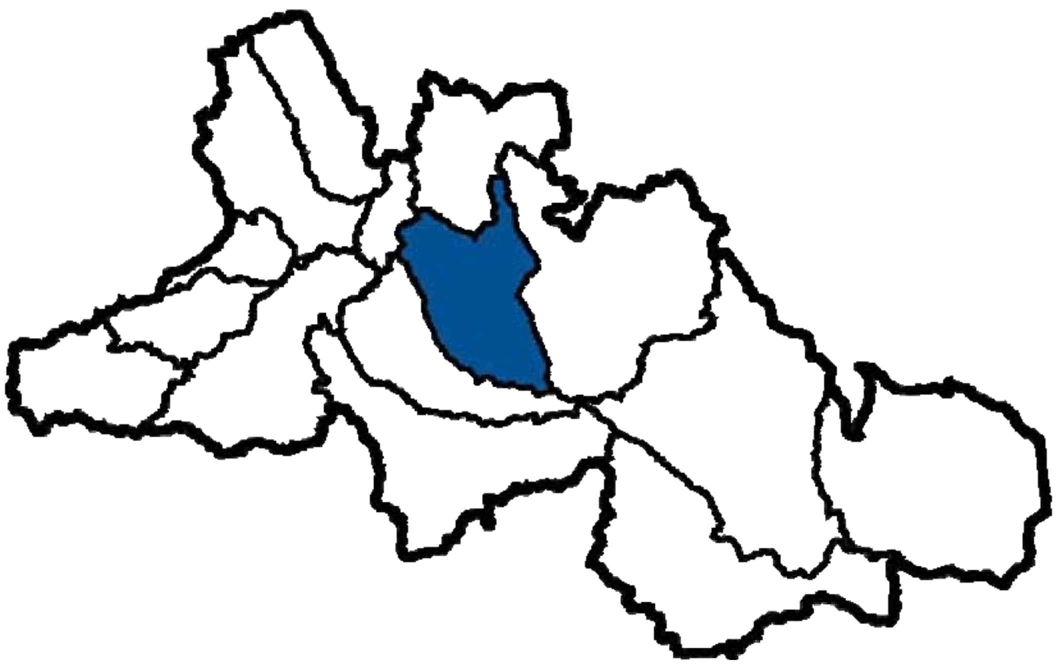
Threehills Subwatershed



Red Deer River Watershed Alliance

State of the Watershed

4.9 Threehills Creek Subwatershed

4.9.1 Watershed Characteristics

The Threehills Creek subwatershed encompasses about 322,063 ha and is located in Kneehill County and Red Deer County (Figure 248).

The Threehills Creek subwatershed is located in the central region of the Red Deer River watershed and lies in the Central Parkland and Northern Fescue Subregions (Figure 249). The Central Parkland Subregion is dominated by grassland with groves of aspen (*Populus* spp.), with the grassland vegetation being dominated by rough fescue (*F. campestris*). The Northern Fescue Subregion is dominated by rough fescue (*F. campestris*) (Heritage Community Foundation, 2008).

The geology of the Threehills Creek subwatershed is dominated by the Paskapoo Formation in addition to localized deposits belonging to the Scollard and Horseshoe Canyon Formations. These formations formed in the Paleocene epoch (56-65 million years ago) and in the Upper Cretaceous period (65-100 million years ago). The youngest of the formations from the Paleocene, Paskapoo, consists of diverse sandstones, siltstones/mudstones and minor shale deposits. The Scollard Formation (Paleocene and Upper Cretaceous) consists of sandstone, mudstone and thick coal deposits. The Horseshoe Canyon Formation (Upper Cretaceous) consists of sandstones, mudstones, shales, ironstone, bentonite and minor limestone deposits (Alberta Geological Survey, 2006).

The climate of the Threehills Creek subwatershed is continental, with mean annual temperatures ranging from 2-4 °C and mean May-September temperatures ranging from 11-14 °C. The mean annual precipitation ranges from 350-500 mm, with the May-September precipitation averaging 280-300 mm (Environment Canada, 2006). There are about 90 frost-free days per annum.

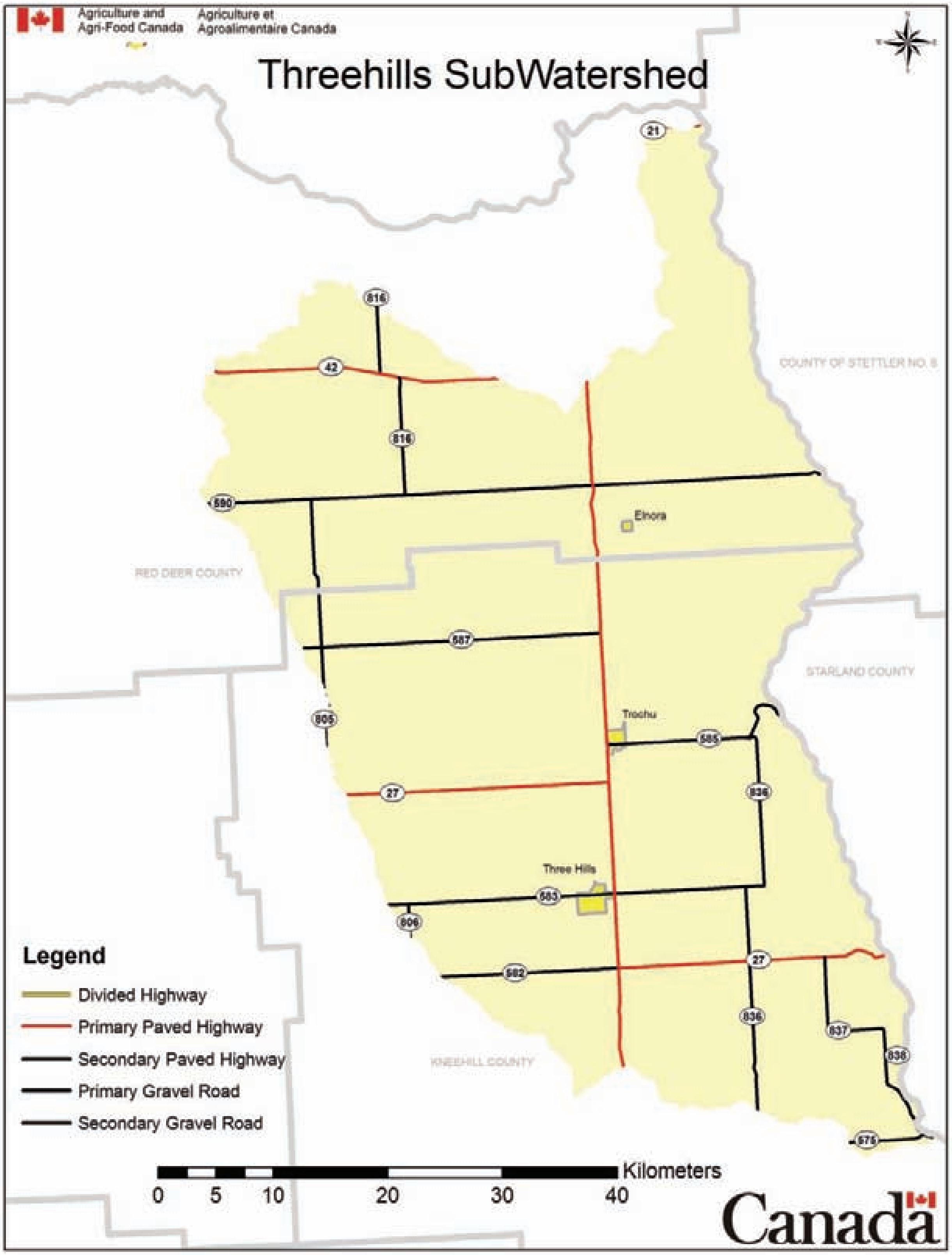


Figure 248. Location of the Threehills Creek subwatershed (AAFC-PFRA, 2008).

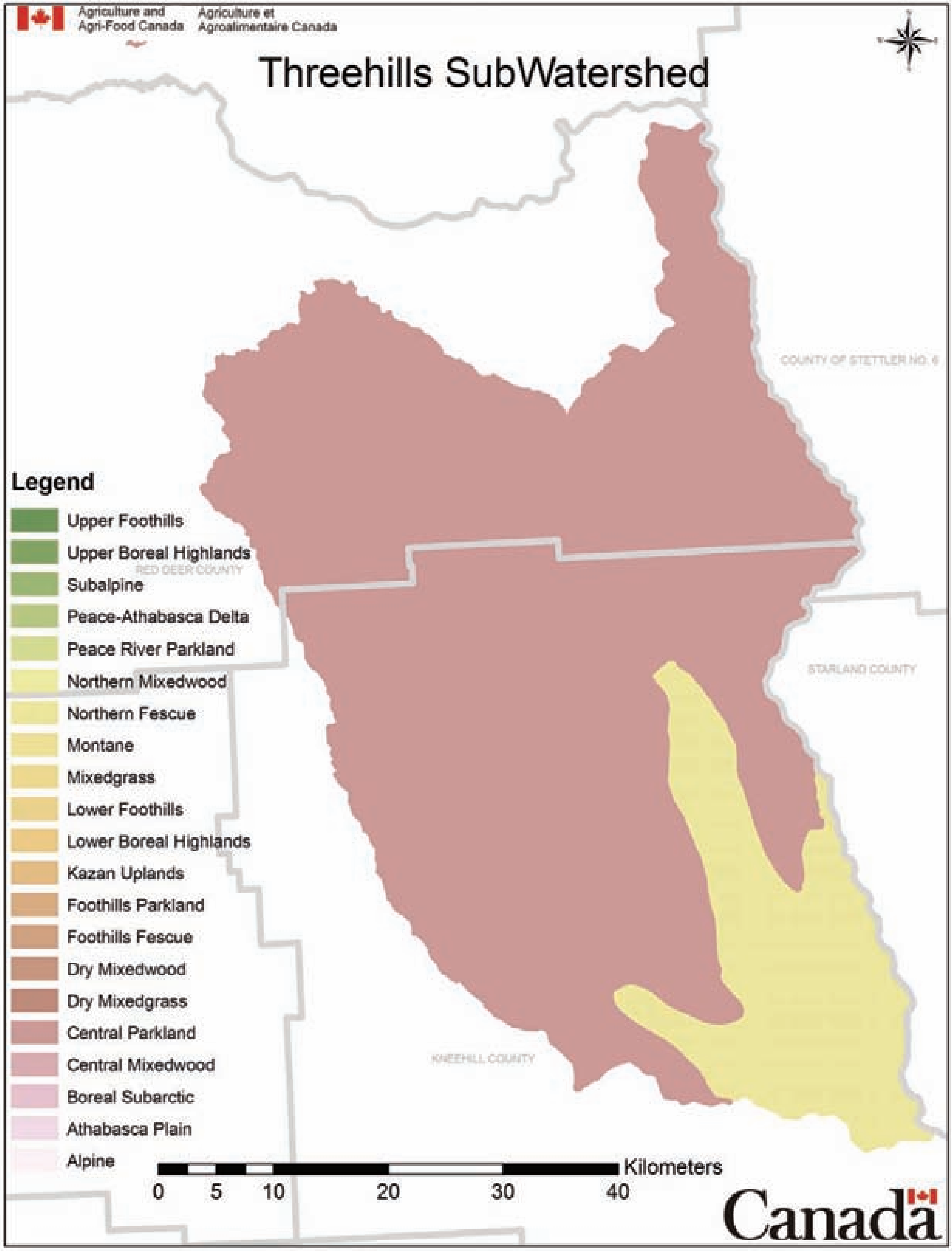


Figure 249. Natural subregions of the Threehills Creek subwatershed (AAFC-PFRA, 2008).

4.9.2 Land Use Indicators

Changes in land use patterns reflect major development trends, such as forested lands converted to agriculture and agricultural lands developed and lost to urban sprawl. Land use changes and the subsequent changes in management practices impact both the quantity and quality of water within the Red Deer River watershed. Six metrics were used to indicate changes in land use and land use practices in the Red Deer River watershed and its 15 subwatersheds:

- Wetland Loss – Condition Indicator
- Riparian Health – Condition Indicator
- Livestock Manure Production – Risk Indicator
- Urban, Rural and Recreational Developments – Risk Indicator
- Linear Developments – Condition Indicator
- Oil and Gas Activities – Risk Indicator

These six land use change indicators also reflect socioeconomic growth in a region. Hence, while human activities in a region can have negative environmental impacts, it is important to strive for a balance between socioeconomic growth and the sustainable management of natural ecosystems to ensure their long-term health and enjoyment by future generations.

4.9.2.1 Wetland Loss

Wetlands serve many functions in the natural landscape including water storage, flood attenuation, wildlife habitat, groundwater recharge and general water quality improvements (e.g., nutrient uptake, degradation of pesticides, sediment retention). Additionally, wetlands provide a cost effective and sustainable alternative to engineered treatment options. The loss of wetlands to development and/or agriculture can be deleterious to surface and groundwater quantity and quality.

Land cover data indicate the presence of 4,152 ha of wetlands (1.29% of the total subwatershed area) in the Threehills Creek subwatershed (AAFC-PFRA, 2008); however, there are no data on the classes, forms and types of wetlands (*sensu* National Wetlands Working Group, 1997) within the subwatershed. Given the presence of lentic (lakes) and lotic (streams and rivers) systems, marshes and shallow open water wetlands are likely present in the subwatershed. In addition, ephemeral, temporary, seasonal and semi-permanent wetlands (*sensu* Stewart and Kantrud, 1971) are likely present in the subwatershed as well.

The Pine Lake landscape has been classified by Ducks Unlimited Canada (DUC) as a critical landscape and in need of immediate action to conserve, restore and enhance its highly productive waterfowl habitat. The objectives for this landscape will include the conservation and restoration of over 1,000 wetland basins and about 2,955 has of upland habitat. Where possible, wetland basins will be restored to their original state and protected alongside those wetlands that are still intact using landowner agreements and conservation easements. Uplands will also be restored or converted by encouraging landowners to adopt wildlife-friendly agricultural practices and by planting high yield fall-seeded crops, such as winter wheat, that do not disturb spring waterfowl nesting (DUC, 2008). In addition, DUC and the Nature Conservancy of Canada jointly established the Kinvig Purchase near Pine Lake in 2005. These 259 ha of natural grassland contain prime wildlife habitat and 65 ha of wetlands and is an important staging and breeding area for migrating waterfowl (DUC, 2008).

The Prairie Habitat Joint Venture program (a partnership between federal and provincial governments, organizations and conservation groups in Manitoba, Saskatchewan and Alberta) has assessed the loss of wetlands in the Parkland Natural Region (in the Central Parkland Subregion) from 1985-2001 (Watmough and Schmoll, 2007). In Alberta, the Parkland Natural Region has lost 7% of its total wetland area and 8% of its total number of wetlands due to anthropogenic disturbances in that 16-year period. Comparatively, there have been losses of 7% in total wetland area and 9% in total number of wetlands in the Grassland Natural Region. There appears to be no change in the rate of wetland loss in the Prairie Parkland Region over the past 50-70 years. Caution must be taken when extrapolating these data to the entire subwatershed, since the Prairie Habitat Joint Venture program has assessed wetland losses along only one transect in this subwatershed (Watmough and Schmoll, 2007).

4.9.2.2 Riparian Health

Riparian areas are an important transition zone between uplands and water. They act as buffer zones, protecting water quality and attenuating floods. Contaminants are adsorbed onto sediments, 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 health assessments could not be located for any waterbody in the Threehills Creek subwatershed.

4.9.2.3 Livestock Manure Production

Areas of higher livestock density within a subwatershed, and their associated higher manure production, are expected to have greater impacts on downstream water quality. Streams that drain land with high intensity livestock operations have higher nutrient concentrations, dissolved nutrients, mass loads, fecal bacteria and exports of total dissolved phosphorus than streams with medium or low intensity livestock operations and manure production.

There are over 60 feedlots/intensive livestock operations in the Threehills Creek subwatershed, located mostly in the south-central area of the subwatershed. The majority of the feedlots finish cattle/cows, swine and poultry. There are also a number of swine rearing and feeding operations dispersed throughout the subwatershed (Figure 250) (Government of Alberta 2007b).

Cattle density ranges from lows of 0-0.2 cattle/ha in the extreme south to 0.21-0.40 cattle/ha in the central areas and 0.61-0.90 cattle/ha in the northern and southern areas of the subwatershed (Figure 251) (AAFC-PFRA, 2008). Manure production is generally low across the subwatershed at < 2.5 tonnes manure/ha; however, the manure production is substantially higher in the headwaters of Ghostpine Creek and Threehills Creek (2.6-5.0 tonnes manure/ha and 5.1-7.5 tonnes manure/ha, respectively) (Figure 252) (AAFC-PFRA, 2008). Overall, manure production in the Threehills Creek subwatershed is considered low relative to the remainder of the Red Deer River watershed.

