of water to the petroleum sector. Petroleum water licenses account for 13% of total water allocations in the watershed. The majority (94%) of the allocations are for surface water (46,240 dam^3). This sector includes water allocations for oilfield injection, gas and petrochemical plants, drilling and various other activities (Alberta Environment, 2007a).

Almost 26% of the allocations are for injection purposes for enhanced oil and gas recovery (12,526 dam^3) (Figure 48). To date, 55 licenses have been issued for injection purposes, with surface water accounting for almost 88% of allocations. Water use for injection began in the 1950s and grew steadily until about 1990, but has remained constant since then (Figure 49) (Alberta Environment, 2007a). Oil production in Alberta for conventional crude is expected to decline as existing fields become depleted and new discoveries become less frequent. Surface water use for injection purposes in the Red Deer River watershed is expected to follow the provincial trend in oil production and decline about 5.0%/year (Associated Engineering Alberta Ltd., 2008).

The licenses issued for injection purposes assume 100% of allocations will be used. Detailed summary of reported water used for injection have been prepared by GEOWA Information Technologies Ltd. based on Energy Resources and Conservation Board (ERCB) data. In 2005, 398 dam^3 of fresh water was diverted for injection purposes. This volume included 182 dam^3 of surface water and 216 dam^3 of groundwater. Injection activities in the watershed are currently diverting and using about 3% of their licensed allocations and use (Alberta Environment, 2007a).

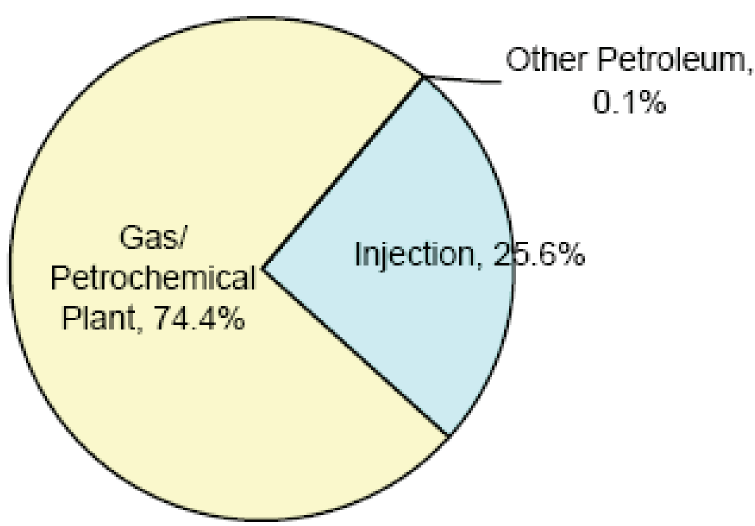


Figure 48. Petroleum water allocation by use in the Red Deer River watershed (Alberta Environment, 2007a).

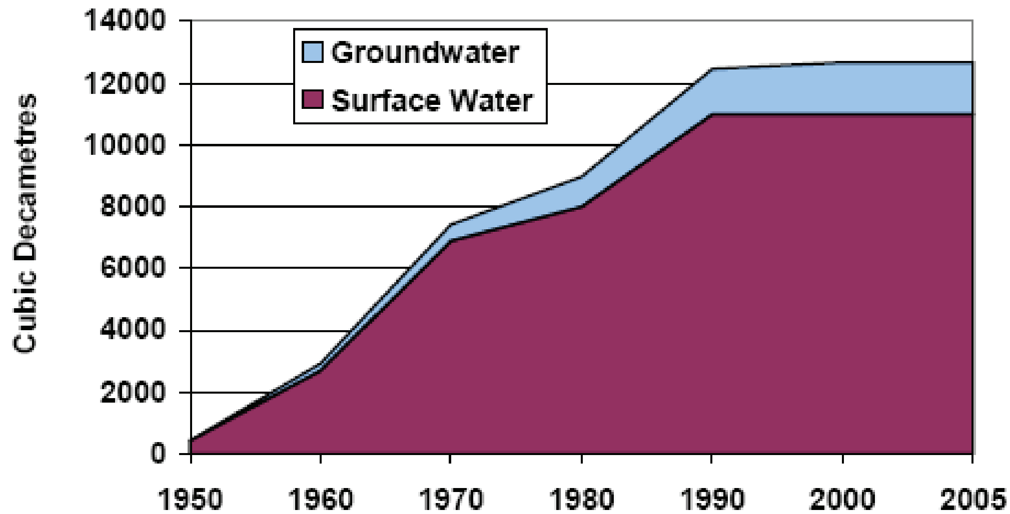


Figure 49. Historical trends in water allocations for injection (Alberta Environment, 2007a).

The majority of the allocations for the petroleum sector in the Red Deer River watershed (74%) are for gas/petrochemical plants (36,460 dam^3). This includes a relatively large number of groundwater licenses (41) with a small total allocation (1,224 dam^3) and 22 surface water allocations with a much larger allocation of 30,872 dam^3 (Alberta Environment, 2007a). The first allocations of surface water for gas/petrochemical plants were issued in the 1950s for a very small amount of water (62 dam^3). Allocations increased sharply in the 1980s, peaked in the 1990s and have declined since then (Figure 50). Groundwater licenses issued to gas/petrochemical plants have no return flow (100% consumption), while surface water licenses assume that 78% of diversions of surface water will be consumed (22% return flow) (Alberta Environment, 2007a).

