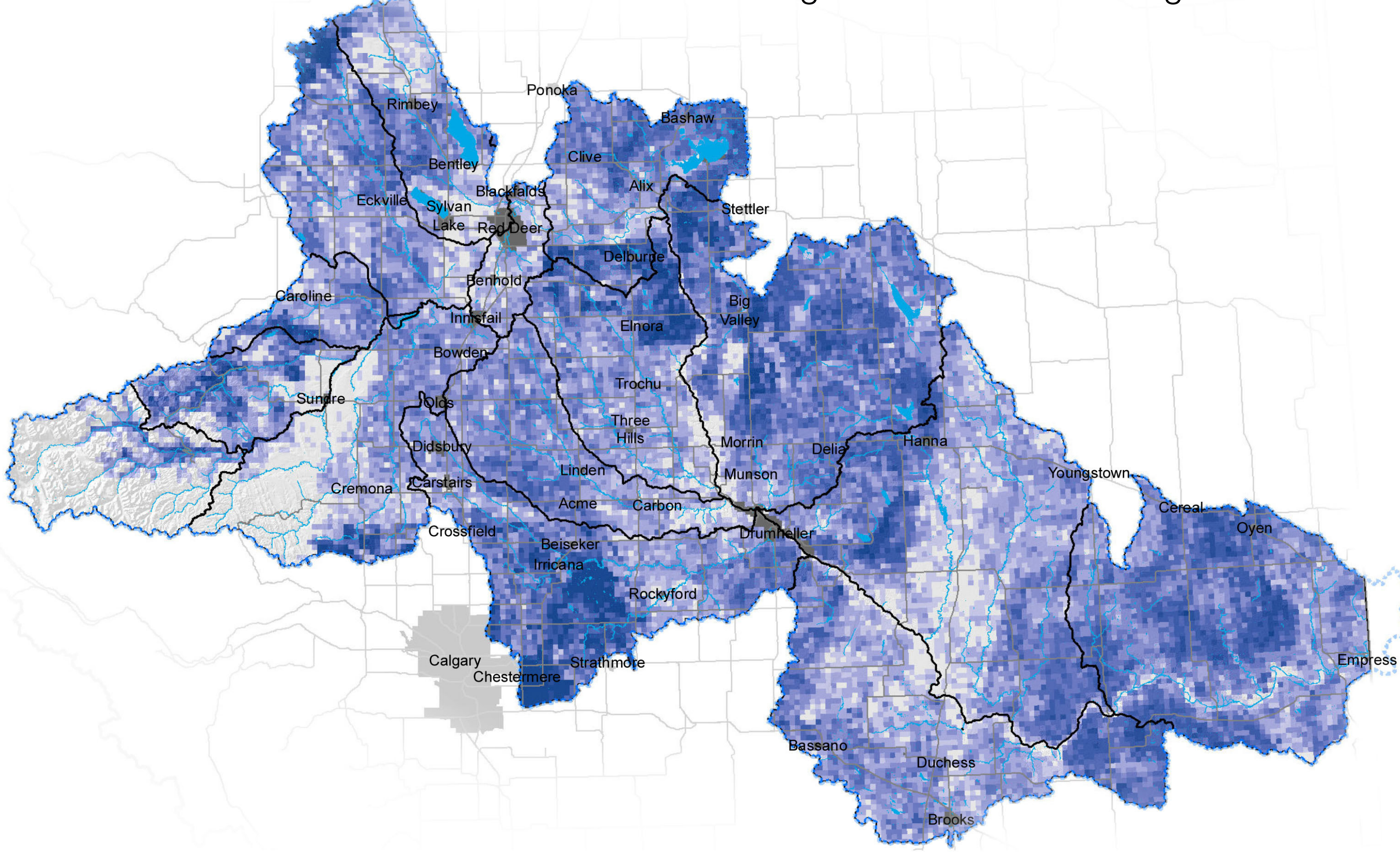
# Background Technical Report on Riparian Areas, Wetlands, and Land Use