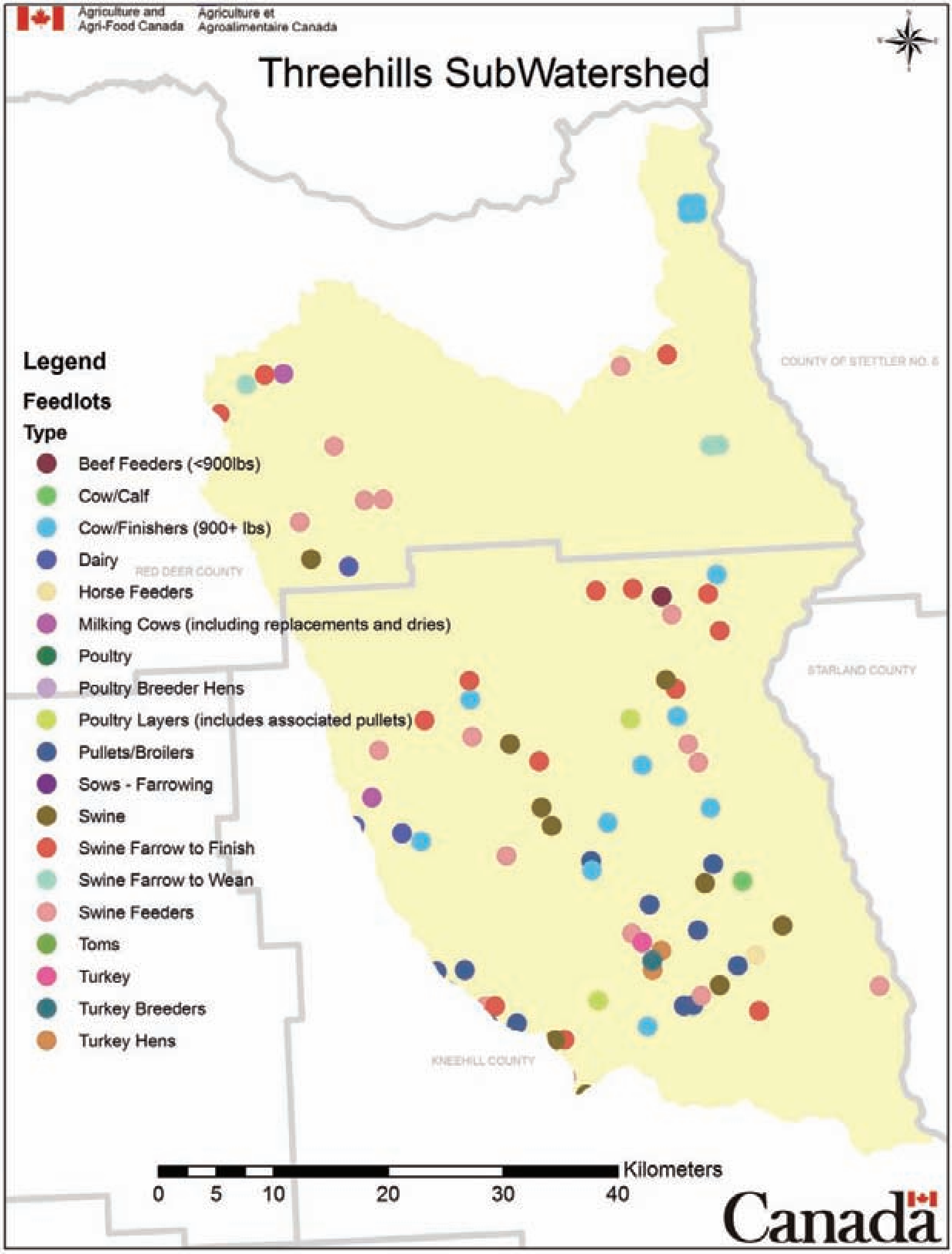


Figure 250. Feedlots and intensive livestock operations in the Threehills Creek subwatershed (AAFC-PFRA, 2008).

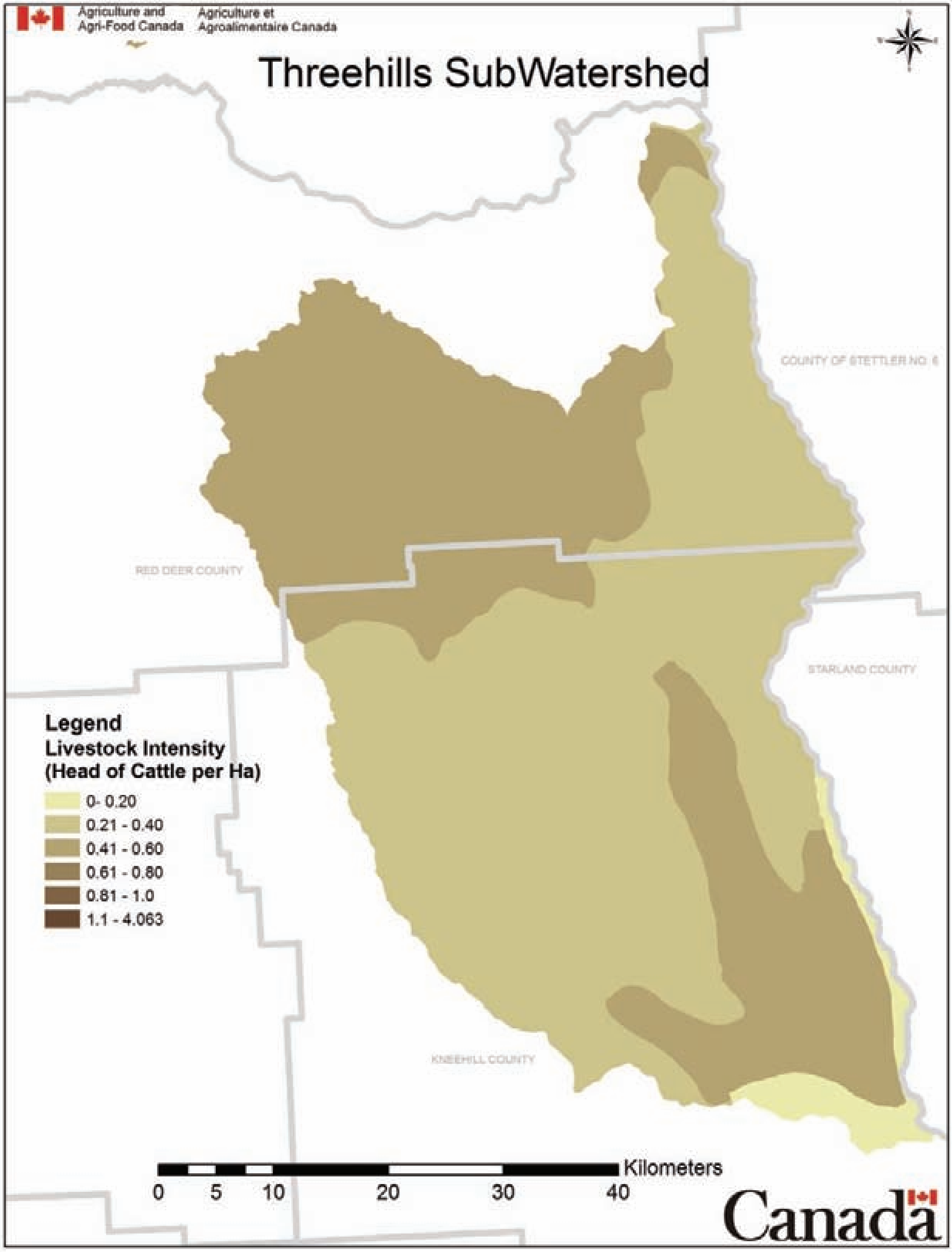


Figure 251. Cattle density (cattle/ha) in the Threehills Creek subwatershed (AAFC-PFRA, 2008).

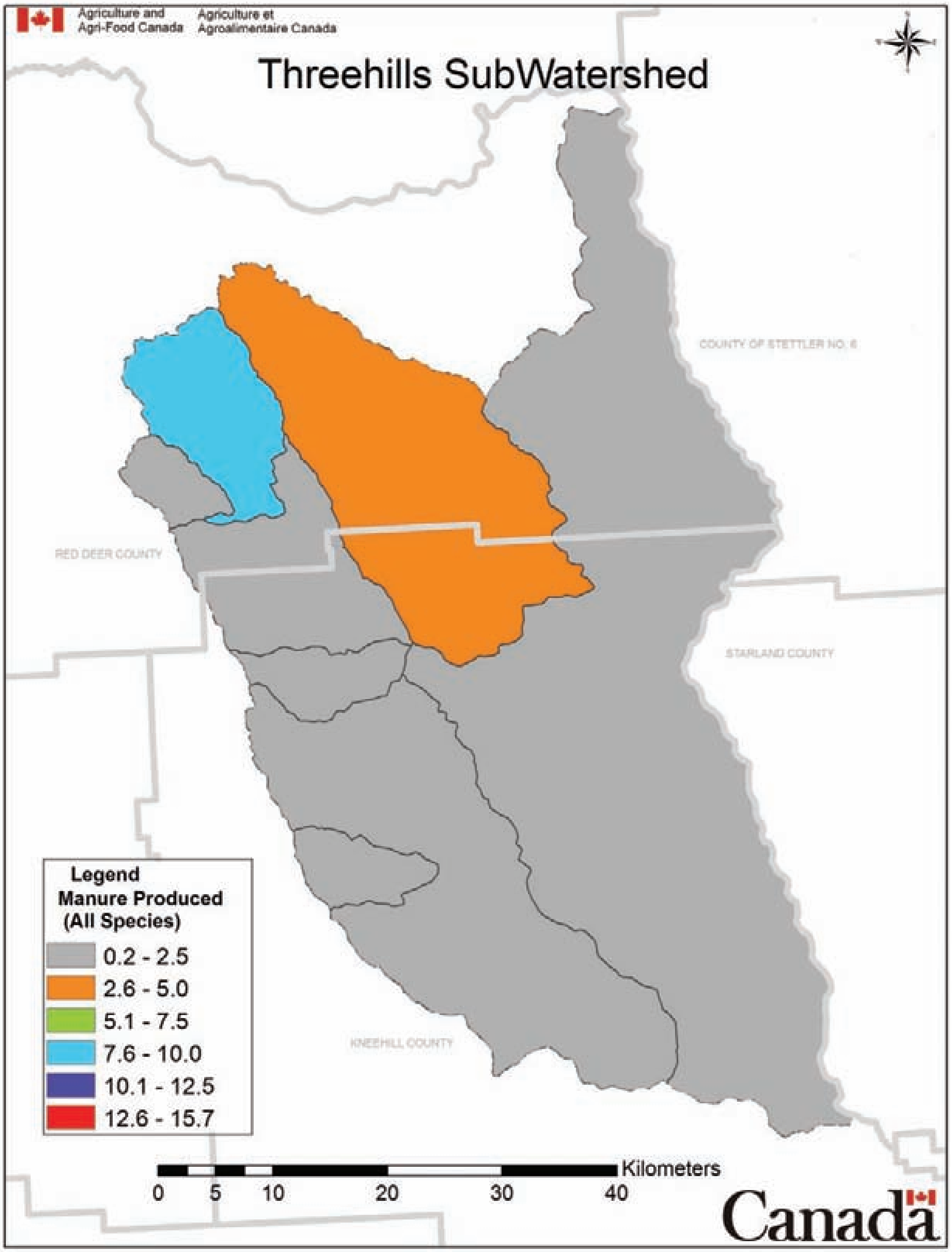


Figure 252. Manure production (tonnes/ha) in the Threehills Creek subwatershed (AAFC-PFRA, 2008).

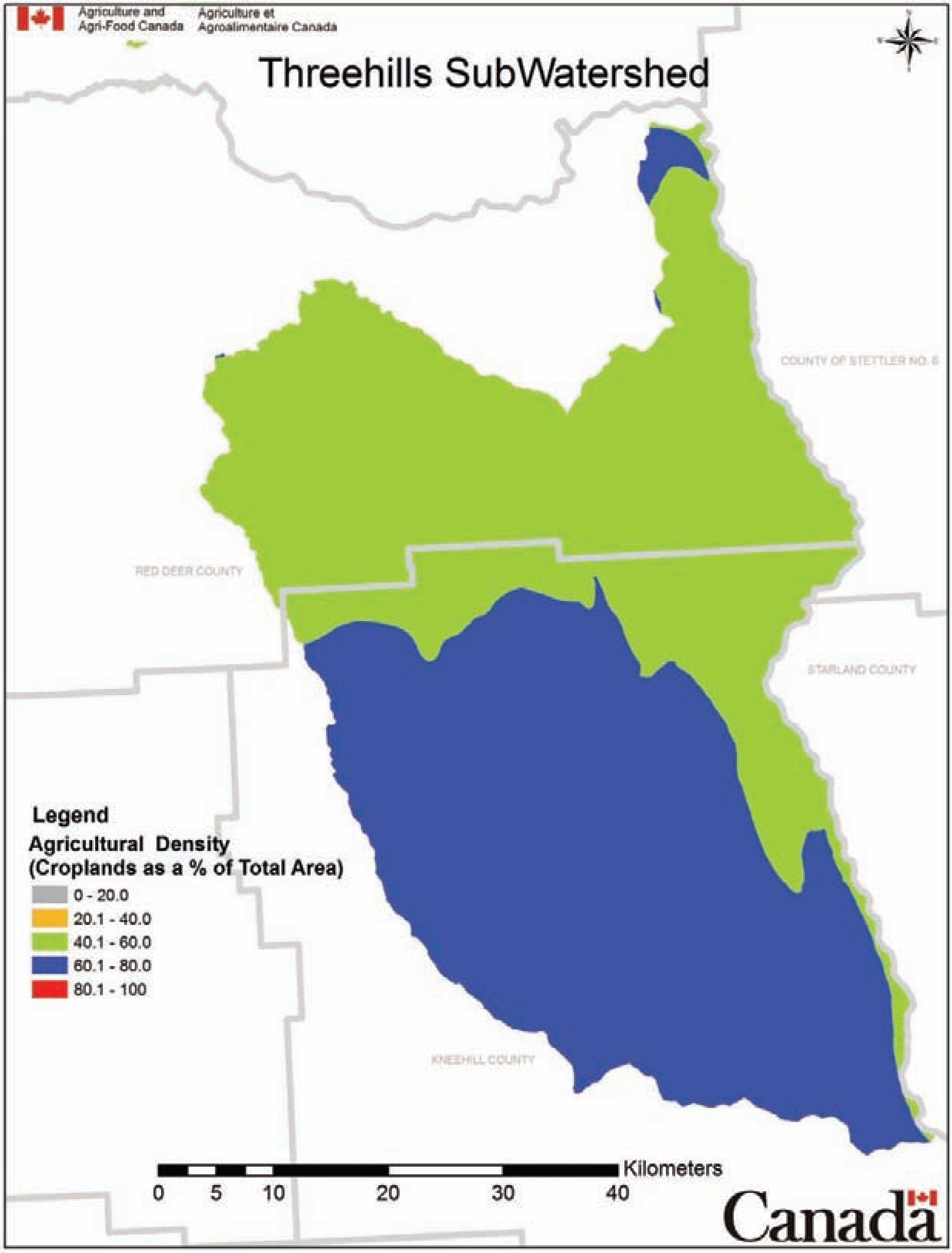


Figure 253. Agricultural intensity (% cropland) in the Threehills Creek subwatershed (AAFC-PFRA, 2008).

Agricultural intensity, expressed as the percent land cover used as croplands, ranges from 40-60% in the northern area and along the Red Deer River and from 60-80% in the southern area of the subwatershed (Figure 253) (AAFC-PFRA, 2008).

4.9.2.4 Urban, Rural, Agricultural and Recreational Developments

Urban sprawl, rural and recreational development is the expansion of urban areas, rural subdivisions and recreational areas into surrounding landscape. This expansion can have many negative effects on the environment, including the loss of wetlands, riparian areas, intermittent streams and wildlife habitat, as well as increased surface runoff into neighboring creeks, rivers and lakes.

Communities in the Threehills Creek subwatershed include the Towns of Three Hills and Trochu, the Village of Elnora and numerous hamlets, including Curlew, Equity, Ghostpine Creek, Highland Ranch, Huxley, Lousana, Milnerton, Perbeck, Pine Lake and Twining (Government of Canada, 2006).

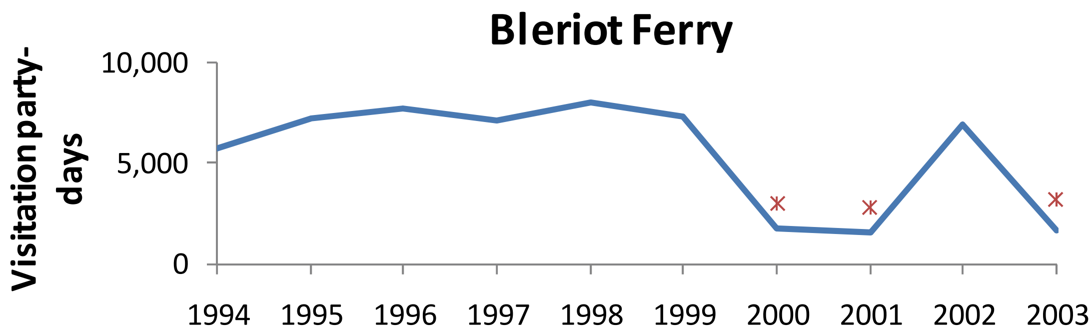
There are five recreational facilities in the subwatershed, including Provincial Natural Areas (PNA), one Provincial Recreation Area (PRA) and one Provincial Park (PP) (Table 103) (Alberta Tourism, Parks and Recreation, 2008b).

Table 103. Recreational facilities in the Threehills Creek subwatershed (Alberta Tourism, Parks and Recreation, 2008b).

Facility	Characteristics
Bleriot Ferry PRA	• 1.89 ha on the Red Deer River • 28 unit campgrounds
Delburne PNA	• now amalgamated into Tolman Badlands Heritage Rangeland PNA
Dry Island Buffalo Jump PP	• 1598.22 ha on the Red Deer River • 66 camping units in two campgrounds, day use sites
Lousana PNA	• now amalgamated into Tolman Badlands Heritage Rangeland PNA
Tolman Badlands Heritage Rangeland PNA	• 5944.89 ha on the Red Deer River • day use site

Note: PNA = provincial natural area, PP = provincial park, PRA = provincial recreation area.

Visitation statistics for two recreation facilities in the subwatershed indicate that the number of visitors to these facilities varies considerably on an annual basis (Figure 254). For those years with available data, the average number of visitors per year was 5,545 and 9,458 in Bleriot Ferry PRA and Dry Island Buffalo Jump PP, respectively. An average 15,003 visitors have used these two recreation facilities annually from 1994-2003; however, there are several years with incomplete visitation data (lack of group camping data), and the number of visitors to these recreation facilities is likely substantially higher (Alberta Tourism, Parks and Recreation, 2008b).



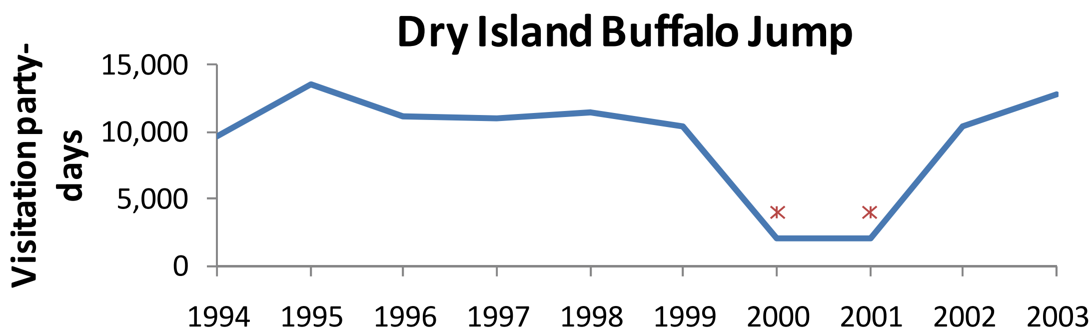


Figure 254. Visitation statistics for two recreation facilities in the Threehills Creek subwatershed (Alberta Tourism, Parks and Recreation, 2008b). Asterisks indicate years for which group camp data were not available.