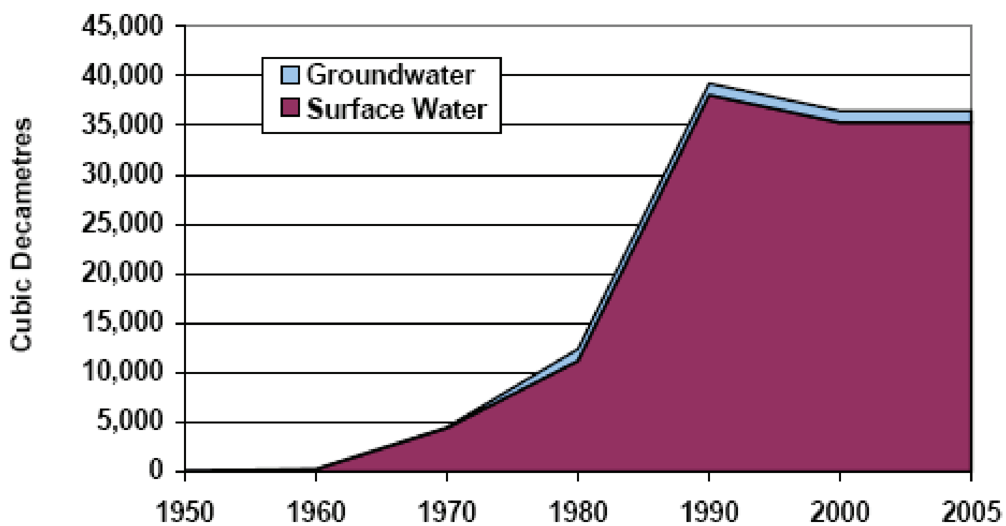


Figure 50. Historical trends in water allocations for gas and petrochemical plants (Alberta Environment, 2007a).

The WURS database has water use information for 24 of the 64 water licenses issued for gas/petrochemical plants in the Red Deer River watershed. These licenses account for only 31% of allocations for surface water and they reported using 59% of their allocations. This information is insufficient to provide a reliable assessment of actual surface water use by all gas/petrochemical plants in the Red Deer River watershed. Thus, estimates of actual water use were based on provincial trends. Analysis of the WURS database for the entire province indicated that plants with surface water allocations were using an average of 48% of their allocations and 58% of the water that they are expected to consume. This matched the water use reported in the Red Deer River watershed. Hence, surface water use in the watershed in 2005 was estimated based on 58% of licensed water use, or about 17,920 dam^3. The WURS database contains actual groundwater use information for licensees that account for 85% of total groundwater allocations. The water use reports indicated that these licensees were actually using 263% of the water that they are licensed to use. Estimates of actual groundwater use in 2005 are based on actual use for the licensees who reported groundwater use quantities and 99% use for the other licensees (matched the provincial rate). Thus, use of groundwater for gas/petrochemical plants in the Red Deer River watershed was estimated to be 2,924 dam^3 in 2005 (Alberta Environment, 2007a).

Two licenses have been issued for drilling, which allow withdrawals of up to 1.2 dam^3 of surface water and 8.6 dam^3 of groundwater. Water licenses issued for drilling began in the 1990s and have increased slightly over time. Licensees are expected to consume all of the water they withdraw. There is no information on actual water diversions and consumption for these other petroleum uses, and it is assumed that licensees are using their full entitlement (Alberta Environment, 2007a).
Five licenses have been issued for other petroleum use. They allow withdrawals of up to 15 dam^3 of surface water and 11 dam^3 of groundwater. The first licensees for other petroleum uses were issued in the 1990s and have increased slightly over time. Holders of the licenses are expected to consume all of the water they withdraw. There is no information on actual water diversions and consumption for these other petroleum uses, and it is assumed that licensees are using their full entitlement and there are no return flows (Alberta Environment, 2007a).

3.1.4.7 Industrial Sector

In the Red Deer River watershed, there are 20 active licenses, which allocate 22,315 dam^3 of water to the industrial sector. Industrial water licenses account for 6% of the total allocations in the watershed. The majority (99.5%) of all water allocations to the industrial sector is for surface water (22,210 dam^3). Water is used for cooling, forestry, fertilizer plants, manufacturing, coal mining and other industrial activities (Figure 51) (Alberta Environment, 2007a).

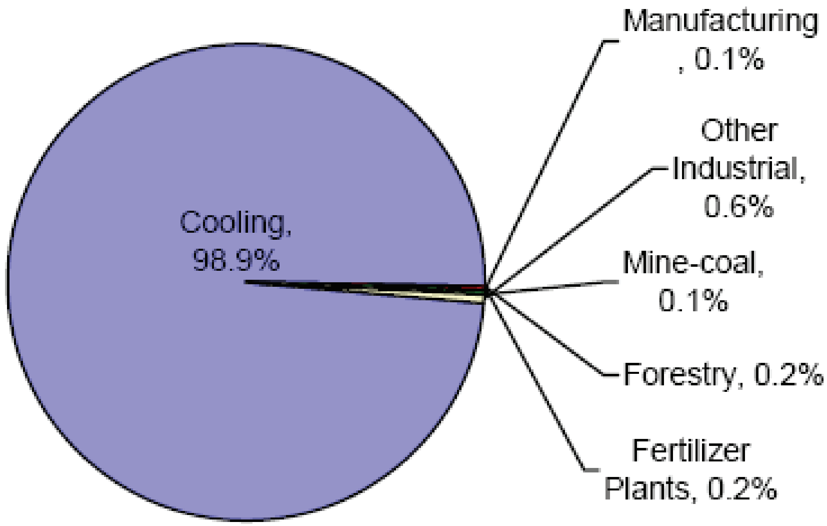


Figure 51. Water allocations for the industrial sector in the Red Deer River watershed (Alberta Environment, 2007a).