Prepared for the Red Deer River
Integrated Watershed Management Plan




**Prepared by: O2 Planning + Design Inc. (O2)**
**in association with LimnoLogic Solutions Ltd.**

**Prepared for: The Red Deer River Watershed Alliance (RDRWA)**
**in association with Alan Dolan and Associates**

February 21 | 2013

February 28, 2013

**Re: "Background Technical Report on Riparian Areas, Wetlands and Land Use"**

Dear reader,

The Red Deer River Watershed Alliance gratefully acknowledges O2 Planning + Design, who researched and wrote the appended report titled, "Background Technical Report on Riparian Areas, Wetlands and Land Use." O2's work benefited greatly from the assistance of the public and stakeholders, who took part in numerous consultation processes, and from the involvement of members of the Technical Advisory Committee and Technical teams, who contributed their time and advice at various stages in the preparation of this report. Alan Dolan, Alan Dolan & Associates, who is Project Manager of the Integrated Watershed Management Plan for the Watershed Alliance, facilitated the community engagement process and chaired the Technical Advisory Committee and Technical Teams.

The report is one in a series of Background Technical Reports that will be completed to provide critical information for the development of the Watershed Alliance's Integrated Watershed Management Plan. Each of the Background Technical Reports is independently authored and the recommendations are those of the author and not necessarily those of the Watershed Alliance.

During the public and stakeholder consultation process, overall response to the report was very positive. A number of important technical comments were put forward at meetings, workshops and in an online response form. O2 Planning + Design, members of the Technical Advisory Committee and Technical Teams, and the IWMP Project Management Unit reviewed the comments and provided advice to O2 Planning + Design on whether they should be considered for inclusion in the report or not. A total of 52 comments were assessed and the rationales for including or not including them in the report are summarized on Watershed Alliance's website.

This report is available for downloading at www.rdrwa.ca.

Yours truly,

Gerard Aldridge
Chair, Project Management Unit,
Integrated Watershed Management Plan

cc: RDRWA Board of Directors, TAC, Technical Teams

# EXECUTIVE SUMMARY

Watershed management requires an effective process to integrate science, policy, and stakeholder and public participation in a flexible manner. The Red Deer River Watershed Alliance (RDRWA) and Alan Dolan and Associates commissioned O2 Planning + Design Inc. (O2) and LimnoLogic Solutions Ltd to prepare this background technical report to support the development of the Integrated Watershed Management Plan (IWMP). The report focuses on developing draft outcomes, indicators and targets for the Red Deer River Basin in three topic areas: (i) wetlands, (ii) riparian areas, and (iii) land use.

The RDRWA increased the capacity of the Technical Advisory Committee by assembling multidisciplinary Technical Teams specific to each of the three topic areas to provide input and technical review to the core project consultants. Technical Team members consisted of multidisciplinary experts from government, industry, non-government organizations, and the consulting industry.

Geographic Information Systems (GIS) mapping tools were used to summarize baseline conditions in the watershed and specify draft targets for selected indicators. This report builds on the 2009 State of the Watershed report, and provides a foundation for strategies to protect and enhance the watershed.

To set targets and synthesize information while still accounting for major landscape differences throughout the Red Deer River watershed, five Landscape Units were defined based on dominant land use and natural patterns: Upper Headwaters, Lower Headwaters, Central Urbanizing, Central Agricultural, and Dry Grasslands.

Recommended outcomes, indicators, and targets for each of the three topics are summarized below. The report also outlines, for each topic, priorities for improved monitoring and data acquisition, research needs, and key Beneficial Management Practices (BMPs) recommended for implementation.