4.9.2.5 Linear Developments

Linear developments include seismic lines, pipelines, roads, railways and utility right of ways. Quantifying linear development will help us understand potential changes in water quality and fish and wildlife populations, e.g., wildlife corridors can be interrupted by roads, and watersheds can have their drainage patterns permanently altered by increases in impervious or compacted surfaces.

The most prominent linear developments in the Threehills Creek subwatershed are urban and rural roads, which have a total length of 3,360 km and cover 53.8 km^2 of the subwatershed's landbase. Other major linear developments include pipelines and cutlines/trails (Table 104). In total, all linear developments cover an area of 80.1 km^2, or 2.5% of the total area of the subwatershed (Figure 255) (AAFC-PFRA, 2008).

In addition to linear developments, the Threehills Creek subwatershed has 295 bridges that cross waterbodies, mostly streams and creeks, or culverts that connect waterbodies (Figure 256) (AAFC-PFRA, 2008). These are primarily associated with Threehills Creek and Ghostpine Creek. Pipeline crossings are distributed throughout the central and southern areas of the Threehills Creek subwatershed. They are less common in the northern area of the subwatershed, e.g., north of Dry Island Buffalo Jump Provincial Park and in the headwaters of Ghostpine and Threehills Creeks (Figure 257) (AAFC-PFRA, 2008).

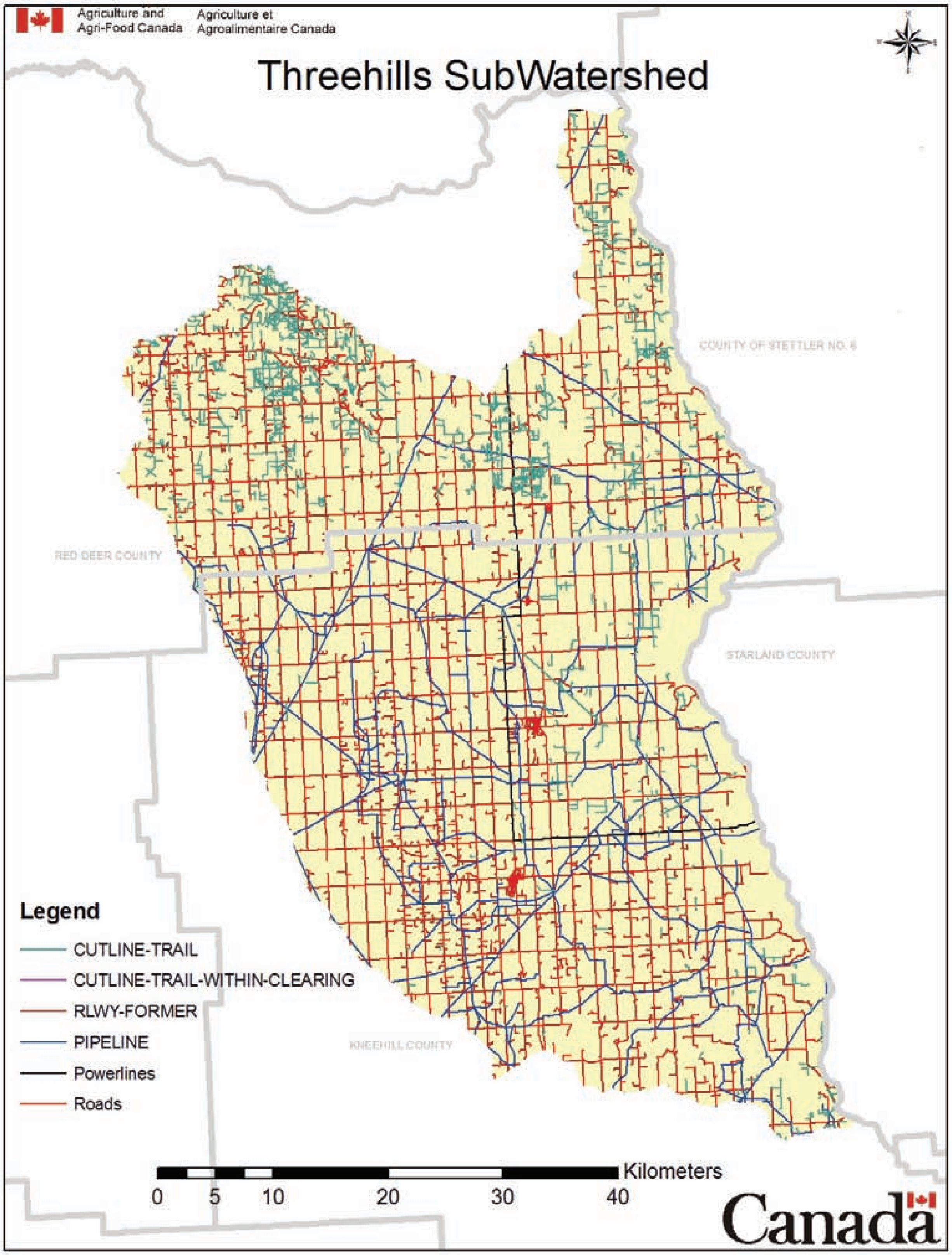


Figure 255. Linear developments in the Threehills Creek subwatershed (AAFC-PFRA, 2008).

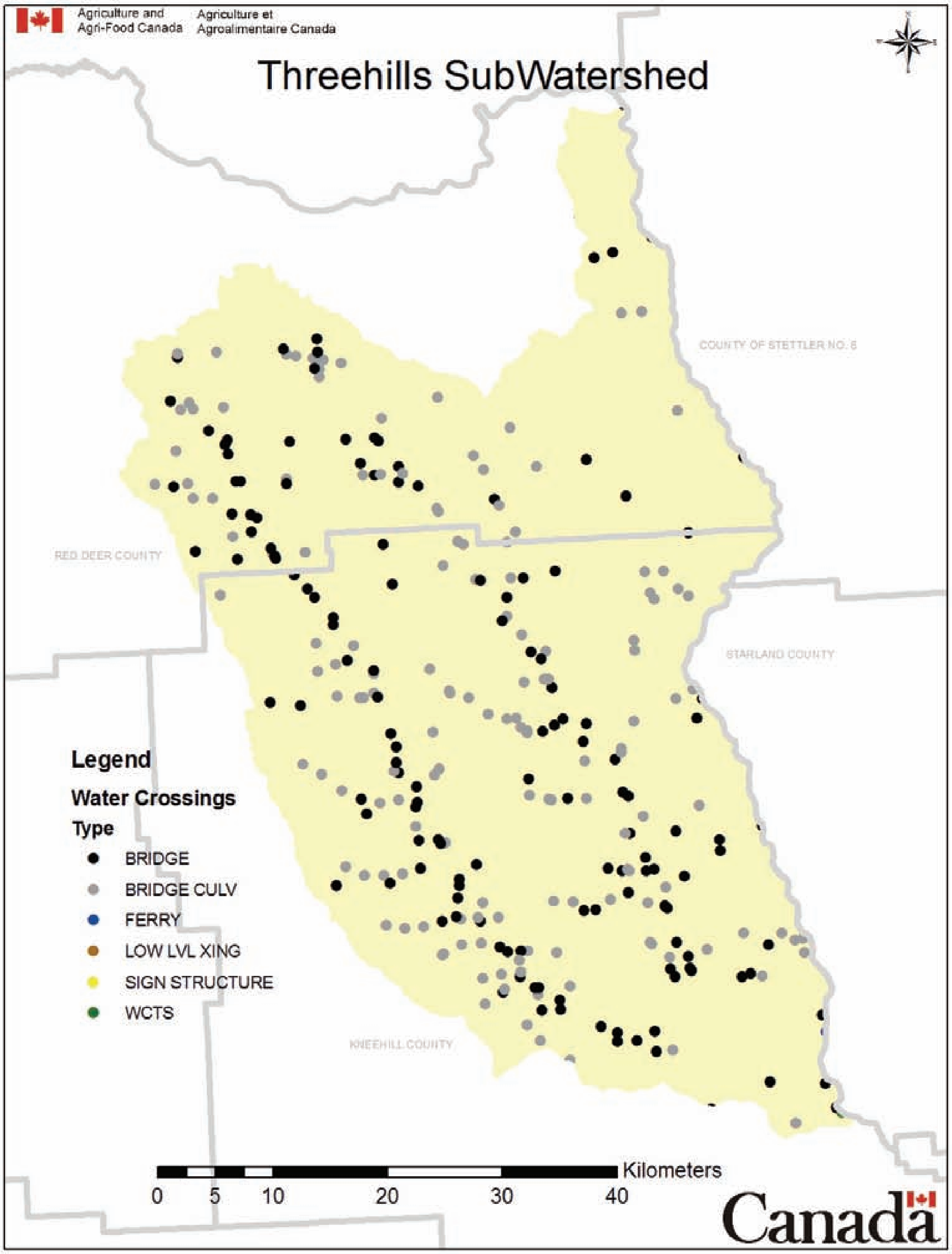


Figure 256. Waterbody crossings in the Threehills Creek subwatershed (AAFC-PFRA, 2008).

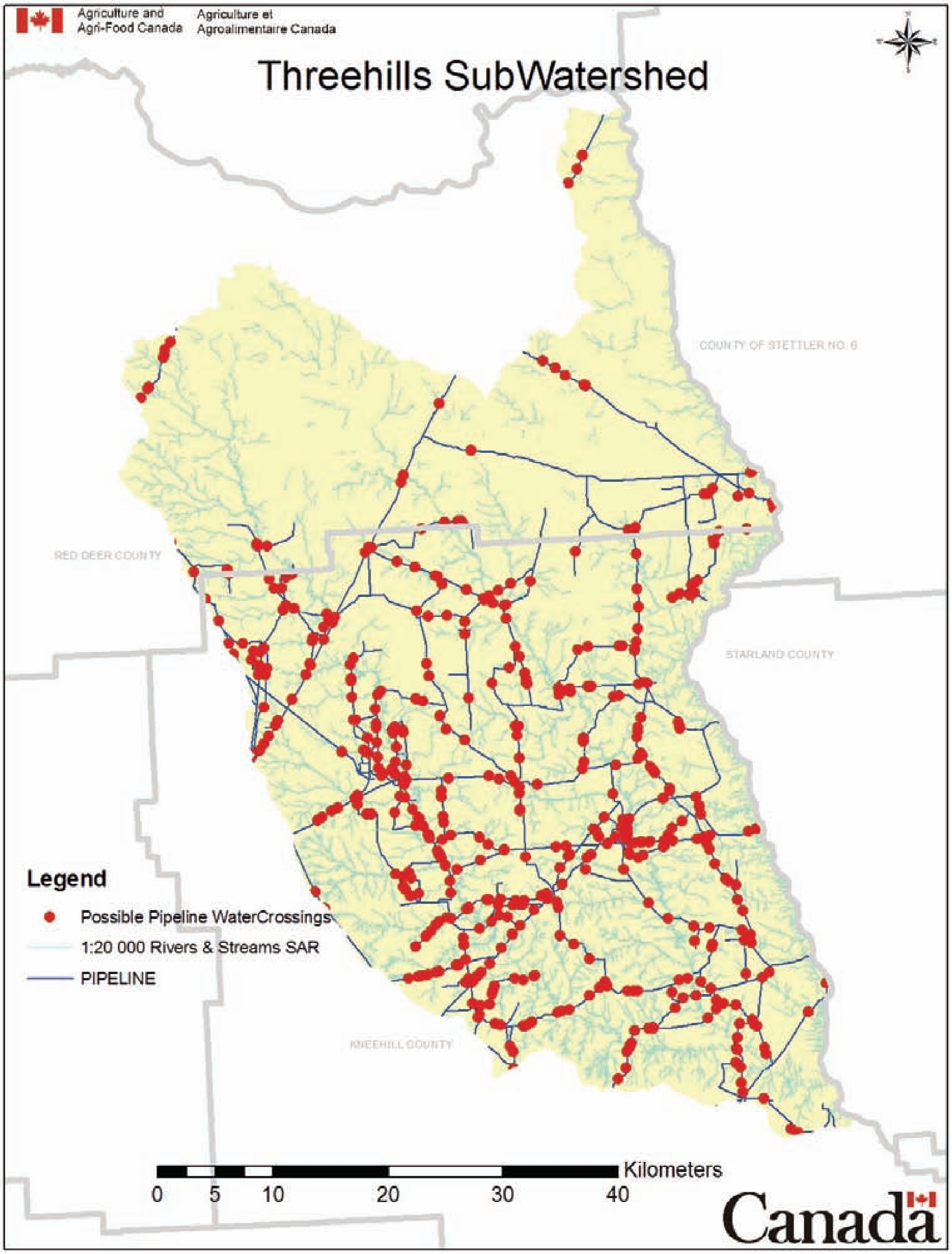


Figure 257. Pipeline crossings over waterbodies in the Threehills Creek subwatershed (AAFC-PFRA, 2008).

Table 104. Linear developments in the Threehills Creek subwatershed (AAFC-PFRA, 2008). The dominant linear development is highlighted.

Linear Development	Length (km)	Width (m)	Area (km^2)	Proportion of total linear disturbances (%)
All roads	3,360	16	53.76	67.1
Cutlines/trails	1,030	6	6.18	7.7
Pipelines	1,080	15	16.20	20.2
Powerlines	90	30	2.70	3.4
Railways	82	15	1.23	1.5
Total	**5,642**		**80.07**	

4.9.2.6 Oil and Gas Activities

Oil and gas activity is very common throughout the province of Alberta. With oil and gas development there can be a number of associated impacts, including loss of wetlands, habitat fragmentation, increased water use and surface water and groundwater contamination (Alberta Centre for Boreal Studies, 2001).

The Threehills Creek subwatershed has an average well density of 2.17 wells/km^2; however, well densities increase up to 10 wells/km^2 near Three Hills and Trochu in the south-central region and near Elnora in the north-east region of the subwatershed (Figure 258). About 71% of all wells are active, with the majority being unspecified wells, followed by gas and oil wells (Table 105) (AAFC-PFRA, 2008).

Table 105. Number of known active and abandoned oil, gas, water and other wells in the Threehills Creek subwatershed (AAFC-PFRA, 2008).

Well type	Quantity
Wells – active *	3,004
Wells – abandoned *	1,490
Total	**4,494**
Gas wells – active	1,448
Gas wells – abandoned	266
Total	**1,714**
Oil wells – active	501
Oil wells – abandoned	238
Total	**739**
Water wells – active	31
Water wells – abandoned	13
Total	**44**
Total active wells in subwatershed	**4,984**
Total abandoned wells in subwatershed	**2,007**
Total wells in subwatershed	**6,991**

* The purpose of these wells is undefined and may include standing, newly licensed, flowing coalbed methane, testing coalbed methane, carbon dioxide injector or general exploration wells.

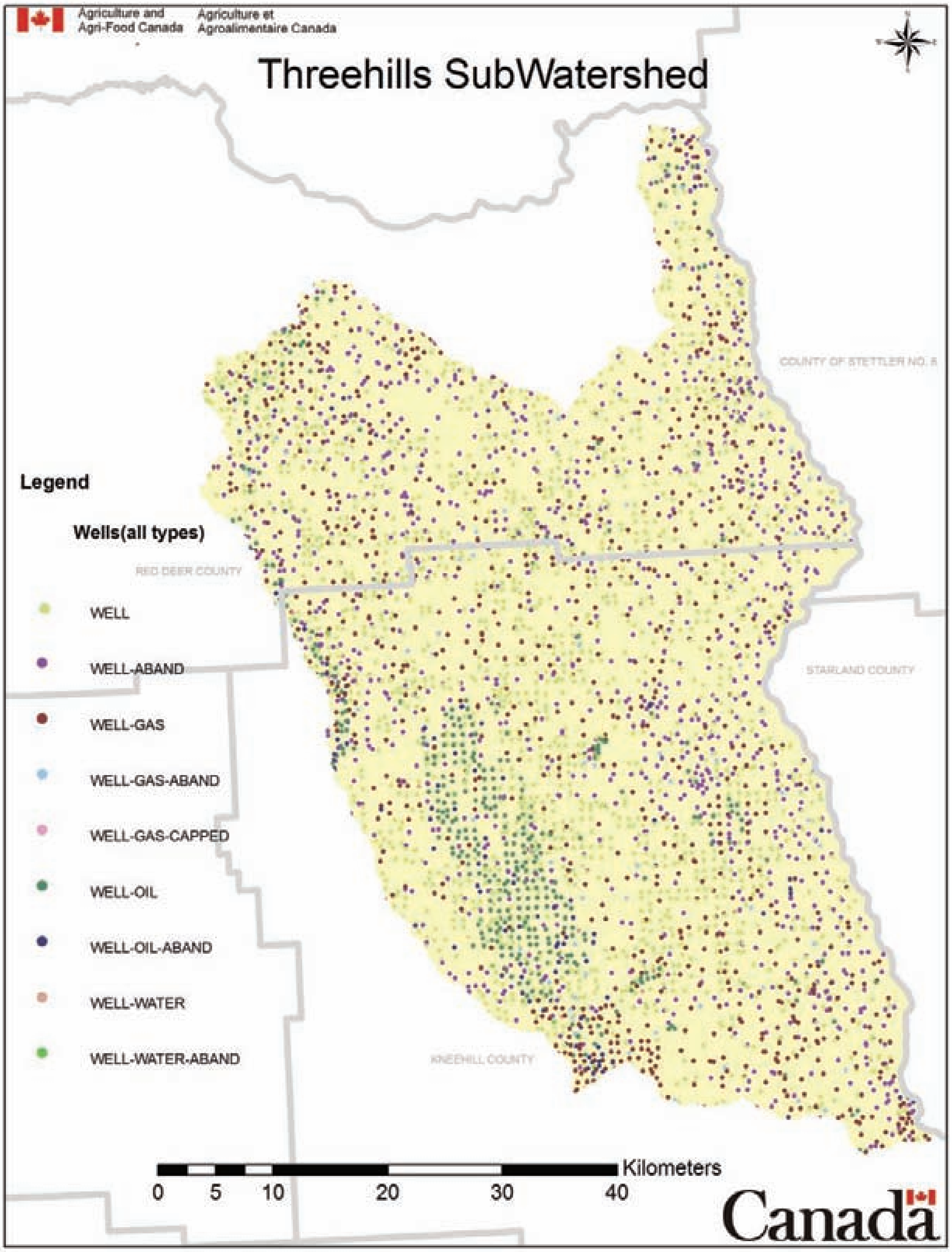


Figure 258. Known active and abandoned oil, gas, water and other wells in the Threehills Creek subwatershed (AAFC-PFRA, 2008).