About 98% of the industrial allocations are for thermal power generation cooling purposes or for general cooling purposes, such as air conditioning (22,076 dam^3). Four surface water licenses have been issued for cooling purposes. Water use for cooling began in the 1970s, increased in the 1980s and 1990s, but has remained constant since 2000 (Figure 52) (Alberta Environment, 2007a). Based on Alberta Environment's (2007a) projection of no growth in the cooling industry sector for the next 20 years, Associated Engineering Alberta Ltd. (2008) anticipated no change in water requirements by this sector until 2031 and the expansion of the industry by one new plant by the year 2056, which would use an addition 3,500 dam^3 (Alberta Environment, 2007a).

The licenses issued for cooling purposes assume 62% of surface water allocations will be used. Return flow allowances in licenses amounted to 8,388 dam^3. There is no information on actual water diversions and consumption for the industrial cooling sector, and it is assumed that licensees are using the full amount of water they are expected to use (Alberta Environment, 2007a).

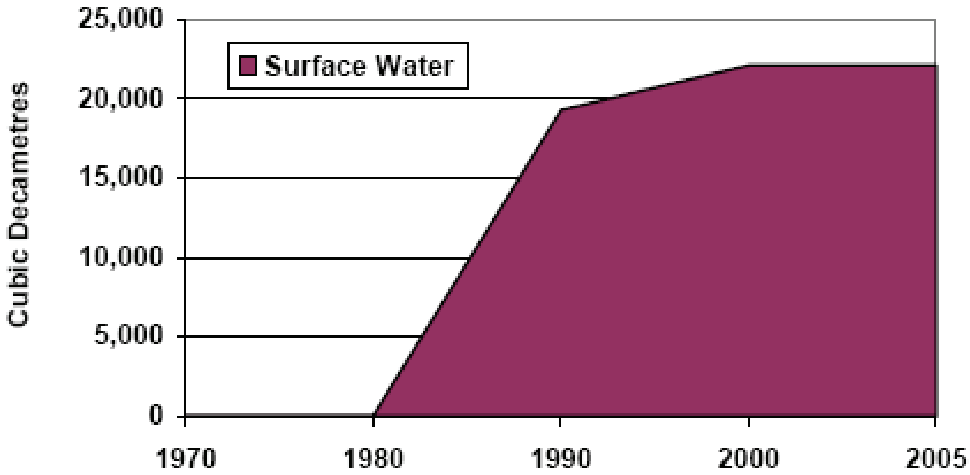


Figure 52. Historical trends in water allocations for cooling in the Red Deer River watershed (Alberta Environment, 2007a).

One license has been issued for forestry in the Red Deer River watershed allowing withdrawals of up to 36 dam^3 of groundwater. Forestry water allocation began in the 1990s and has remained the same since. The licensee is expected to consume 100% of the groundwater that is allocated. There is no information on actual water diversions and consumption for forestry-related activities, and it is assumed that the licensee is using its full entitlement (Alberta Environment, 2007a).

Two licenses have been issued for fertilizer plants in the Red Deer River watershed allowing withdrawals of up to 44 dam^3 of groundwater. The allocations for fertilizer plants were issued in the 1980s and have remained the same since. Licenses assume that fertilizer plants will use 22% of the water they are allocated. Return flow allowances in licenses amounted to 35 dam^3. There is no information on actual water diversions, consumption or return flows for fertilizer plants, and it is assumed that licensees are using their full entitlement. In the absence of information about this component of the industrial sector, it is assumed that water used by fertilizer plants in the Red Deer River watershed will remain constant for the forecast period (2005-2025) (Alberta Environment, 2007a).

Four licenses have been issued for manufacturing activities in the Red Deer River watershed allowing withdrawals of up to 14 dam^3 of groundwater. Manufacturing water allocation commenced in the 1970s and did not grow until the early 2000s. Licensees are assumed to consume 100% of the water they are allocated. There is no information on actual water diversions, consumption or return flows for manufacturing activities, and it is assumed that licensees are using their full entitlement. In the absence of information about this component of the industrial sector, it is assumed that water used by manufacturing in the Red Deer River watershed will remain constant for the forecast period (Alberta Environment, 2007a).

Three licenses have been issued for mining activities other than coal in the Red Deer River watershed allowing withdrawals of up to 3 dam^3 of groundwater. Mining other than coal water allocation commenced in the 1980s and grew slightly in the early 2000s. Licensees are assumed to consume 100%

of the water they are allocated. There is no information on actual water diversions, consumption or return flows for mining activities other than coal, and it is assumed that licensees are using their full entitlement. In the absence of information about this component of the industrial sector, it is assumed that water used by mining activities other than coal in the Red Deer River watershed will remain constant for the forecast period (2005-2025) (Alberta Environment, 2007a).

One license has been issued for coal mining in the Red Deer River watershed allowing withdrawals of up to 12 dam^3 of groundwater annually. Coal mining water allocation commenced in the 1980s and has remained the same since. The licensee is assumed to consume 100% of the groundwater that is allocated. There is no information on actual water diversions and consumption for coal mining, and it is assumed that licensees are using their full entitlement. In the absence of information about this component of the industrial sector, it is assumed that water used by coal mining in the Red Deer River watershed will remain constant for the forecast period (2005-2025) (Alberta Environment, 2007a).