Coal bed methane (CBM) is natural gas that is found within coal formations. It has received attention recently as an additional source of energy; however, it brings with it potential environmental impacts, some of which are similar to conventional oil and gas exploration and production endeavors. Conversely, some potential impacts it brings with it are new, including an increased intensity in wells, compressors, pipeline infrastructure and completion and production of natural gas from formations above the base of groundwater protection. Some CBM wells are estimated to produce over 65,000 L of waste water per day (Lennon, 2008). In addition, common to oil, gas and unconventional gas (CBM and Shale gas) production is the risk of groundwater contamination through fracturing. Fracturing results from pumping fluids or gases into bedrock formations at high rates and pressures to 'fracture' the bedrock and increase gas or oil production. Fracturing fluids may contain toxic or carcinogenic compounds, which may leach into groundwater sources and pose a threat to human health through contaminated drinking water (Natural Resources Defense Council, 2002).

4.9.3 Water Quality Indicators

Changes in water quality indicate either a deterioration or improvement in the condition of the watershed and demonstrate specific areas that require further attention or protection. Changes in water quality result from changes in land use or land management practices, landscape disturbance and natural events. The major anthropogenic impacts on water quality result from natural resource extraction and processing, wetland drainage, dredging, dam construction, agricultural runoff, industrial wastes, municipal wastes, land erosion, road construction and land development. Five metrics were used to indicate changes in water quality in the Red Deer River watershed and its 15 subwatersheds:

- Nutrients – Condition Indicator
- Bacteria – Condition Indicator
- Parasites – Condition Indicator
- Pesticides – Condition Indicator
- Point Source Inputs

These five water quality indicators reflect socioeconomic growth in a region. Hence, while human activities in a region can have negative impacts on aquatic ecosystems, it is important to strive for a balance between socioeconomic growth and the sustainable management of these aquatic ecosystems to ensure their long-term health and enjoyment by future generations.

4.9.3.1 Nutrients

Nitrogen and phosphorus are essential nutrients for most aquatic plants, whereby excess nutrients can lead to eutrophication, i.e., an excessive amount of aquatic plant and phytoplankton growth. Concomitant with increased plant and phytoplankton growth, oxygen levels may significantly decrease in the water column, which may negatively impact aquatic organisms, including fish. In addition, excessive phytoplankton growth, particularly of cyanobacteria, can lead to the release of toxins into the water column, which may be harmful to aquatic organisms, waterfowl, livestock and humans.

Total phosphorus (TP) and total nitrogen (TN) concentrations in Pine Lake are generally elevated, with many concentrations exceeding the ASWGQ PAL limits of 0.05 mg/L and 1.0 mg/L, respectively (Figures 259, 260, respectively). Concentrations from 1990-2002 consistently exceeded this limit; however, TP and TN concentrations have considerably decreased since then and show fewer extremely high values. These decreases are likely in response to the initiation of a number of projects by the Pine Lake Restoration Society in an effort to reduce nutrient loading into the lake (Alberta Environment, 1997). The Pine Lake Restoration Society originally started off as the Pine Lake Advisory Committee. The committee formed because of rising inquiries about the amount of blue-green algae blooms and unexplained fish kills. In order for testing and technical work to be done, the Pine Lake Advisory committee needed to be formed. The objective of the committee was to evaluate the condition of the lake and to assess its potential for improvement. In 1992, a detailed field program was conducted at Pine Lake, and it was concluded that a long-term objective and goal would be to restore the lake to its natural condition. This was accomplished by implementing a hypolimnetic withdrawal system, which withdraws phosphorus-rich water from the bottom of the south basin of the lake, thereby lowering internal phosphorus loading rates (Sosiak, 1997; Pine Lake Restoration Society, 2008). The water is released into wetlands adjacent to Ghostpine Creek.

TP and TDP concentrations in Ghostpine Creek are generally high, with an average concentration of about 0.24 mg/L. The majority of samples since 1986 had TP concentrations well above the ASWQG PAL limit of 0.05 mg/L (Figure 261). A linear regression performed using StatFi in Excel 2007 shows that TP concentrations have increased significantly in the creek over the past 20 years ($p = 0.02$). TN concentrations in Ghostpine Creek are consistently high, with an average value of about 1.94 mg/L (Figure 262). Every sample collected since 1986 has exceeded the ASWQG PAL limit of 1.0 mg/L; however, there is no evidence that concentrations have increased or decreased over time.

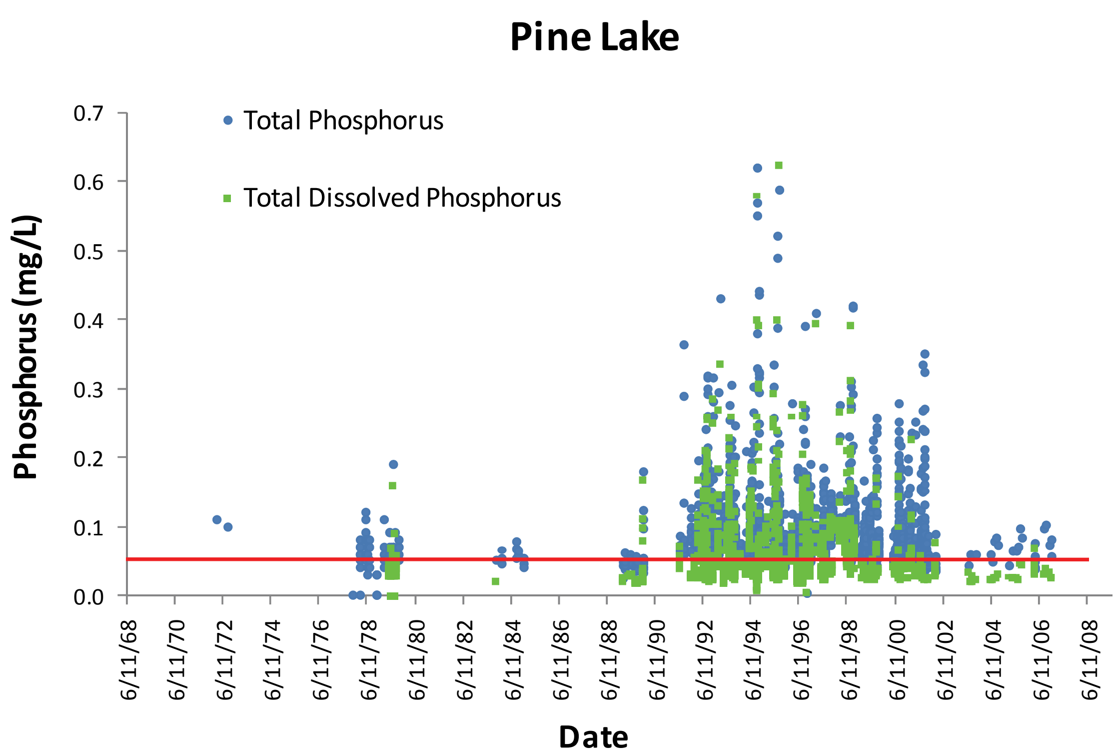


Figure 259. Total phosphorus (TP) and total dissolved phosphorus (TDP) concentrations in Pine Lake (data from Alberta Environment, 2008). The ASWQG PAL for TP (0.05 mg/L) is indicated by the red line.

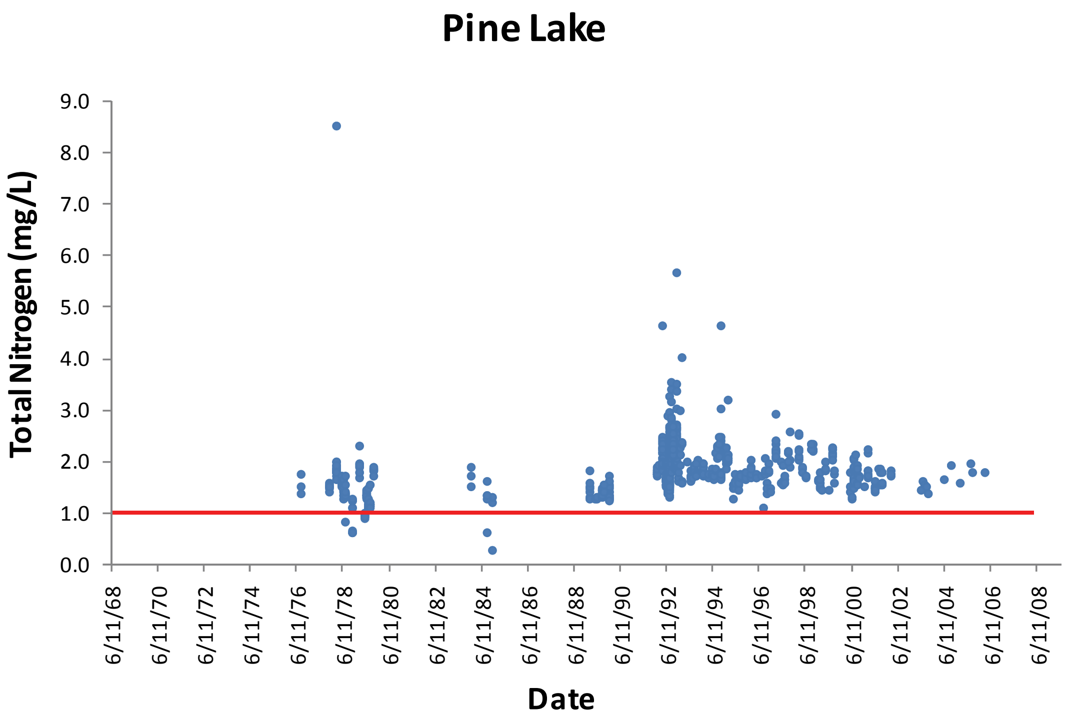


Figure 260. Total nitrogen (TN) concentrations in Pine Lake (data from Alberta Environment, 2008). The ASWQG PAL for TN (1.0 mg/L) is indicated by the red line.

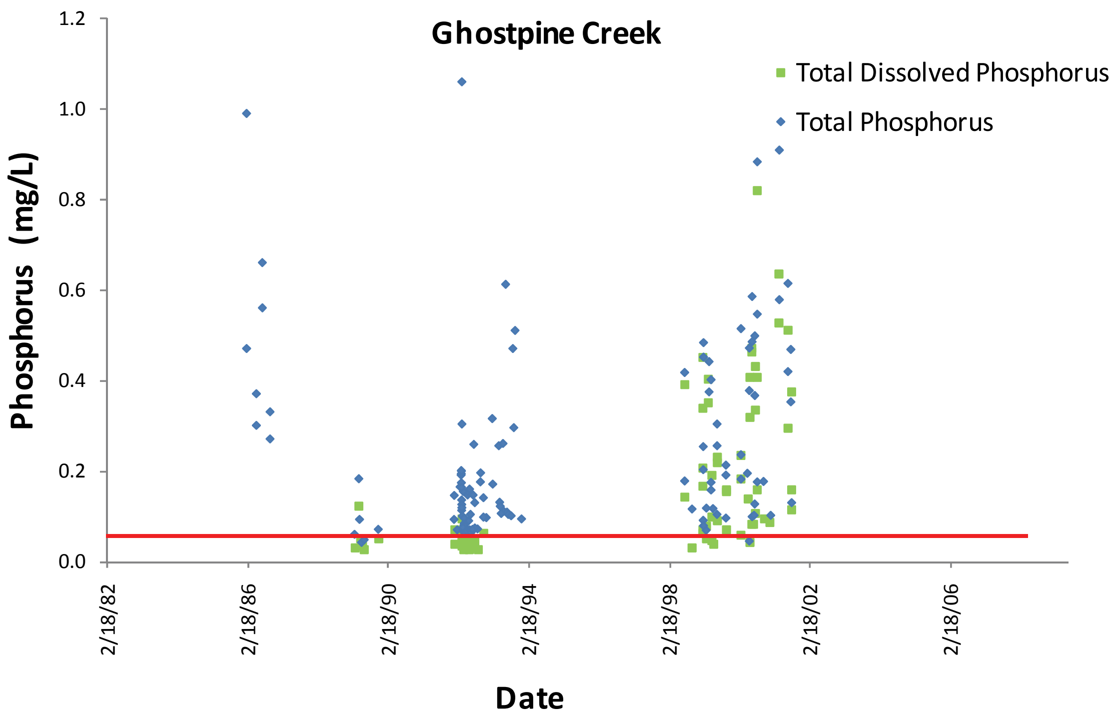


Figure 261. Total phosphorus (TP) and total dissolved phosphorus (TDP) concentrations in Ghostpine Creek (data from Alberta Environment, 2008). The ASWQG PAL for TP (0.05 mg/L) is indicated by the red line.

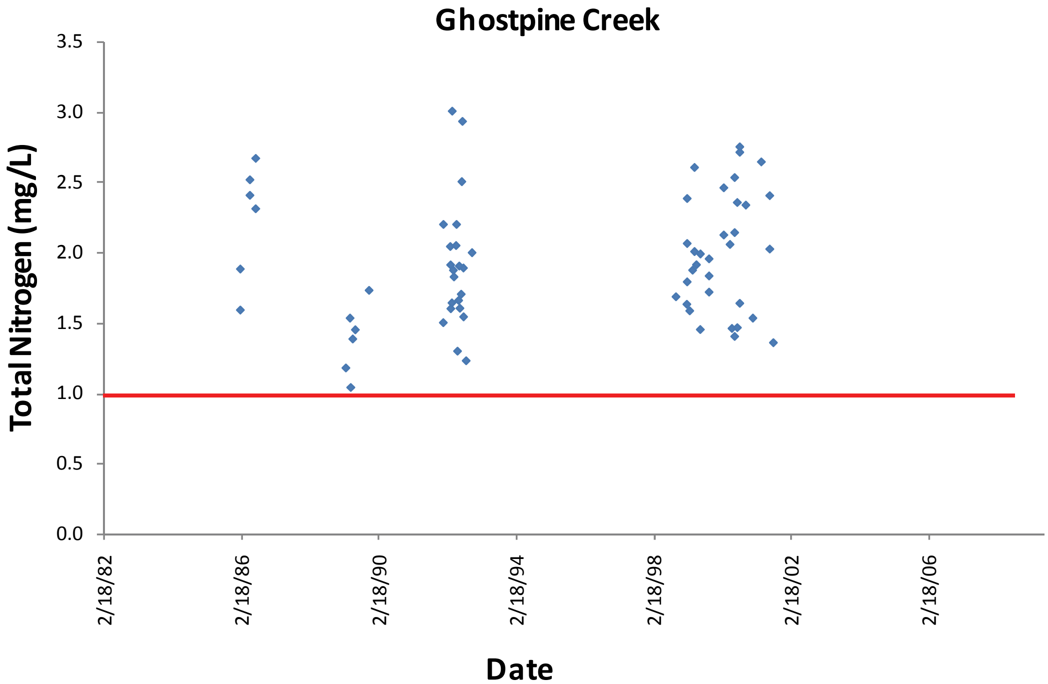


Figure 262. Total nitrogen (TN) concentrations in Ghostpine Creek (data from Alberta Environment, 2008). The ASWQG PAL for TN (1.0 mg/L) is indicated by the red line.

Ammonia (NH_3) and nitrate-nitrite (NO_3^--NO_2^-) concentrations in Pine Lake follow a similar trend to TN and TP (Figures 263, 264, respectively), with very high concentrations occurring in the 1990s. In that decade, NH_3 constituted a substantial proportion of TN in the water column. The highest NH_3 and NO_3^--NO_2^- concentrations occur from late summer to winter, which may be linked to the decay of organic matter following senescence and death of aquatic vegetation. NH_3 and NO_3^--NO_2^- concentrations have declined somewhat since 2000, likely in response to the initiation of a number of projects by the Pine Lake Restoration Society to reduce nutrient loading into the lake (Alberta Environment, 1997).

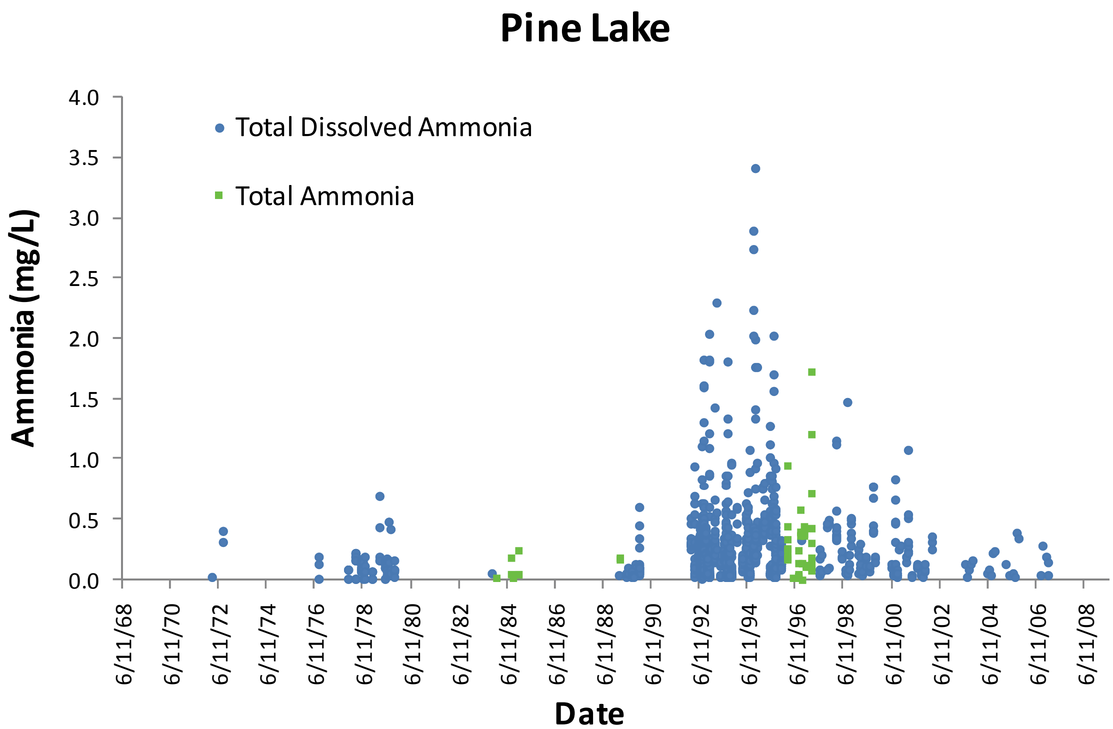


Figure 263. Total ammonia and total dissolved ammonia concentrations in Pine Lake (data from Alberta Environment, 2008).