Five licenses have been issued for "other" industrial purposes. They allow withdrawals of up to 122 dam^3 of surface water and 7 dam^3 groundwater. Other industrial water allocations commenced in the 1950s for surface water and the 1920s for groundwater. Both sources have remained the same over time. Licensees are assumed to consume 100% of the water they are allocated. There is no information on actual water diversions, consumption or return flows for other industrial activities, and it is assumed that licensees are using their full entitlement. In the absence of information about this component of the industrial sector, it is assumed that water used by other industrial activities in the Red Deer River watershed will remain constant for the forecast period (2005-2025) (Alberta Environment, 2007a).

3.1.4.8 Other Users

In the Red Deer River watershed, a total of 263 active licenses have been issued for other purposes, and these licenses allow diversions of up to 114,640 dam^3 of water. These allocations consist almost entirely of surface water (111,635 dam^3, or 97%). Water allocations to the other sector uses are primarily for water management, fish, wildlife and habitat enhancement and uses specified by a director of Alberta Environment (Figure 53) (Alberta Environment, 2007a). These allocations generally increase or restore water storage capability in the landscape.

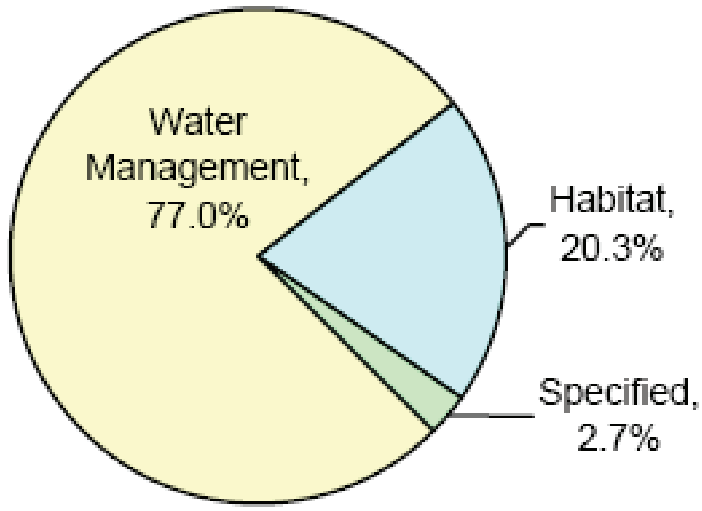


Figure 53. Other sector water allocations by use in the Red Deer River watershed (Alberta Environment, 2007a).

Almost 77% of the allocations are for water management purposes, such as flood control and lake stabilization (88,263 dam^3). To date, 41 licenses have been issued for water management purposes, and all but one are for surface water. One groundwater license with an allocation of 0.5 dam^3 has been issued for water management in the Red Deer River watershed. Historically, surface water use for water management commenced in the 1940s, stayed relatively constant until the 1960s, grew rapidly during the 1980s, and has remained constant since 1990 (Figure 54) (Alberta Environment, 2007a).

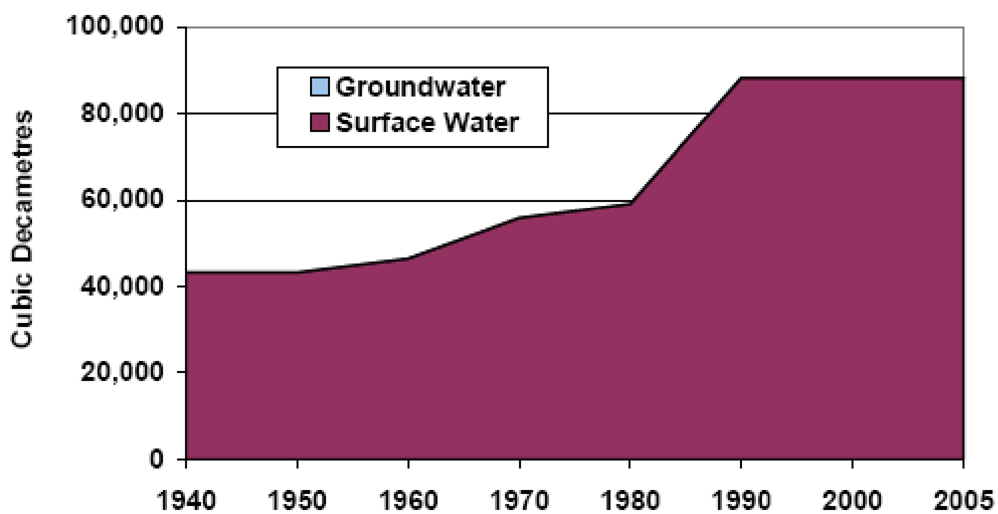


Figure 54. Historical trends in water allocations for water management in the Red Deer River watershed (Alberta Environment, 2007a).

Licenses issued for water management purposes assume about 46% of their surface water allocations and 100% of groundwater allocations to be used. Return flow allowances in licenses total 47,557 dam^3 for surface water. There is no information on actual water diversions and consumption for water management activities, and it is assumed that licensees are using their full entitlement. In the absence of information about this component of the other sector, it is assumed that water used for water management in the Red Deer River watershed will remain constant for the forecast period (2005-2025) (Alberta Environment, 2007a) and beyond (2056; Associated Engineering Alberta Ltd., 2008).

About 20% of the allocations are for fish, wildlife and habitat enhancement (23,287 dam^3). In total, 218 licenses have been issued for habitat projects, with nearly 91% of these for surface water. Twenty licenses have been issued for groundwater, with allocations of 144 dam^3. Surface water use for habitat commenced in the 1940s, but grew rapidly between the 1950s and the early 2000s. The first licenses for water for habitat enhancement were issued in the 1920s and allocations increased slightly between the 1990s and the 2000s. Licenses issued for habitat enhancement purposes assume that about 90% of surface water allocations and 63% of groundwater allocations will be used. Return flow allowances in licenses amounted to 2,392 dam^3 for surface water and 54 dam^3 for groundwater. There is no information on actual water diversions and consumption for habitat enhancement activities, and it is assumed that licensees are using their full entitlement (Alberta Environment, 2007a). Assuming a 1.0% growth rate for the forecast periods, projected water use will increase by about 30% by 2031 and 65% by 2056 (Associated Engineering Alberta Ltd., 2008).

Less than 3% of the allocations for other purposes are for uses specified by a director of Alberta Environment. These allocations total 3,089 dam^3. Two licenses have been issued for groundwater (2,860 dam^3) and account for 93% of allocations for this activity. The initial licenses were issued for surface water use in the 1910s and allocations have only increased slightly since then. Allocations of groundwater for specified activities began in the 1950s and have remained relatively constant since then. Licenses issued for director-specified purposes allow use of up to 100% of surface water allocations and 55% of groundwater allocations. Return flow requirements in licenses amounted to 1,277 dam^3 for groundwater. There is no information on actual water diversions and consumption for specified activities, and it is assumed that licensees are using their full entitlement. In the absence of information about this component from other users, it is assumed that water used by activities specified by the director in the Red Deer River watershed will remain constant for the 2005-2025 forecast period (Alberta Environment, 2007a) and beyond (2056; Associated Engineering Alberta Ltd., 2008).

3.2 Natural Regions in the Red Deer River Watershed

The Red Deer River traverses five Natural Regions within Alberta: the Rocky Mountain, Foothills, Boreal, Parkland and Grassland Natural Regions (Figure 55) (Government of Alberta, 2007). The Natural Regions classification was adopted by the Government of Alberta to represent ecosystem and biodiversity elements of importance to protected areas. The classification system emphasizes the overall landscape pattern, which mainly reflects climate, but in other cases may predominantly reflect geological and soil factors. The purpose of the Natural Regions classification is to account for the entire range of natural landscapes and ecosystem diversity and is related primarily to ecosystem and biodiversity conservation.

Brief descriptions of the five Natural Regions and 12 relevant Subregions follow below (Heritage Community Foundation, 2008). For more details, please refer to Achuff (1994).

3.2.1 Rocky Mountain Natural Region

The Rocky Mountain Natural Region is underlain primarily by upthrust and folded bedrock. This region is the most rugged topographically. Elevations drop from west to east, from 3,700 m along the Continental Divide to 1,500-1,000 m in river valleys. Two Subregions reflect changes in environmental conditions in response to changes in altitude (Heritage Community Foundation, 2008).

3.2.1.1 Alpine Subregion

The Alpine Subregion includes all areas above the tree line. Materials generally are residual bedrock and colluvium (loose bodies of sediment that have been deposited or built up at the bottom of a low-grade slope or against a barrier on that slope). Extensive areas of unvegetated bedrock occur. The mean May-September temperature is about 6 °C, and frost-free periods are rare. Mean annual precipitation is highly variable and ranges from 420-850 mm. Much of this Subregion has no soil. Alpine vegetation typically forms a complex mosaic, in which microclimatic variations are reflected in marked changes in dominant species (Heritage Community Foundation, 2008).

3.2.1.2 Subalpine Subregion

The elevation of the Subalpine Subregion ranges from about 1,600-2,300 m. Morainal materials (glacially formed accumulation of unconsolidated debris, e.g., soil and rock) occupy the majority of the Subregion with colluvial and residual bedrock materials frequent at higher elevations. Fluvial (deposits and landforms created by the action of rivers or streams) and glaciofluvial (deposits and landforms associated with glacial processes) deposits are common along stream valleys. The mean annual temperature ranges from -1 °C to 3 °C, with a mean July temperature of about 15 °C. Below freezing temperatures occur in all months. Total annual precipitation is highly variable and ranges from 460-1,400 mm. Winter precipitation is higher in this Subregion than in any other, with often more than 200 cm of snowfall. Soils vary widely, reflecting the great diversity in parent materials and ecological conditions. The Subalpine Subregion is often divided into a Lower Subalpine characterized by closed forests of lodgepole pine (*Pinus contorta* Douglas *ex* Louden), Engelmann spruce (*Picea engelmannii* Parry *ex* Engelm.) and subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.) and an Upper Subalpine with spruce-fir closed forests and open forests near the tree line. At lower elevations, lodgepole forests cover extensive areas following fire. Engelmann spruce and subalpine fir forests typically occur on higher, moister sites that have not been subject to fire. Open forests in the Upper Subalpine are transitional to the treeless Alpine Subregion above. Dominant trees include Engelmann spruce (*P. engelmannii*), subalpine fir (*A. lasiocarpa*) and whitebark pine (*Pinus albicaulis* Engelm.). High elevation grasslands occur in the Subalpine Subregion (Heritage Community Foundation, 2008).