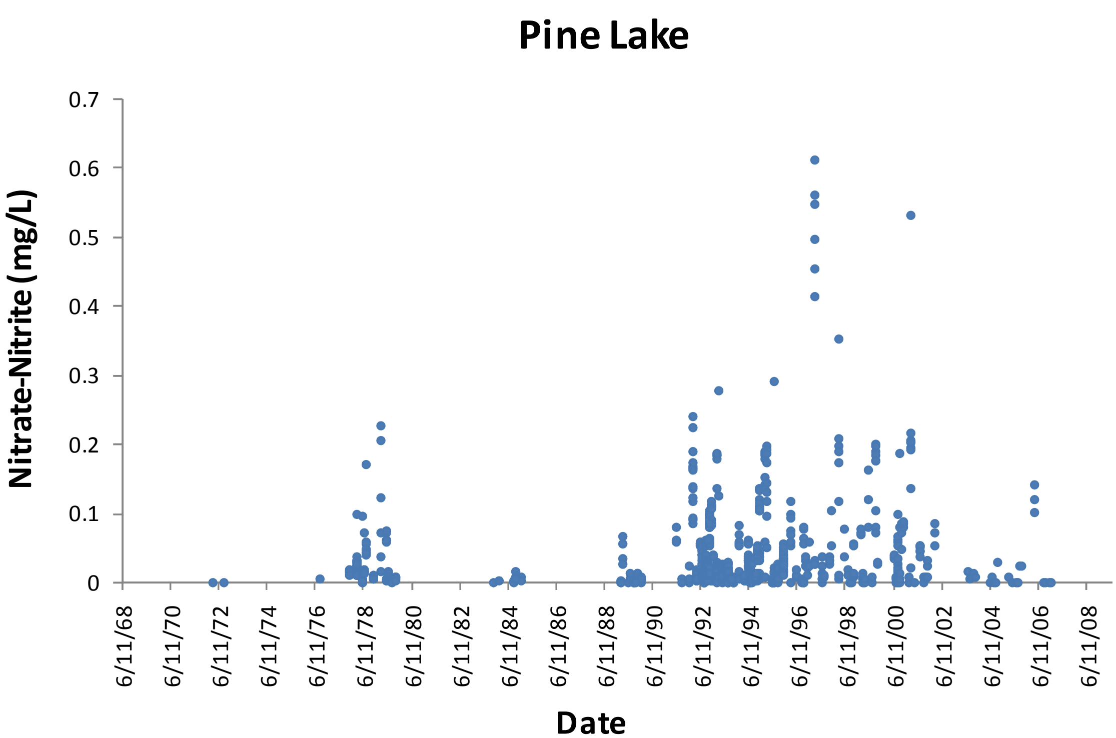


Figure 264. Nitrate-nitrite concentrations in Pine Lake (data from Alberta Environment, 2008).

There is a high degree of variability in dissolved oxygen (DO) concentrations in Pine Lake (Figure 265). Levels at the surface are consistently moderate throughout both the summer and winter; however, the water column tends to be hypoxic or anoxic at depths > 9 m, a condition that is common in bodies of water showing strong thermal stratification. In February 2002, DO concentrations were consistently below the ASWQG PAL limit throughout the water column. Combined with the generally hypoxic conditions in deeper water, this suggests that there may be a risk of winterkill in this lake.

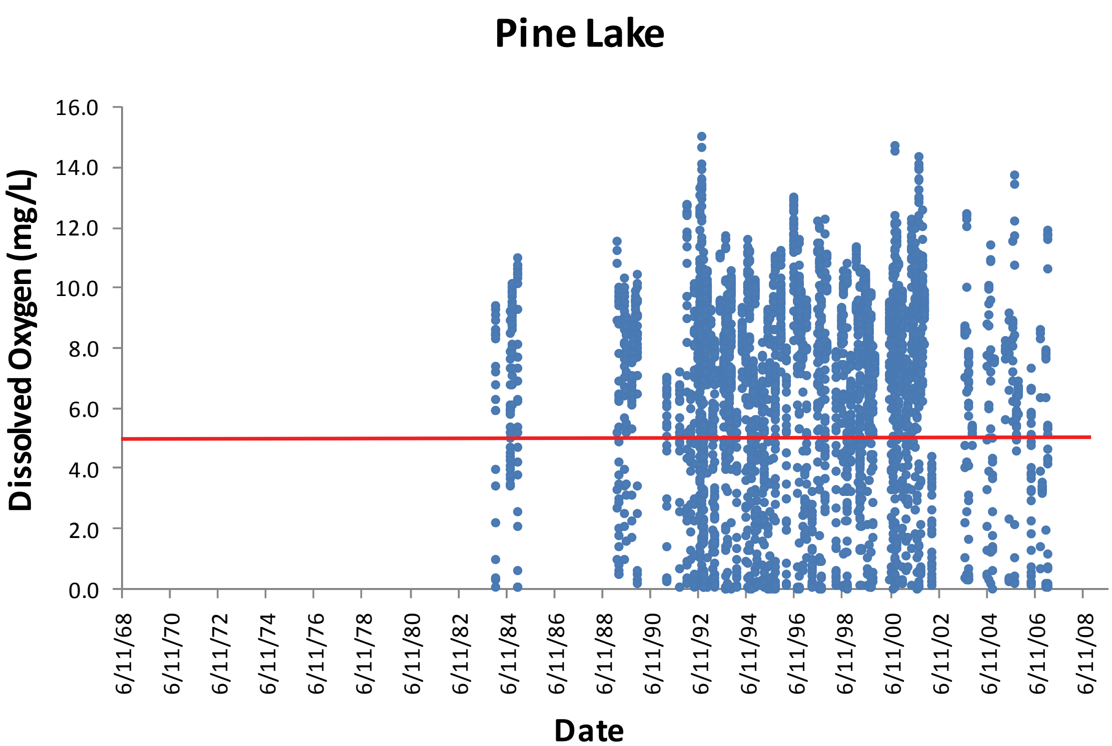


Figure 265. Dissolved oxygen (DO) concentrations in Pine Lake (data from Alberta Environment, 2008). The ASWQG PAL lower limit for DO (5.0 mg/L) is indicated by the red line.

The water quality has been assessed in the Pine Lake outflow from 1999-2001. Both TP and TN concentrations have been above ASWQ and CCME PAL guidelines, averaging 0.177 mg/L and 1.815 mg/L, respectively (Table 106). Sources of phosphorus and 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. Both agricultural and livestock operations occur in the vicinity of Pine Lake in the subwatershed and may contribute to the nutrient loading of the lake and consequently its outflow.

Table 106. Water quality in the Pine Lake siphon outflow. Data are average values of samples collected June 1999-August 2001 (data from Alberta Environment). n = sample size. All concentrations in mg/L unless otherwise noted. Concentrations exceeding water quality guidelines are highlighted *.

Parameter	Mean	n
TP	0.177	8
TDP	0.160	8
TN	1.815	8
NO_3^--NO_2^-	0.052	8
NH_3	0.553	8
DO	2.16	12
Chl. *a* (µg/L)	---	---
pH	8.06	12
Specific Conductivity (µS/cm)	741	12
TDS	---	---

* TN from ASWQG PAL chronic exposure guideline; all others from CCME PAL. Variable abbreviations as in Table 10.

4.9.3.2 Bacteria

Coliforms are a broad class of bacteria found in human and animal wastes. Total coliforms include *Escherichia coli*, fecal bacteria and other coliforms that occur naturally in warm blooded animals. *E. coli* is one of three bacteria commonly used to measure the direct contamination of water by human or other mammal wastes. Ingestion of or exposure to fecal bacteria can have negative health impacts. Sources of this type of bacteria include agricultural and municipal runoff, wildlife, faulty septic systems and septic fields.

Coliform concentrations in Pine Lake have been generally low; however, CCME Agriculture/Irrigation guidelines have been exceeded on occasion (Figure 266), e.g., in 1992, levels of both fecal and total coliforms exceeded acceptable limits, and in 2000, fecal coliforms and *E. coli* concentrations exceeded limits. No data are available since then, but the previously elevated concentrations warrant further attention. Coliform concentrations have not been determined in the Pine Lake siphon outflow or in any other creek in the subwatershed (Table 106).

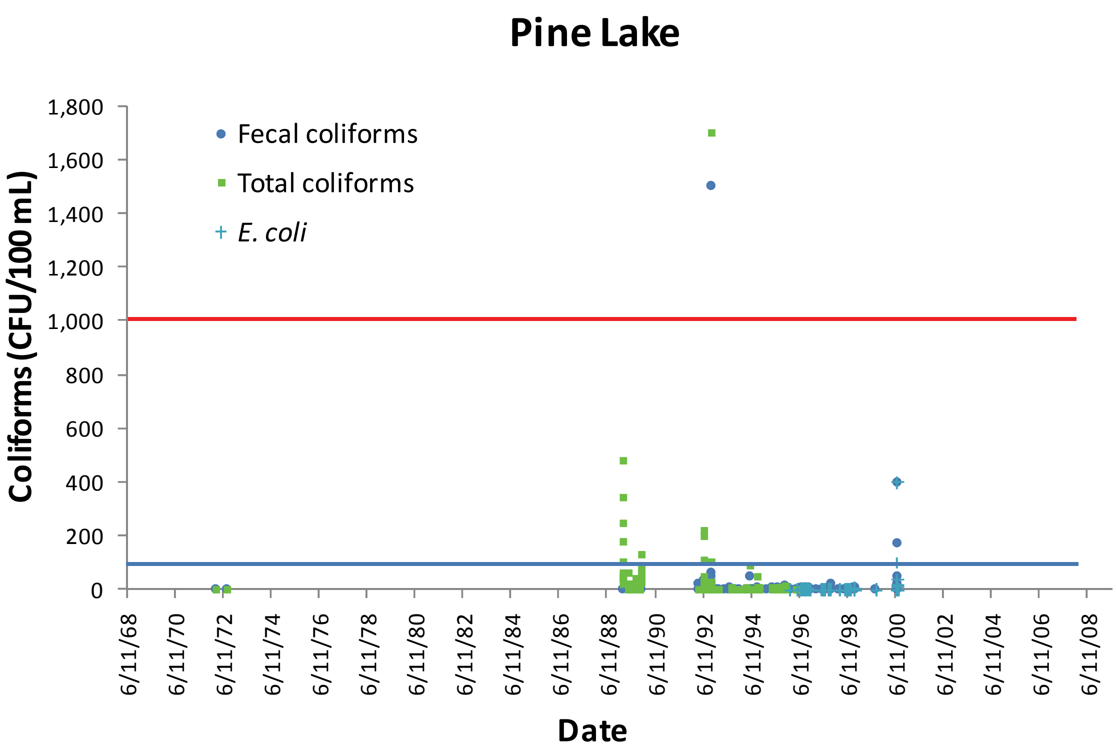


Figure 266. Total coliform and fecal coliform concentrations in Pine Lake (data from Alberta Environment, 2008). The CCME Agriculture/Irrigation guideline for fecal coliforms (100 CFU/100 mL) is indicated by the blue line, and the CCME Agriculture/Irrigation guideline for total coliforms (1,000 CFU/100 mL) is indicated by the red line.

4.9.3.3 Parasites

Waters that are polluted may contain several different disease-causing organisms, commonly called parasites. Enteric parasites, those that live in the intestine of warm blooded animals, can carry or cause a number of infectious diseases. *Cryptosporidium* and *Giardia* spp. are two such parasites. Both occur in almost all environments, including lakes, rivers, reservoirs and groundwater. They come from the feces of rodents, birds, cows, pigs and humans, and the ingestion of these parasites causes gastrointestinal conditions known as cryptosporidiosis and giardiasis.

Parasite data were not located for any waterbody in the Threehills Creek subwatershed.

4.9.3.4 Pesticides

Pesticides are a group of chemicals, including herbicides, insecticides, rodenticides and fungicides, used for many purposes, including pest control and aesthetics in urban areas, golf courses and in forestry and agricultural production. Pesticides are a common contaminant of streams and dugouts in the high intensity agricultural areas of Alberta.

Pesticide concentrations have been measured in six waterbodies in the Threehills Creek subwatershed. In these waterbodies, 20 different pesticides have been measured, with 2,4-D occurring in five of the six waterbodies and Dicamba and MCPA occurring in four of the six waterbodies (Table 107). None of the pesticides exceeded CCME PAL guidelines; however, half of the measured pesticides currently do not have maximum concentration guidelines.

Table 107. Pesticide concentrations in waterbodies in the Threehills Creek subwatershed. All concentrations in µg/L. The most common pesticides have been highlighted.

Waterbodies	Pesticide	Mean range *	Maximum	CCME PAL	n
Braconnier Reservoir	2,4-D	0.030-0.035	0.051	4.0	4
	Dicamba	0.029-0.039	0.070	10.0	4
	MCPA	0.043-0.053	0.120	2.6	4
Ghostpine Creek	Bis(2-ethylhexyl) phthalate	1.272	1.272	---	1
	Dichloromethane	0.13	0.13	98.1	1
	Di-n-butyl phthalate	0.285	0.285	19.0	1
Pine Lake Inflow	2,4-D	0.35-0.45	0.70	4.0	2
Ray Creek	2,4-D	0.019-0.021	0.282	4.0	79
	2,4-DP	0.0001-0.0050	0.010	---	73
	Bromoxynil	0.002-0.005	0.060	5.0	79
	Clopyralid	0.010-0.025	0.170	---	73
	Dicamba	0.0004-0.0037	0.027	10.0	79
	Diazinon	0.0001-0.0050	0.008	---	73
	Ethalfluralin	0.001-0.005	0.039	---	73
	Glyphosate	0.080-0.249	1.067	65.0	20
	Imazamethabenz-methyl	0.155-0.167	2.055	---	79
	Imazethapyr	0.001-0.020	0.051	---	70
	MCPA	0.025-0.027	0.295	2.6	79
	MCPP	0.0004-0.0050	0.014	---	73
	Picloram	0.007-0.0104	0.374	29.0	79
	Triallate	0.006-0.009	0.146	0.24	79
Renwick Creek	2,4-D	0.141-0.143	4.834	4.0	61
	2,4-DB	0.0001-0.0050	< 0.005	---	57
	2,4-DP	0.0001-0.0050	0.006	---	57
	Bromoxynil	0.006-0.011	0.093	5.0	61
	Clopyralid	0.023-0.034	0.204	---	57
	Dicamba	0.0001-0.0068	< 0.005	10.0	33
	Ethalfluralin	0.0001-0.0060	0.009	---	61
	Gamma-benzenehexachloride	0.001-0.0067	0.011	---	61
	Glyphosate	0.442-0.564	2.626	65.0	18
	Imazamethabenz-methyl	0.088-0.123	0.797	---	61
	Imazethapyr	0.005-0.024	0.146	---	54
	MCPA				
	MCPP	0.068-0.070	1.292	2.6	61
	Picloram	0.0001-0.005	0.005	---	57
	Triallate	0.039-0.043	0.392	29.0	61
Threehills Creek	2,4-D	0.018-0.021	0.109	4.0	81
	2,4-DP	0.001-0.005	0.074	---	76
	Bromoxynil	0.002-0.007	0.081	5.0	81

Clopyralid	0.017-0.030	0.207	---	76
Diazinon	0.0001-0.0050	0.012	---	76
Dicamba	0.0003-0.0101	0.006	10.0	81
Ethalfluralin	0.0004-0.0054	0.029	---	81
Glyphosate	0.056-0.236	0.966	65	21
Imazamethabenz-methyl	0.325-0.349	9.005	---	81
Imazethapyr	0.001-0.020	0.054	---	68
MCPA	0.036-0.038	0.395	2.6	81
MCPP	0.0002-0.0050	0.016	---	76
Picloram	0.014-0.018	0.536	29.0	81
Triallate	0.006-0.010	0.096	0.24	81

* A precise mean could not be determined because the analytical methods used do not distinguish between values of zero and values that are below the detection limit (BDL). The range of the mean was calculated by first assuming that all BDL samples were equal to zero (providing the lower end of the range), and then by assuming that all BDL samples were equal to the detection limit (providing the upper end of the range). Where no values below the detection limit were present, a single average value was calculated. In Braconnier Reservoir, samples were collected from August 1995-September 1996 (data also from CAESAA); in Ghostpine Creek, water samples were collected in July 2000; in Pine Lake Inflow, water samples were collected in April 1990; in Ray Creek, water samples were collected January 1997-December 2005 (data also from CAESAA); in Renwick Creek, water samples were collected March 1997-December 2005 (data also from CAESAA); in Threehills Creek, water samples were collected January 1997-December 2005 (data also from CAESAA) (data from Alberta Environment).

4.9.3.5 Point Source Inputs

Point source inputs include effluents from waste water treatment plants (WWTP), stormwater outfalls and industry. Effluent from WWTP's, although regulated, generally has higher concentrations of certain compounds (e.g., nutrients, solids, pharmaceuticals, metals, etc.) than the receiving environment. Similarly, stormwater outfalls contain elevated levels of nutrients, salts and solids compared to the receiving environment, and industrial effluents can contribute elevated levels of a suite of different contaminants, such as metals, solids, hydrocarbons and/or salts, as well as other chemicals used in processing or manufacturing, to aquatic ecosystems.

At least 55 upstream oil/gas facilities, seven oil sands/heavy oil processing facilities, one oil/gas refining/storage facility and one agricultural processing/storage facility have released pollutants continuously or sporadically into the air in the Threehills Creek subwatershed since 2003. Pollutants from the upstream oil/gas facilities and the oil/gas processing facility include carbon monoxide (CO), nitrous oxide (N_2O) and particulate matter < 10 µm in size. The pollutants from the oil sands/heavy oil processing facilities include N_2O and CO, while those from the agricultural processing/storage facility were particulate matter < 10 µm in size (NPRI, 2008). No pollutants were released directly into aquatic ecosystems according to the National Pollution Release Inventory.

4.9.4 Water Quantity Indicators

Water quantity is important for the maintenance of aquatic habitat, it has functions related to water quality and it is essential for the treatment and production of sufficient volumes of drinking water to meet current demands. Irrigation, industry and livestock production are highly dependent on a minimum amount of water. Sufficient water quantity is necessary for many recreational activities, and in recent years many cottagers and recreational lake users across Alberta have voiced concerns about the decreasing volumes of water seen across the province. Five metrics were used as water quantity indicators in the Red Deer River watershed and its 15 subwatersheds:

- Volume

- Minimum Flows to Maintain Ecological Integrity – Condition Indicator
- Contributing Areas to the Watershed
- Allocations
- Groundwater Recharge/Discharge

Water discharge rates, allocations and minimum flow rates to maintain ecological integrity can reflect socioeconomic growth in a region. Human activities in a region frequently reduce available water quantities required to maintain healthy aquatic ecosystems. It is important to balance socioeconomic growth and the sustainable management of these aquatic ecosystems to ensure their long-term health and enjoyment by future generations.

4.9.4.1 Volume

Water volume is the amount of water flowing past one point over a given time, or in the case of lakes or other standing waterbodies, the total amount of water present in the waterbody at a given time. This amount varies seasonally and annually with shifts in weather patterns. Water withdrawals for consumptive uses have increased dramatically in recent years and have resulted in some watersheds within the province being closed to new water licenses.

The total length of all water courses in the Threehills Creek subwatershed is about 2,256 km (Figure 267) (AAFC-PFRA, 2008). The major streams in the subwatershed are Ghostpine Creek, Ray Creek, Renwick Creek and Threehills Creek. The largest waterbodies are Bigelow Reservoir, Braconnier Reservoir, Goosequill Lake, Mikwan Lake, Pine Lake and Wood Lake. In addition, there are numerous small creeks, lakes and sloughs in the subwatershed (Government of Canada, 2006).

Alberta Environment has been monitoring water discharge rates in the Threehills Creek subwatershed at seven locations: in Ray Creek (real-time active, 05CEB010), below the confluence of Ray and Threehills Creeks (real-time active, 05CEB018), Renwick Creek near Three Hills (real-time active, 05CEB011), Bigelow Reservoir near Wimborne (active, 05CE901), Ghostpine Creek near Huxley (discontinued, no station identifier), Threehills Creek below Bigelow Reservoir (discontinued, 05CE015) and Threehills Creek above the confluence with Ghostpine Creek (active, no station identifier) (Government of Alberta, 2008c).

Water discharge rates in Threehills Creek below the confluence with Ray Creek generally range from 0.1-1 m^3/sec. Historically, water discharge rates are negligible (Figure 268). Water discharges from Renwick Creek into Threehills Creek only in the spring. Discharge rates are generally < 0.02 m^3/sec. Historically, water discharge rates have been consistently < 0.1 m^3/sec (Figure 269). Similarly, water discharge rates in Ray Creek near Innisfail are low (about 0.1 m^3/sec) in the spring and cease by mid-summer (Figure 270) (Government of Alberta, 2008c).

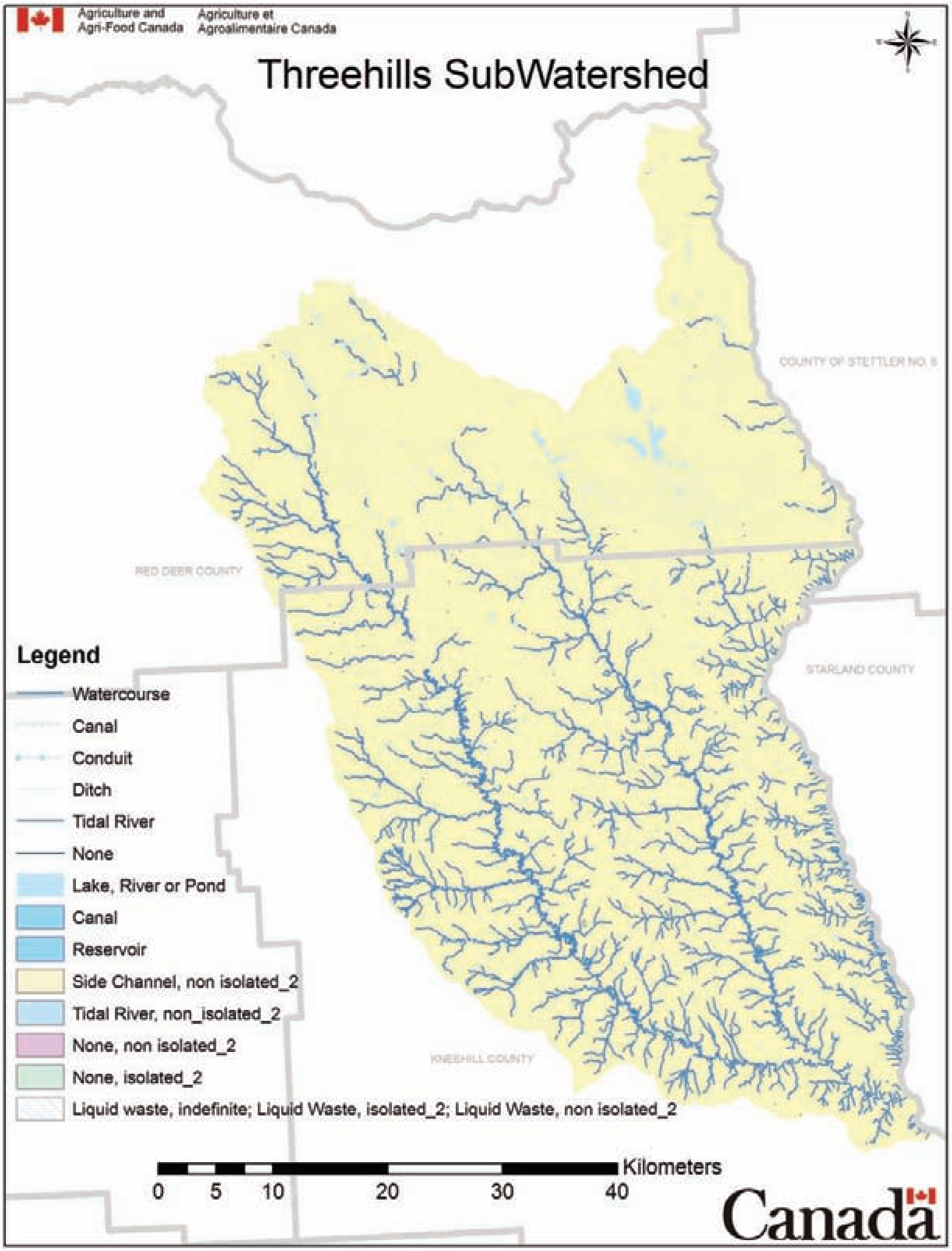


Figure 267. Waterbodies in the Threehills Creek subwatershed (AAFC-PFRA, 2008).

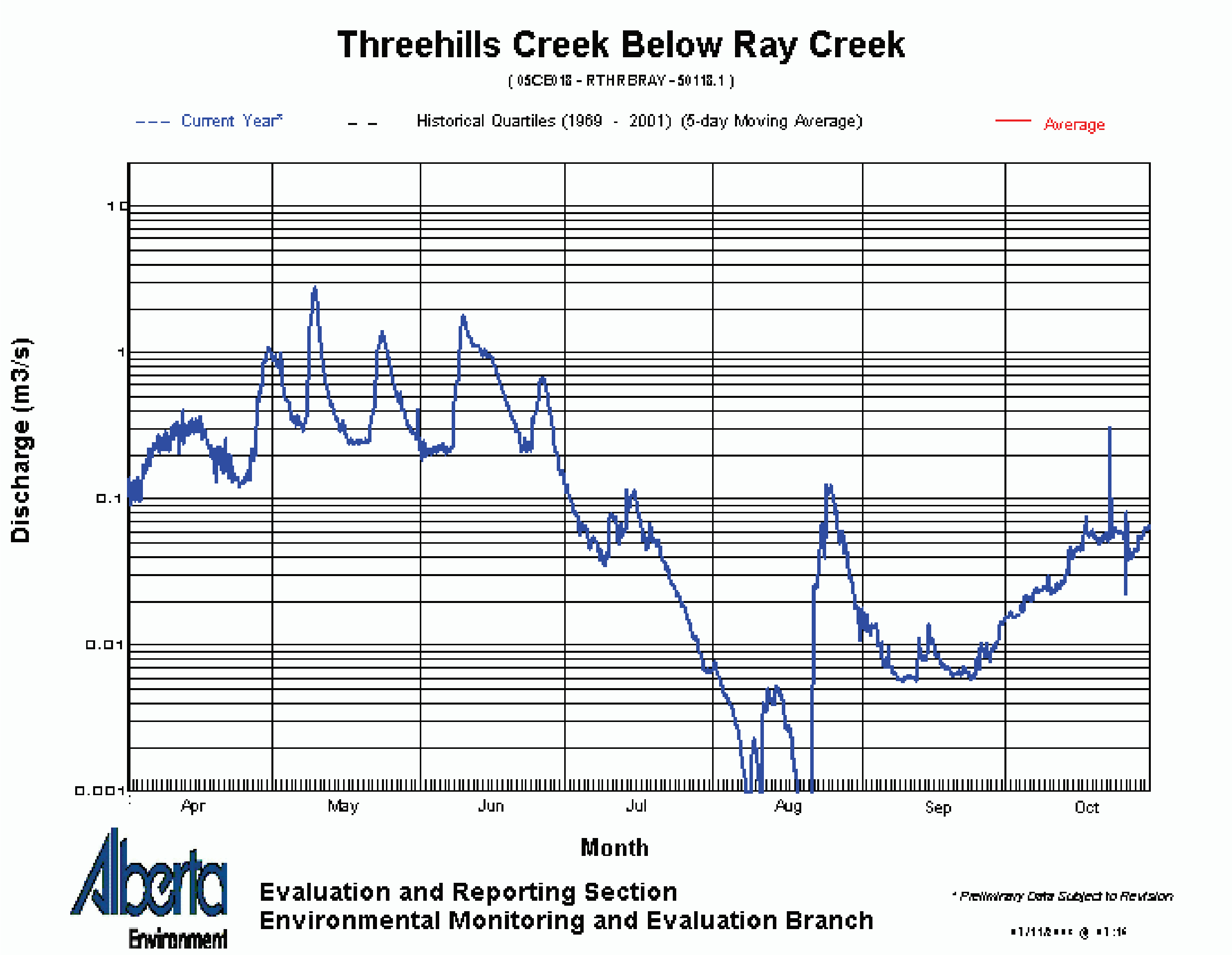


Figure 268. Discharge rates in Threehills Creek below Ray Creek (Government of Alberta, 2008c). "Current year" indicates water discharge rates in 2008.

Water discharge rates in Renwick and Ray Creeks were well above average levels in the spring and early summer 2008, when they approached 0.1 m^3/sec on several occasions. They remained substantially higher than average levels for the remainder of the season (Figures 270, 271, respectively) (Government of Alberta, 2008c).

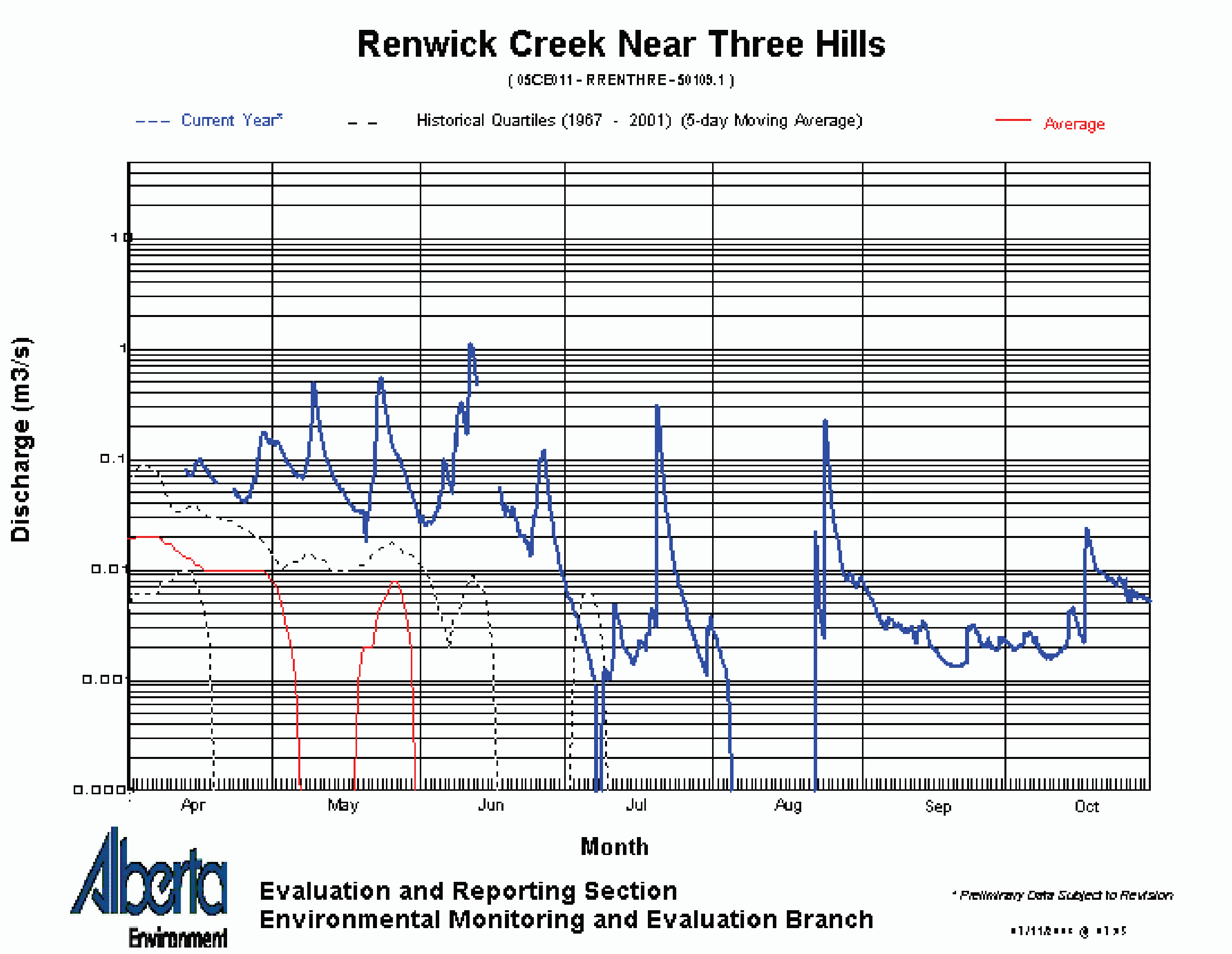


Figure 269. Discharge rates in Renwick Creek near Three Hills (Government of Alberta, 2008c). “Current year” indicates water discharge rates in 2008.

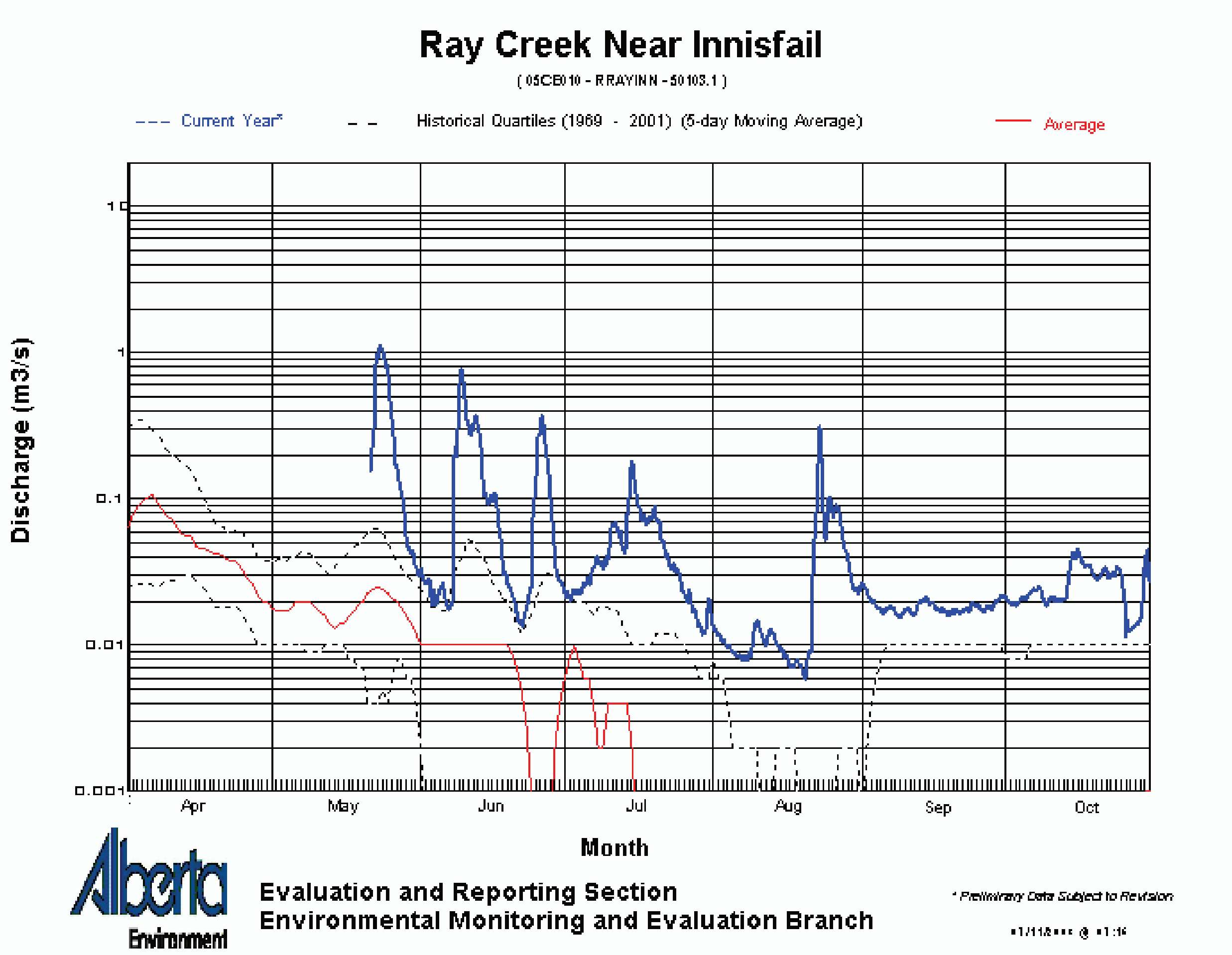


Figure 270. Discharge rates in Ray Creek near Innisfail (Government of Alberta, 2008c). "Current year" indicates water discharge rates in 2008.

There are two major dams in the Threehills Creek subwatershed (Figure 271). Bigelow Dam is located in the upper reaches of Threehills Creek, creating Bigelow Reservoir upstream of the dam. A dam on a tributary of Threehills Creek south of the town of Three Hills has created Braconnier Reservoir. In addition, there are numerous smaller water infrastructures in the subwatershed, e.g., small dams, sluices, weirs and dykes, which control water flow.

Figure 271. Major dams in the Threehills Creek subwatershed (AAFC-PFRA, 2008).

4.9.4.2 Minimum Flows to Maintain Ecological Integrity

Minimum flows to maintain ecological integrity are the lowest flows or volumes (lakes) required to sustain native aquatic species and natural ecosystem functions. Minimum flows must be determined before allocation of water can safely take place to preserve the ecological functionality of aquatic ecosystems.

Minimum flow requirements for the maintenance of ecological integrity have not been determined in the Threehills Creek subwatershed.