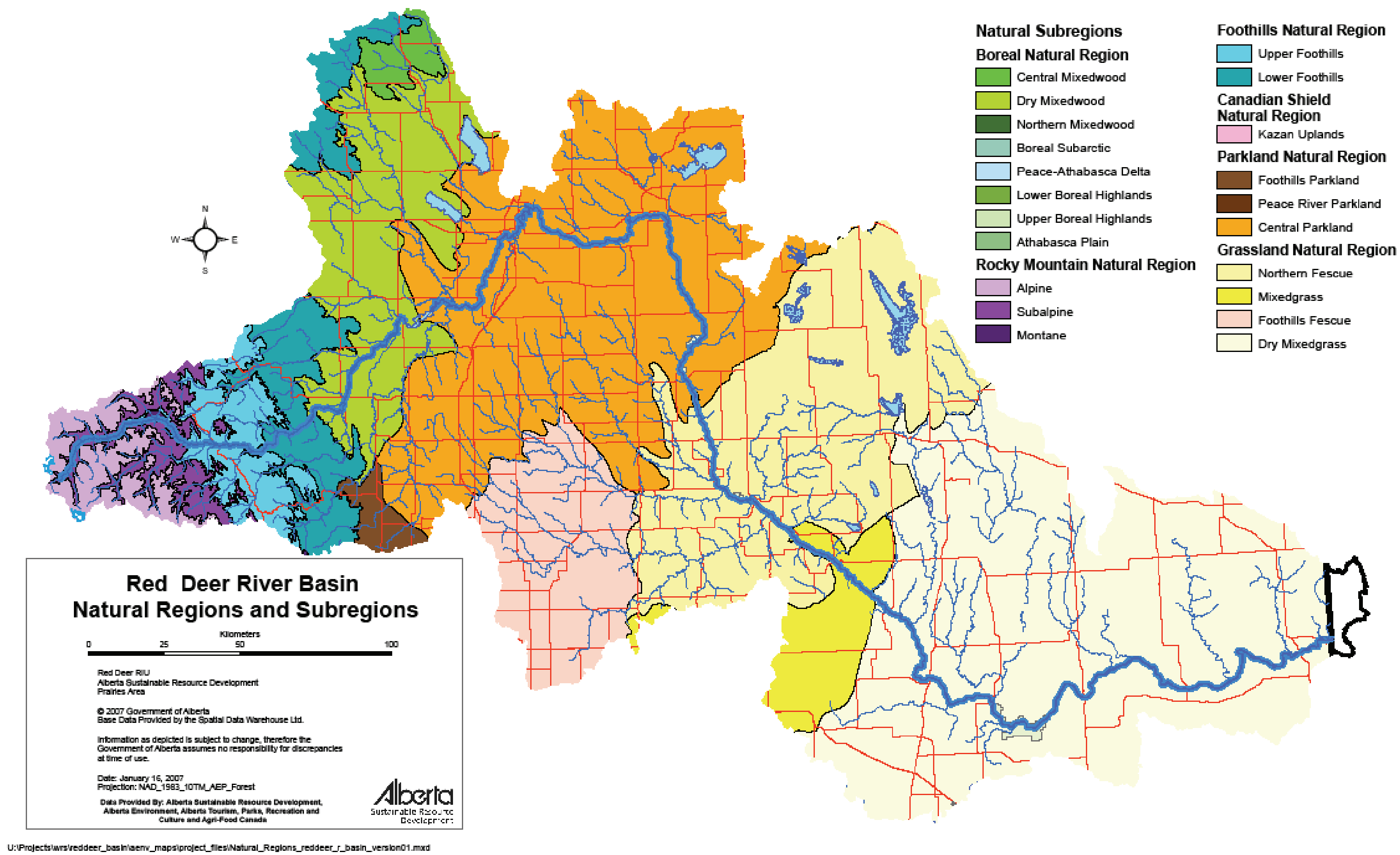


Figure 55. The Natural Regions and Subregions of the Red Deer River watershed (Government of Alberta, 2007).

3.2.2 Foothills Natural Region

The Foothills Natural Region is transitional between the Rocky Mountains Natural Region and the Boreal Forest Natural Region. It consists of the Upper and the Lower Foothills Subregions (Heritage Community Foundation, 2008).

3.2.2.1 Upper Foothills Subregion

The Upper Foothills Subregion occurs on strongly rolling topography along the eastern edge of the Rocky Mountains. The upper elevation limit is about 1,500 m. Bedrock outcrops of marine shales and non-marine sandstones are frequent. Morainal deposits are common over bedrock throughout much of the area. The Subregion has a mean annual precipitation of about 540 mm, with about 340 mm occurring from May-September. The mean May-September temperature is 10-12 °C. Upland forests are nearly all coniferous and dominated by white spruce (*Picea glauca* (Moench) Voss), black spruce (*Picea mariana* (Mill.) Britton, Sterns & Poggenb.), lodgepole pine (*P. contorta*) and subalpine fir (*A. lasiocarpa*). Lodgepole pine forests occupy large portions of upland sites and black spruce dominates on wet sites (Heritage Community Foundation, 2008).

3.2.2.2 Lower Foothills Subregion

The Lower Foothills Subregion is generally rolling topography created by deformed bedrock along the edge of the Rocky Mountains. Elevations range from about 1,250-1,450 m. Surficial materials are commonly thin morainal deposits over bedrock. Extensive organic deposits occur in valleys and wet depressions. Mean annual precipitation averages 465 mm, of which two-thirds falls from May-September. The mean May-September temperature is 11-13 °C. The forests reflect the transitional nature of the Subregion, in which mixed forests of white spruce (*P. glauca*), black spruce (*P. mariana*), lodgepole pine (*P. contorta*), balsam fir (*Abies balsamea* (L.) Mill.), aspen (*Populus* spp.), balsam poplar (*Populus balsamifera* L.) and paper birch (*Betula papyrifera* Marsh.) occur. Lodgepole pine communities are perhaps the best indication of the lower boundary of the Lower Foothills Subregion. The upper boundary is marked by the occurrence of nearly pure coniferous forest cover. Black spruce forests occur on moist upland sites, and fens are common in much of the Subregion (Heritage Community Foundation, 2008).