4.9.4.3 Contributing Areas to the Watershed

Contributing areas to the watershed are areas from which runoff flows into the lakes, creeks and rivers of the watershed. These data are used to determine an estimated volume of water contributed to the river on an annual basis.

In the Threehills Creek subwatershed, 67,643 ha (or 22.5% of the total area of the subwatershed) of land do not contribute to the drainage of the subwatershed (Figure 272) (Government of Alberta, 2007g, AAFC-PFRA, 2008). These areas are located primarily in the northern areas of the subwatershed, e.g., between the headwaters of Ghostpine Creek and Threehills Creek and east of the headwaters of Ghostpine Creek, where the topography is highly undulating (Figure 273) and precipitation does not run off into nearby waterbodies.

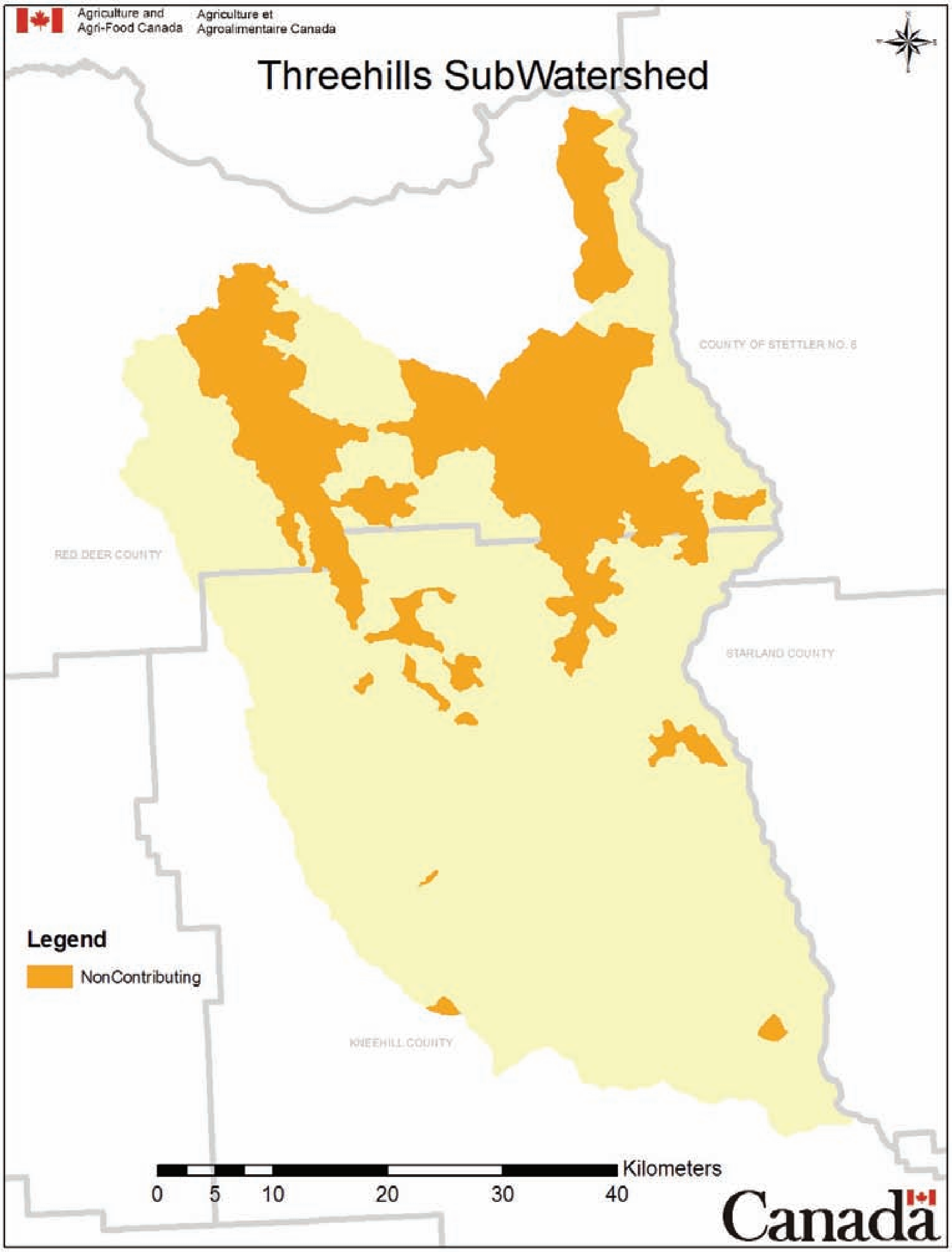


Figure 272. Non-contributing drainage area in the Threehills Creek subwatershed (AAFC-PFRA, 2008).

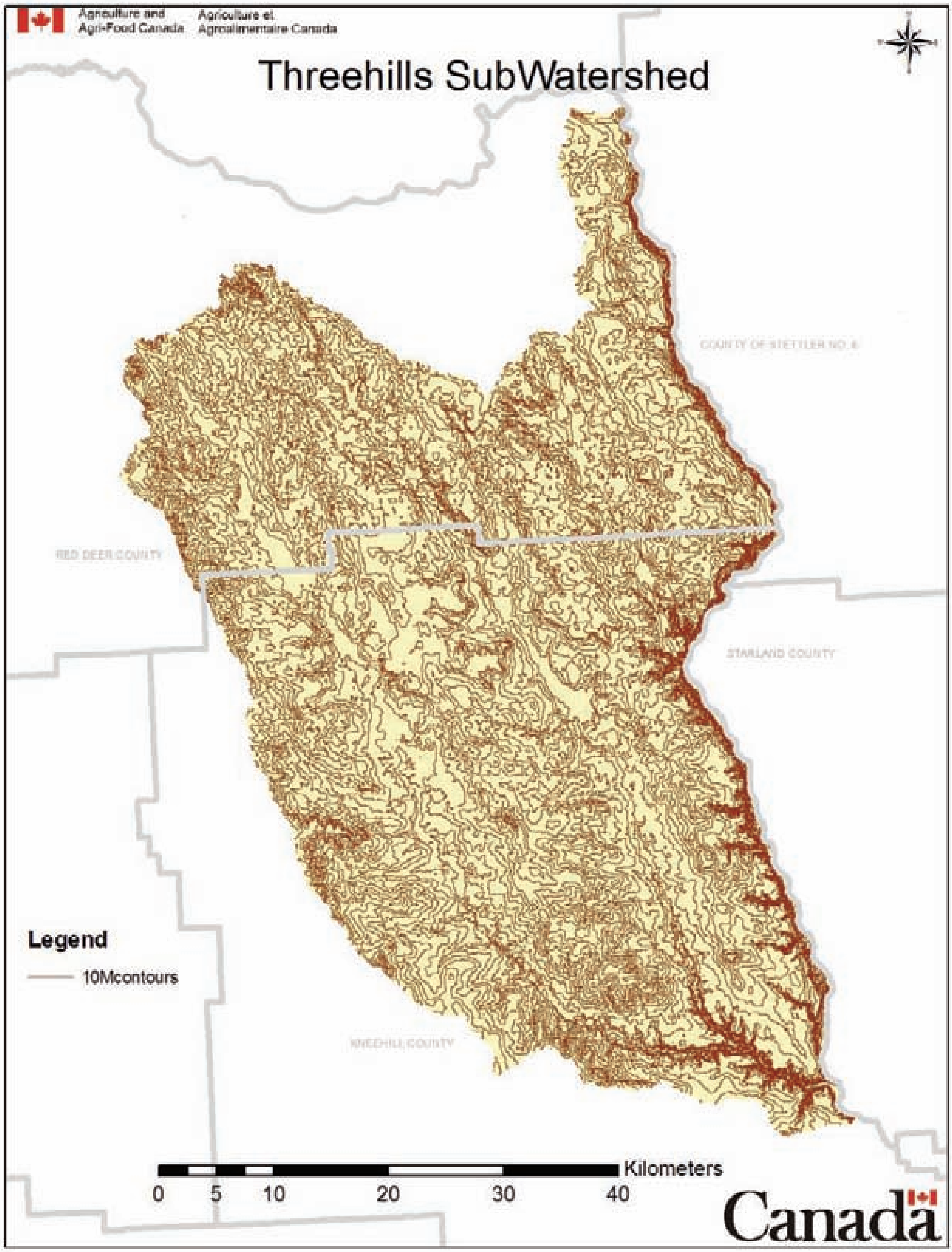


Figure 273. Topography (10-m intervals) of the Threehills Creek subwatershed (AAFC-PFRA, 2008).

4.9.4.4 Allocations

Surface and groundwater water withdrawal permits for the watershed are quantified by user sector along with information on licenses, consumption and return flows. This information will be used along with water flow data to identify areas of potential future constraints on surface water availability, which may have implications for future development.

In the Threehills Creek subwatershed, 2,249 surface water licenses and 1,068 groundwater licenses have been issued for water diversion projects (Figures 274, 275, respectively) (AAFC-PFRA, 2008). They are distributed throughout the entire subwatershed.

About 4.62 million m^3 of surface and groundwater are diverted annually in the Threehills Creek subwatershed (Government of Alberta, 2008d). The most prominent use of surface water is water management (40% of total surface water diversions) and agricultural operations (21% of total surface water diversions), while the most prominent users of groundwater are agricultural operations (67% of total groundwater diversions) (Table 108). The majority of water diverted in the entire subwatershed comes from surface water sources, e.g., lakes, streams and rivers (74%) (Government of Alberta, 2008d). Additional groundwater diversion information is provided in HCL (2004) and Stantec Consulting Ltd. (2005).

Table 108. Surface and groundwater diversions in the Threehills Creek subwatershed (Government of Alberta, 2008d). The highest uses for water have been highlighted. Data reported exclude any water diverted from the Red Deer River mainstem.

Purpose	Surface water (m^3/yr)	Groundwater (m^3/yr)
Agriculture	729,984	790,064
Commercial	358,280	102,272
Groundwater exploration	---	6,818
Habitat enhancement	530,368	---
Irrigation	433,000	---
Management of fish	---	4,930
Management of wildlife	22,000	---
Municipal	2,460	126,934
Other purposes specified by the Director	---	1,052
Recreation	---	103,956
Water management	1,362,100	---
Total	**3,438,192**	**1,185,356**
Grand total		**4,623,548**

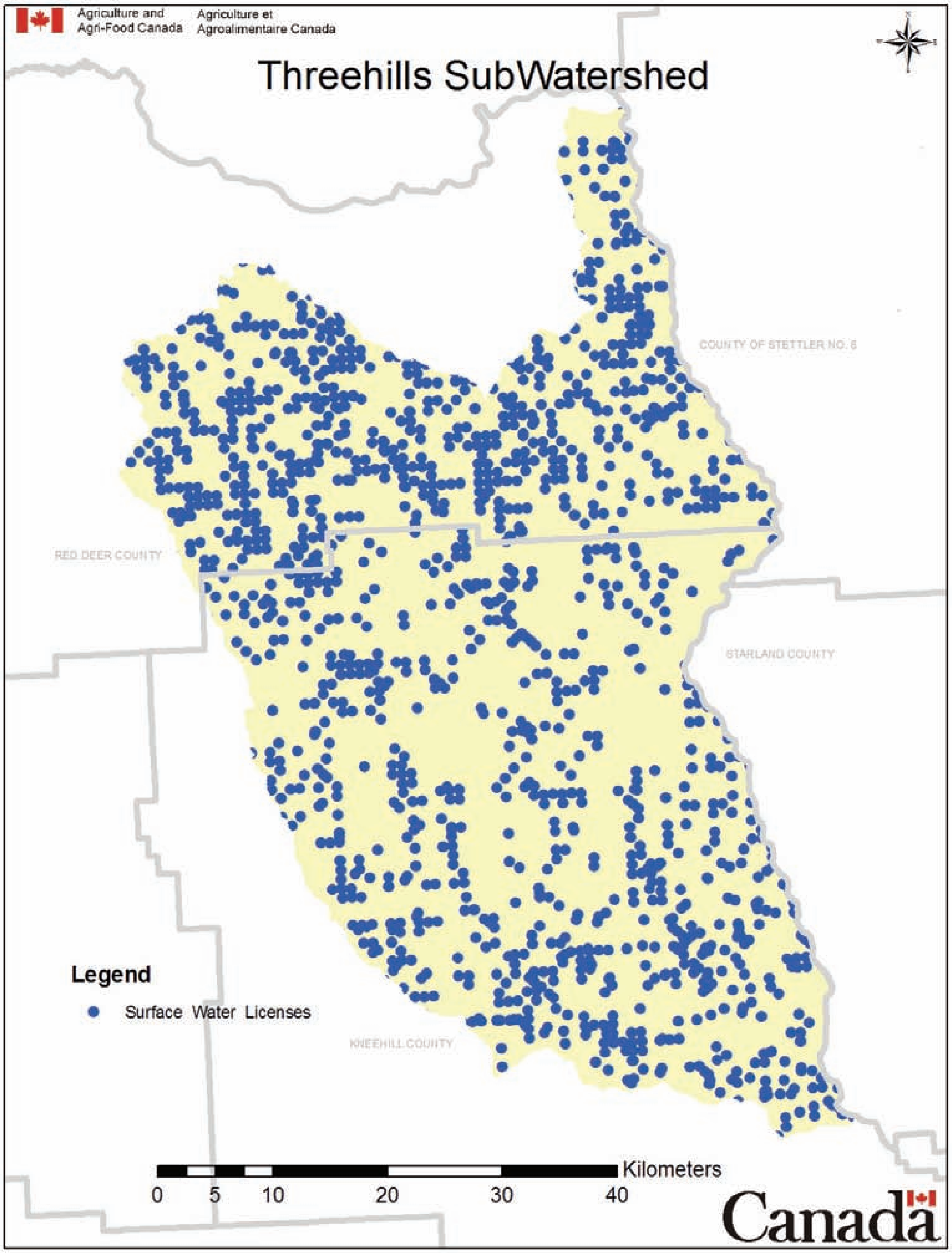


Figure 274. Surface water licenses in the Threehills Creek subwatershed (AAFC-PFRA, 2008).

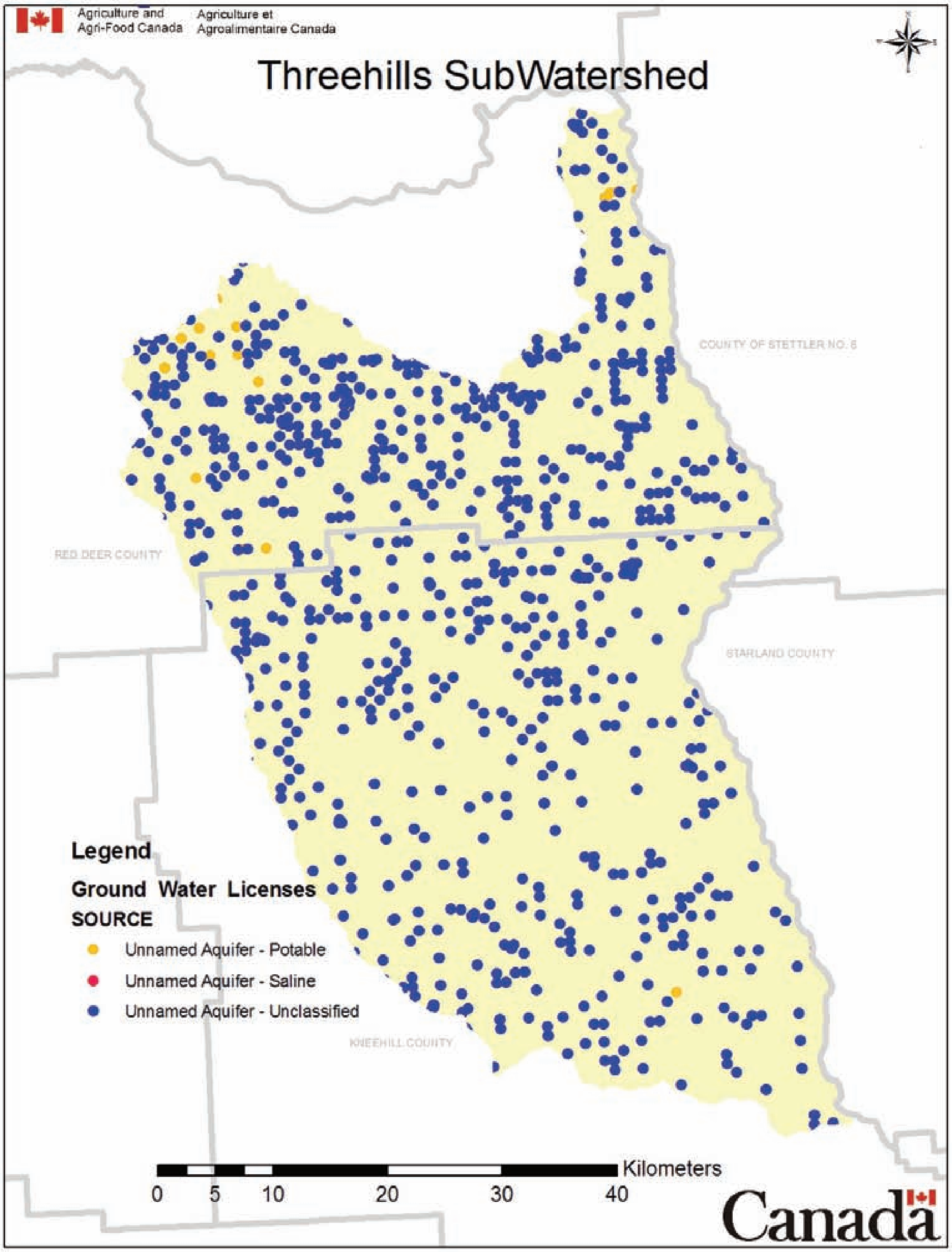


Figure 275. Groundwater licenses in the Threehills creek subwatershed (AAFC-PFRA, 2008).

4.9.4.5 Groundwater Recharge/Discharge

Areas where groundwater gets recharged or discharges to the surface indicate areas where the groundwater table is close to the surface and the soils are generally more permeable. These areas are at greater risk of becoming negatively impacted from development or agricultural and/or industrial activities. Knowing where groundwater recharges and discharges occur will help to identify areas requiring special protection and limitations to land use.

Freshwater springs are points in the landscape where the aquifer surface meets the ground surface, i.e., freshwater springs are areas of groundwater discharge. The Threehills Creek subwatershed has > 100 freshwater springs, the most of any of the 15 subwatersheds of the Red Deer River watershed. Most of the freshwater springs are located near the Town of Trochu and in the upper reach of Ghostpine Creek near Pine Lake. Less than ten springs are located along or in the vicinity of Threehills Creek.

The Threehills Creek subwatershed lies in Red Deer County and Kneehill County, for which groundwater assessments have been conducted by HCL (2004) and Stantec Consulting Ltd. (2005), respectively. The assessments indicated that the area in the headwaters of Threehills and Ghostpine Creeks is primarily a groundwater recharge area (i.e., water moves from the surface into groundwater reservoirs), whereas the area in the middle and lower reaches of Threehills Creek is primarily a discharge area (i.e., water moves from groundwater reservoirs to the surface). Specific areas of groundwater recharge include small depressions in the landscape and temporary and ephemeral wetlands, which collect rainwater and snow melt and release a proportion of this accumulated water into shallow groundwater and regional aquifers (van der Kamp and Hayashi, 1998; Hayashi et al., 2003). Additional information on aquifers, water quantity and quality of the groundwater associated with each aquifer, hydraulic relationship among aquifers and possible groundwater depletion areas associated with each upper bedrock aquifer is provided in HCL (2004) and Stantec Consulting Ltd. (2005).

4.9.5 Biological Indicators

Bioindicators are biological (plant and animal) data from which various aspects of ecosystem health can be determined or inferred. The presence, absence and abundance of such data can be linked to water quality, quantity and ultimately to overall watershed health. Four metrics were used as biological indicators in the Red Deer River watershed and its 15 subwatersheds:

- Wildlife Biodiversity
- Fish
- Land Cover – Condition Indicator
- Species at Risk

Changes in biological populations often reflect socioeconomic growth in a region. Human settlement and the subsequent exploration and extraction of natural resources alters the landscape and with it the habitat of the indigenous flora and fauna. It is important to balance socioeconomic growth with the preservation of natural habitat integrity to ensure the long-term health of natural biological populations.

4.9.5.1 Wildlife Biodiversity

Wildlife inventories to determine the biodiversity within the watershed will indicate changes in environmental conditions (e.g., habitat fragmentation, loss of nesting and breeding sites, nutrient enrichment, etc.). A loss of biodiversity can cause an ecosystem to become less stable and more vulnerable to environmental change. A change in diversity may also affect nutrient cycling and/or energy flow through the ecosystem.

Wildlife biodiversity assessment data have not been located for the Threehills Creek subwatershed.

4.9.5.2 Fish

Inventories of selected fish populations may show increases or declines through introductions or changes in environmental conditions. Indicator species sensitive to environmental pollution may show areas of concern through their absence, while others may show similar with their presence. Invasive species, if present, will indicate areas of concern requiring future monitoring.

Pine Lake fish records contain only three species of fish, northen pike, walleye and yellow perch (Figure 276). The yellow perch are the most abundant, followed by northern pike and walleye. There have not been any significant changes in these populations over this time period ($p > 0.2$, 0.4 and 0.3, respectively).

Yellow perch inhabit lakes, ponds, pools of creeks and rivers and is also found in brackish water and in salt lakes. Most commonly found in clear water near vegetation; tends to shoal near the shore during spring. It feeds on immature insects, larger invertebrates, fishes and fish eggs during the day. Yellow perch are preyed upon by fishes and birds. It spawns from February-July (Nelson and Paetz, 1992; Scott and Crossman, 1998).

Northern pike are found in sluggish streams and shallow, weedy places in lakes, as well as in cold, clear, rocky waters. Pike are typical ambush predators, feeding mainly on fish, but on occasion also feed on frogs, insect, leeches, water voles and ducklings (Nelson and Paetz, 1992; Scott and Crossman, 1998).

Walleye are tolerant of a great range of environmental situations, but appear to reach greatest abundance in large, shallow, turbid lakes. Large streams or rivers, provided they are deep or turbid enough to provide shelter in daylight, are also preferred habitat of the walleye. They use sunken trees, boulder shoals, weed beds or thicker layers of ice and snow as a shield from the sun. Generally, it is a “cool-water” species, preferring warmer water than trout and cooler water than bass and panfish. Walleye feeds at night, mainly on insects and fishes (prefers yellow perch and freshwater drum but will take any fish available) but also on crayfish, snails, frogs, mudpuppies and small mammals when fish and insects are scarce (Nelson and Paetz, 1992; Scott and Crossman, 1998).

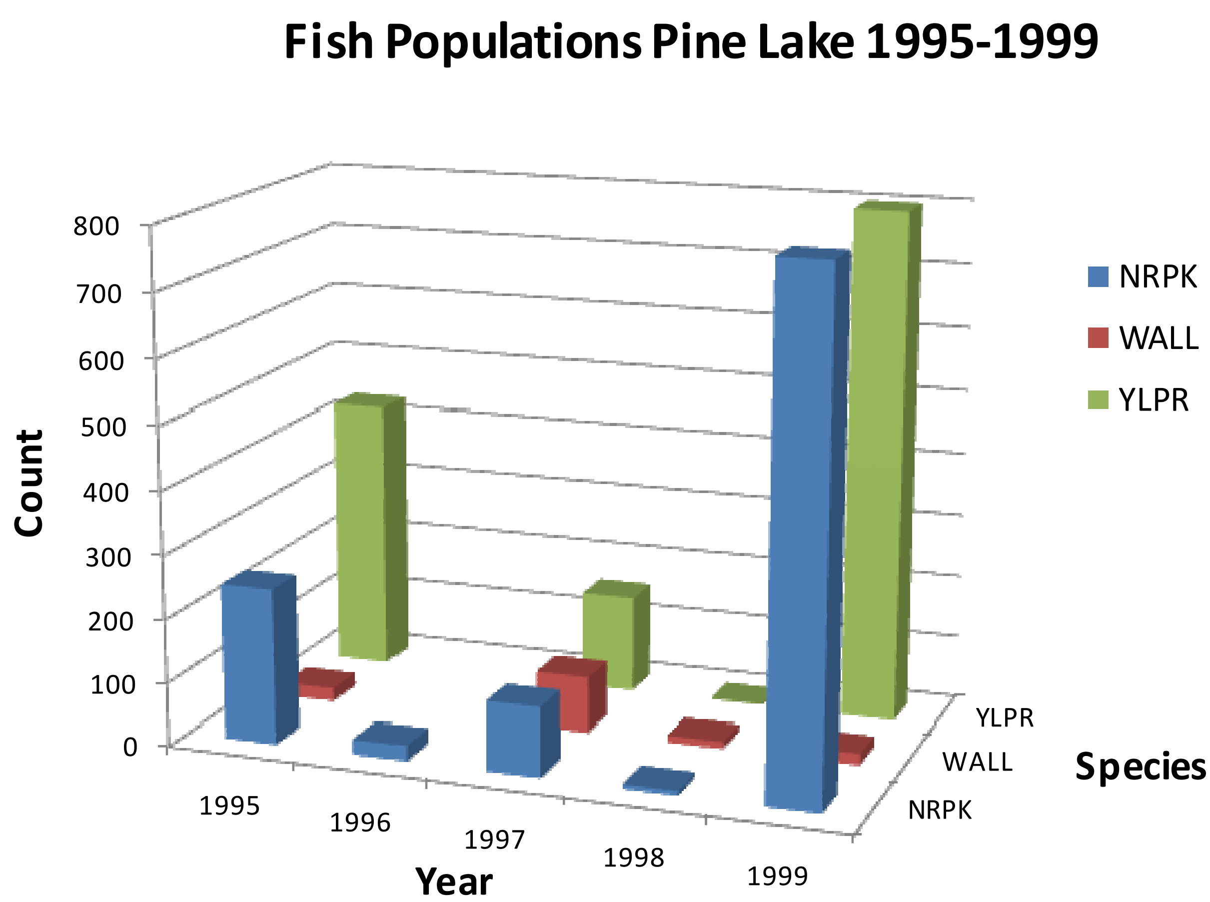


Figure 276. Fish populations in Pine Lake from 1995-1999 (data from Alberta Sustainable Resource Development, 2008). For full names of species, please refer to Table 23.

4.9.5.3 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 Threehills Creek subwatershed is covered by annual and perennial croplands/pastures (59% and 21%, respectively). The remaining land cover types cover <5% individually (Figure 277, Table 109) (AAFC-PFRA, 2008).

Table 109. Land cover in the Threehills Creek subwatershed (AAFC-PFRA, 2008). The most prominent land cover types are highlighted.

Land cover type	Area (ha)	Proportion of subwatershed area (%)
Waterbodies	4,075	1.27
Exposed land	5,346	1.66
Developed land	2,011	0.62
Shrubland	12,488	3.88
Wetland	4,152	1.29
Grassland	5,702	1.77
Annual cropland	191,167	59.36
Perennial cropland/pastures	67,099	20.83
Coniferous forests	2,435	0.76
Deciduous forests	7,894	2.45
No data	19,693	6.11
Total	**322,063**	

There are three Ecologically Significant Areas in the Threehills Creek subwatershed: Mikwan-Goosequill-Hummock Lakes, Pine Lake and Willow Lake (Table 110). There are no internationally designated Ecologically Significant Areas in the subwatershed (Alberta Environmental Protection, 1997).

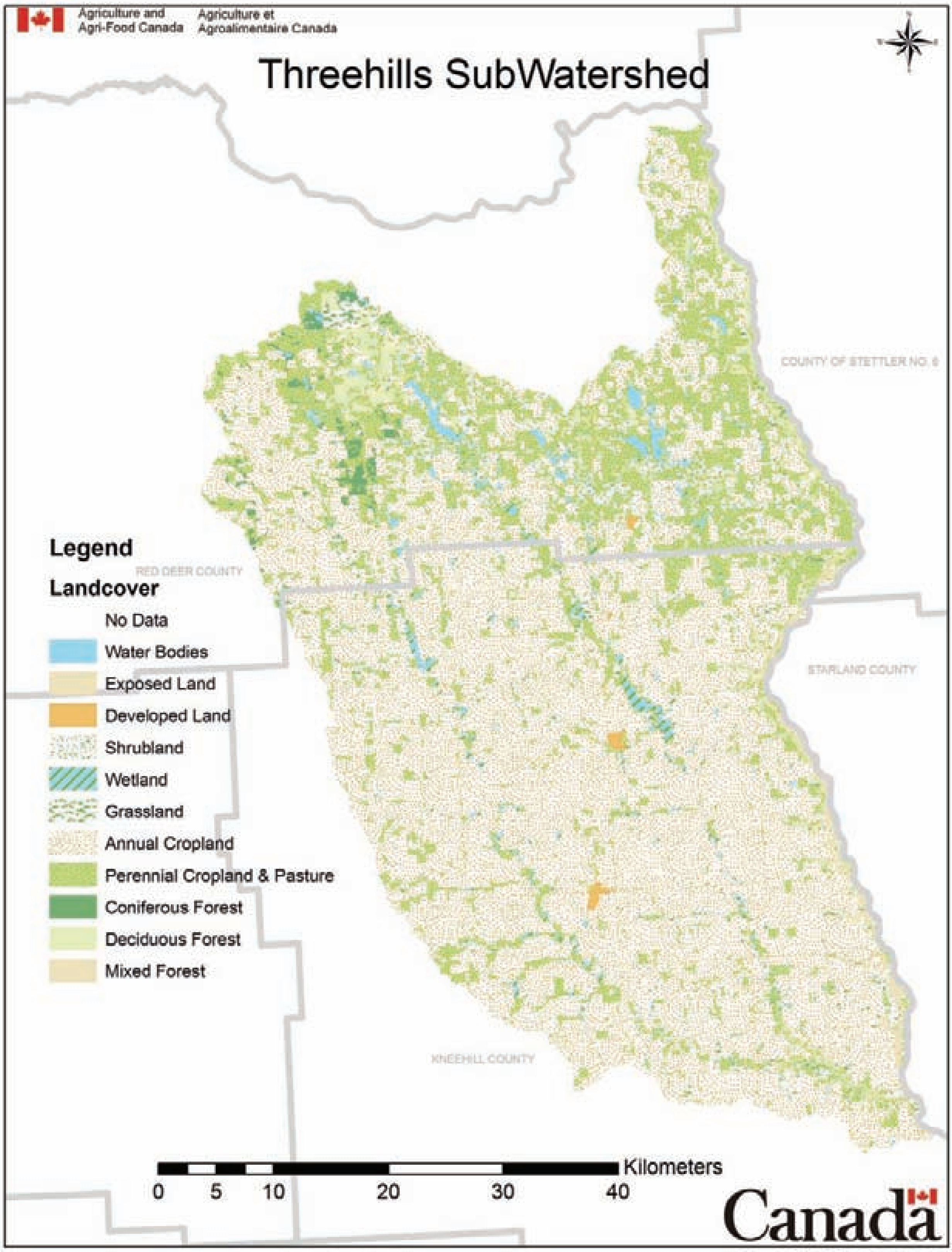


Figure 277. Land cover of the Threehills Creek subwatershed (AAFC-PFRA, 2008).

Table 110. Ecologically Significant Areas in the Threehills Creek subwatershed (Alberta Environmental Protection, 1997).

Ecologically Significant Area	Location	Area (ha)	Significance	Description
Mikwan-Goosequill-Hummock Lakes and adjacent discontinuous aspen parkland and wetlands	Twp. 35-36, Rge. 22-23, W 4, County of Red Deer	3,510	Nationally	Alkali lakes and ponds, extensive bulrush marsh east of southeast corner of Mikwan Lake, partially cleared upland with remnant patches of aspen parkland and fescue grassland; nesting piping plover, an endangered species, at Goosequill Lake; important shorebird and waterfowl, including diving ducks and grebes, staging areas on Mikwan Lake; Mikwan Lake is one of a limited number of important shorebird migration lakes in southern Alberta; key white-tailed deer habitat
Pine Lake and portions of Ghostpine Creek	Twp. 35-36, Rge. 24-25, W 4, County of Red Deer	1,300	Provincially	Provincially significant duck breeding habitat; spawning areas in Pine Lake for northern pike, walleye and suckers; rearing areas for northern pike and yellow perch along Ghostpine Creek; former osprey nesting area
Willow Lake	Twp. 35-36, Rge. 22-24, W 4, County of Red Deer	2,830	Provincially	Open water, sedge, cattail and bulrush marsh and woodlands and extensive willow and swamp birch shrubbery along wetland edges; remnant patches of aspen parkland in a mostly cultivated landscape; diversity of breeding birds; two great blue heron nesting areas, important for marshbirds and for production and staging of waterfowl, including diving ducks, grebes and Canada geese; key white-tailed deer habitat

4.9.5.4 Species at Risk

Identifying species at risk and their habitats 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 extirpated or 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 Threehills Creek subwatershed is home to one endangered species (piping plover, *C. melodus circumcinctus*), three threatened species (loggerhead shrike, *L. ludovicianus excubitorides*; peregrine falcon, *F. peregrinus anatum*; Sprague's pipit, *A. spragueii*) and three species of special concern (long-billed curlew, *N. americanus*; monarch butterfly, *D. plexippus*; yellow rail, *C. noveboracensis*). Detailed treaties of these species can be found in section 3.1.3.7.

4.9.6 Subwatershed Assessment

The Threehills Creek subwatershed lies in the Central Parkland and Northern Fescue Subregions and is characterized by medium livestock intensity and medium to high agricultural intensity relative to the Alberta average. There are over 60 feedlots in the subwatershed, located in the vicinity of urban centres, such as the Towns of Threehills and Trochu, the Village of Elnora and numerous hamlets. Resource exploration and extraction has contributed to a complex network of linear developments (mostly roads) and the establishment of 4,984 wells (mostly for unspecified purposes). These land use practices have contributed to the deterioration of the water quality in numerous waterbodies in the subwatershed. For example, TN and TP concentrations in Pine Lake and Ghostpine Creek generally exceed CCME PAL guidelines. In addition, 20 pesticides have been detected in various waterbodies in the subwatershed. No parasite data were located for any waterbody in the subwatershed. Water discharge rates are generally low (about 1 m^3/sec following the spring freshet) and may exacerbate the pressure put upon aquatic ecosystems following water diversion projects, which divert about 4.62 million m^3 of water annually. Most of this water is used for water management and agricultural practices. Fish communities in Pine Lake are dominated by yellow perch and walleye. While no biodiversity assessment data have been located for the annual cropland-dominated subwatershed, it is home to one endangered species, three threatened species and three species of special concern.

An Indicator Workshop held in March 2008 identified a total of 20 indicators to be used to assess the overall health of the Red Deer River watershed and its 15 subwatersheds. These indicators included land use, water quality, water quantity and biological indicators. In November 2008, a subset of these indicators was selected to indicate the overall condition of, or risk to, the individual subwatersheds.

There were nine "condition indicators" and three "risk indicators". The condition indicators were ranked "good", "fair" or "poor" based on existing guidelines, while risk indicators were ranked "low", "medium" or "high" relative to the other subwatersheds. The overall subwatershed ranking is based on an "A"-"B"-"C" ranking system with "+" and "-" subrankings. The overall ranking system is based on a subjective evaluation of the combined rankings of the condition and risk indicators.

Based on the available data, the Threehills Creek subwatershed receives a rating of "poor" for the condition indicators and a rating of "medium" for the risk indicators (Tables 111, 112). Overall, this subwatershed receives a ranking of "B-". There are substantial data gaps, and several of the condition rankings are based on limited data. Consequently, it is recommended to implement a detailed water quality sampling program, conduct a wetland inventory and regularly monitor riparian health conditions along the major waterbodies in the subwatershed. Of particular concern are (1) nutrient concentrations that occasionally exceed water quality guidelines, likely due to widespread impaired riparian area health conditions and excessive agricultural runoff, municipal effluent and urban runoff that reach waterbodies throughout the subwatershed, (2) the loss of wetlands, which likely occurred as a result of agricultural land conversions, drainage, infilling and the disruption of their hydrology following linear developments and (3) the conversion of the landbase from its natural state into annual and perennial croplands and pastures.

Table 111. Condition and risk indicator summary for the Threehills Creek subwatershed. Gray logos indicate data gaps.

Condition Indicators

Risk Indicators

Table 112. Condition and risk assessments of the Threehills Creek subwatershed. Indicators with a "poor" or "high" ranking are highlighted.

Indicators		**Rating**
Condition	Wetland loss	POOR
	Riparian health	---
	Linear developments	FAIR
	Nutrients	
	Total phosphorus	POOR
	Total nitrogen	POOR
	Bacteria	GOOD
	Parasites	---
	Pesticides	GOOD
	Minimum flows to maintain ecological integrity	---
	Land cover	POOR
Overall		**POOR**
Risk	Livestock manure production	LOW
	Urban, rural, agricultural and recreational developments	MEDIUM
	Oil/gas wells	MEDIUM
Overall		**MEDIUM**