3.2.3 Boreal Forest Natural Region

The Boreal Forest Natural Region is the largest in Alberta; however, most of this Natural Region occurs north of the Red Deer River watershed. The region consists of broad lowland plains and discontinuous but locally extensive hill systems. The presence of extensive wetlands is a major characteristic of the Boreal Forest Natural Region. Bogs, fens and swamps are abundant and marshes are locally prevalent. The region has been divided into six Subregions, but only the Dry Mixedwood and Central Mixedwood Subregions occur in the Red Deer River watershed (Heritage Community Foundation, 2008).

3.2.3.1 Dry Mixedwood Subregion

The Dry Mixedwood Subregion is characterized by low relief and level to undulating terrain. Surficial materials are mostly till with some areas of aeolian dunes (generated by wind) and sandy outwash plains. The climate of the Subregion is subhumid, continental with short, cool summers and long, cold winters. The mean May-September temperature is about 13 °C, and the growing season is about 90 days. Annual precipitation averages 350 mm, with June and July being the wettest months. Winters are relatively dry, with about 60 mm of precipitation. Aspen (*Populus* spp.) is an important tree species in the Subregion, occurring in both pure and mixed stands. Balsam poplar (*P. balsamifera*) frequently occurs with aspen on the moister sites. Over time, white spruce (*P. glauca*) and, in some areas, balsam fir (*A. balsamea*) can be expected to increase or replace aspen and balsam poplar (*P. balsamifera*) as the dominant species; however, frequent fire seldom permits this to occur, and pure deciduous stands are common in the southern part of the Subregion. Dry, sandy sites are usually occupied by jack pine (*Pinus banksiana* Lamb.) forests. Peatlands are common and may be extensive (Heritage Community Foundation, 2008).

3.2.3.2 Central Mixedwood Subregion

Surficial materials in the Central Mixedwood Subregion are predominantly till as ground moraine and hummocky moraine landforms with some areas of Aeolian dunes, sandy outwash plain and glaciolacustrine plain. The terrain has low relief and a level to undulating surface. The Subregion includes much of the central and southeastern part of the Boreal Forest Natural Region and is the largest Subregion in Alberta. The climate of this Subregion is subhumid and continental with short, cool summers and long, cold winters. While the average temperature from May-September is about 12 °C, the frost-free period is about 85 days. Annual precipitation averages about 380 mm, with June and July being the wettest months. Winters tend to be relatively dry and, overall, the climate is somewhat moister and cooler than the Dry Mixedwood Subregion with somewhat lower moisture deficits. The vegetation of the Central Mixedwood Subregion is similar to that of the Dry Mixedwood Subregion. The differences are largely in the proportion of various vegetation types and other landscape features. Aspen (*Populus* spp.) is the characteristic forest species occurring in both pure and mixed stands, while balsam poplar (*P. balsamifera*) frequently occurs with aspen, especially on moister sites in depressions and along streams. Mixedwood forests, containing a mosaic of deciduous and coniferous patches with species typical of each, are widespread throughout the Subregion and characteristic of upland sites. Jack pine (*P. banksiana*) forests typically occupy dry, sandy upland sites. These may be quite open and have a prominent ground cover of lichens. Peatlands are also a common feature in this Subregion (Heritage Community Foundation, 2008).

3.2.4 Parkland Natural Region

The Parkland Natural Region forms a broad transition between the drier grasslands of the plains and the coniferous forests of the Boreal Forest and Rocky Mountain Natural Regions. The Parkland Natural Region consists of three Subregions: Foothills, Central and Peace River Subregions. The latter of these does not occur in the Red Deer River watershed. The Subregions are distinguished based on geographical location and major floristic differences. The Parkland Natural Region is the most densely populated region in Alberta, and settlement has changed much of the native vegetation from aspen groves and grasslands to cultivated land (Heritage Community Foundation, 2008).

3.2.4.1 Central Parkland Subregion

Surficial deposits in the Central Parkland Subregion range from intermediate-textured hummocky and ground moraines to fine-textured glaciolacustrine deposits and coarse outwash. Elevations range from 500-1,100 m. Numerous permanent streams cut across the Subregion, and lakes and permanent wetlands are scattered throughout. Many of the lakes and wetlands are naturally slightly to strongly alkaline. The mean annual temperature is 2 °C, with a May-September average of 13 °C. The frost-free period averages 95 days. The mean annual precipitation is about 350-450 mm, with the May-September precipitation averaging 300 mm. The vegetation changes from grassland with groves of aspen (*Populus* spp.) in the south to closed aspen forests in the north. The two major forest types in the Subregion are trembling aspen (*Populus tremuloides* Michx.) and balsam poplar (*P. balsamifera*) on moister sites in depressions and in the northern part of the Subregion. Both are characterized by a dense, lush, species-rich understory. The grassland vegetation of the 'parks' is dominated by rough fescue (*Festuca campestris* Rydb.) (Heritage Community Foundation, 2008).

In Alberta, the Central Parkland Subregion is one of the most productive waterfowl areas; however, only about 2% of this landscape is formally protected in parks or other conservation areas. The area's deep, rich soils and reliable moisture have largely been converted to productive farm land. It is now the most heavily-impacted and fragmented ecoregion in Alberta, with only about 5% remaining in its natural state (van Tighem, 1993).

3.2.4.2 Foothills Parkland Subregion

This Subregion occupies a narrow band along eastern edge of the geological foothills from Calgary south to the Porcupine Hills, and from Pincher Creek south to the American border in the Waterton Lakes National Park area. The topography is rougher than that of the Central Parkland Subregion, and elevations are higher, ranging to over 1300 m near Paine Lake. Surficial deposits include extensive areas of hummocky and ground moraine as well as more restricted areas of outwash and glaciolacustrine deposits along valleys. Extensive river terraces also occur in some areas. Mean annual precipitation ranges from 500-650 mm, and the average May-September precipitation is about 290 mm. The mean May-September temperature is about 12-13 °C, while the region experiences about 90 frost-free days each year. Aspen (*Populus* spp.) is generally dominant in the upland forests, with balsam poplar (*P. balsamifera*) occurring on moister sites. Willow groveland dominated by Bebb willow (*Salix bebbiana* Sarg.) occurs extensively on fine-textured glaciolacustrine material and on imperfectly to poorly-drained morainal sites. The understory in all forest stands is lush and dominated by a variety of herbaceous plants (Heritage Community Foundation, 2008).

3.2.5 Grassland Natural Region

The Grassland Natural Region is a flat to gently rolling plain with a few major hill systems. Most of the bedrock is covered with extensive, thick glacial till deposits. The Grassland Natural Region contains four subregions: Dry Mixedgrass, Mixedgrass, Northern Fescue and Foothills Fescue. These Subregions are separated primarily based on climate, soils and vegetation (Heritage Community Foundation, 2008).

3.2.5.1 Northern Fescue Subregion

The Northern Fescue Subregion is characterized by gently rolling terrain, commonly low-relief ground moraine and hummocky moraine. The mean May-September temperature is 14 °C, and the frost-free period is about 90 days. Mean annual precipitation is about 400 mm, with mean May-September precipitation of about 280 mm. The vegetation is dominated by rough fescue (*F. campestris* Rydb.) (Heritage Community Foundation, 2008).

3.2.5.2 Foothills Fescue Subregion

The Foothills Fescue Subregion occurs largely on the outwash deposits of the foothills. Elevations are higher in this Subregion than in the Northern Fescue Subregion. The climate differs from the Northern Fescue Subregion in having a greater frequency of chinooks and thus, a milder winter climate. There also is more snowfall in later winter and early spring, with the majority of precipitation falling during the growing season. The mean annual precipitation is about 500 mm with 290 mm falling from May-September. The mean May-September temperature is 11-13 °C, and the mean annual temperature is 3 °C. The average frost-free period is 90 days. Grasslands are dominated by rough fescue (*F. campestris*), Idaho fescue (*Festuca idahoensis* Elmer) and oat grass (*Trisetum* spp.) (Heritage Community Foundation, 2008).

3.2.5.3 Dry Mixedgrass Subregion

The topography of the Dry Mixedgrass Subregion is generally subdued with only a few minor uplands. The predominant landform is a low-relief ground moraine, but there are significant areas of hummocky moraine, glaciofluvial outwash, glaciolacustrine sand plains, fine-textured glaciolacustrine lake deposits and eroded plains. Elevations range from 600-1,300 m. Although permanent streams are relatively rare, the ones that do exist are well defined. The Subregion is drained by several major rivers that have carved deeply into the bedrock in some places. This has exposed Cretaceous shales and sandstones, creating extensive “badlands” in some areas. It has a typical continental climate with cold winters, warm summers and low precipitation. The average summer temperature is about 16 °C, and the total annual precipitation is about 260-280 mm. Summer precipitation is the lowest of any Subregion in Alberta. Spring is usually the wettest season, with about two-thirds of the annual precipitation falling as rain, mostly in June. Chinooks are most common along the western border of the subregion, with more than 30 chinook days per year. The vegetation is dominated by spear grass (*Piptochaetium* spp.) and blue grama (*Bouteloua gracilis* (Willd. *ex* Kunth) Lag. *ex* Griffiths), with western wheat grass (*P. smithii*) and northern wheat grass (*E. lanceolatus*) also being important in hummocky moraine areas (Heritage Community Foundation, 2008).

Although much of the natural vegetation of the Dry Mixedgrass Subregion has been replaced by agricultural crops, extensive areas of native rangeland remain, which are managed primarily for grazing by domestic livestock.

3.2.5.4 Mixedgrass Subregion

The topography of the Mixedgrass Subregion typically includes gently undulating to rolling morainal and glacial lake deposits, but there are substantial areas of glaciolacustrine sand plains, and fine-textured glaciolacustrine lake deposits. This Subregion is generally subdued with only a few minor uplands; however, the Cypress Hills are an exception as they are considered a prominent upland. The few permanent streams are well defined. The mean annual temperature is about 5 °C, with a mean summer temperature of about 15 °C. Winter temperatures in this Subregion are a few degrees warmer than in the Dry Mixedgrass Subregion, with a greater frequency of chinook days (20-30 more days) but with greater snow cover due to greater precipitation in the winter. Annual precipitation is also about 20% greater than for the Dry Mixedgrass Subregion. The vegetation of the Mixedgrass Subregion is similar to the Dry Mixedgrass Subregion; however, it is characterized by greater biomass production and a greater abundance of species that tend to favour cooler and moister sites. The majority of Mixedgrass vegetation is dominated by spear grass (*Piptochaetium* spp.), western porcupine grass (*Hesperostipa spartea* (Trin.) Barkworth), western wheat grass (*Pascopyrum smithii* (Rydb.) A. Löve) and northern wheat grass (*Elymus lanceolatus* (Scribn. & J.G. Sm.) Gould (Heritage Community Foundation, 2008).

Much of the natural vegetation of the Mixedgrass Subregion has been replaced by agricultural crops. The moister, cooler conditions of this Subregion are reflected in the greater productivity of rangelands, which typically produce 25% more biomass (Heritage Community Foundation, 2008).