### Wetlands

Wetlands provide a wide range of important ecosystem services in a watershed. Recommended draft goals and outcomes for wetlands are provided below.

| DRAFT MANAGEMENT GOALS FOR WETLANDS | DRAFT OUTCOMES FOR WETLANDS |
|---|---|
| WG1. Wetlands as well as their functions and ecosystem services are protected, restored, or enhanced<br><br>WG2. Wetlands contribute to maintaining or improving surface water quality and other watershed management objectives (e.g., water conservation, flood damage minimization, biodiversity) | WO1. No further net loss of wetland area and functions |
| | WO2. Restore lost or degraded wetlands where feasible and beneficial |
| | WO3. Where ecologically significant wetland complexes exist, maintain or restore associated upland areas to retain or enhance landscape connectivity |
| | WO4. Maintain core ecological functions and services of wetlands (e.g., water storage, flood control, biodiversity support, climate regulation, etc.) through planning of compatible adjacent land uses |
| WG3.Landowners, governments, and other stakeholders are active stewards of wetland environments | WO5. The values and functions of wetlands are recognized by all stakeholders when making decisions and taking action |
| | WO6. Wetlands are conserved and managed by all stakeholders based on a watershed stewardship approach |
| WG4. Knowledge of wetlands is improved | WO7. Knowledge of wetlands in the watershed is enhanced, including distribution, functions, and services of wetlands and interrelationships with surrounding areas and society |

A summary of key recommended indicators and targets for wetlands is provided below.

| Indicator | Type of Indicator | Scale of Analysis | Targets | Notes |
|---|---|---|---|---|
| Wetland Cover (%) | Environmental | Watershed | >7.5% | Greater than baseline conditions to achieve no net loss outcome |
| | | Landscape Units + sub-watershed | e.g., >13.6% in Medicine sub-watershed | |
| Peatland Cover (%) | Environmental | Landscape Units | e.g., >6.0% in Upper Headwaters | Greater than baseline conditions |
| Municipalities with Wetland Conservation/ Restoration Bylaws or Policies | Programmatic | Watershed<br>Municipal | 100% of all municipalities in the watershed | May be combined with riparian bylaws/policies<br>Should address avoidance, Environmental Reserve, compensation, setbacks, etc. |
| Awareness of residents and/or farmers | Social | Watershed | e.g., 30% increase over 10 years | Will require standardized and statistically random surveys |

**Riparian Areas**

Riparian areas are critical to watershed health and pollution prevention. Draft management goals and outcomes for riparian areas are provided below.

| DRAFT MANAGEMENT GOALS FOR RIPARIAN AREAS | DRAFT OUTCOMES FOR RIPARIAN AREAS |
|---|---|
| RG1. Riparian areas and their related functions and ecosystem services are protected or restored<br>RG2. Riparian areas contribute to maintaining or improving surface water quality and other watershed management objectives | RO1. Riparian ecosystems and associated adjacent upland areas are kept intact and ecologically functional |
| | RO2.No further net loss of riparian areas |
| | RO3. Core ecological functions of healthy riparian lands are maintained<br>(e.g., bank stability, water quality protection, water storage and flood mitigation, biodiversity, fish habitat support, etc.) |
| | RO4. Invasive plant species are reduced, particularly in riparian lands adjacent to watercourses and water bodies |
| RG3. Landowners, governments, and other stakeholders are active stewards of riparian areas | RO5. The values and functions of wetlands are recognized and considered by stakeholders when making decisions and taking actions that may affect riparian areas. |
| | RO6. Riparian areas are conserved and managed by multiple stakeholders |
| RG4. Knowledge of riparian areas is improved over time | RO7. Enhanced knowledge and understanding of:<br>- Distribution variable width riparian areas<br>- Functions and services of riparian areas<br>- Importance of the composition, structure and health of upland areas adjacent to riparian areas |

One key analysis for riparian areas was the use of existing remote sensing and GIS data to assess, map, and synthesize data on the location of variable-width riparian areas and land use patterns within them. This was used to specify targets for % riparian areas with perennial vegetation; targets were based on improving riparian land cover conditions over time. Existing riparian health data were also considered in developing indicators and targets. A summary of key recommended indicators and targets for riparian areas is provided below.

| Indicator | Type of Indicator | Scale of Analysis | Targets (Summary) | Notes |
|---|---|---|---|---|
| % Riparian Areas with Perennial Vegetation Land Cover | Environmental | Watershed | 82% | Will require shifting approximately half of all crops to hay in riparian areas |
| | | Landscape Units | e.g., >85% in Lower Headwaters | |
| Riparian Health Scores | Environmental | Reach-specific | e.g. >30% "Healthy" along Medicine River | Will require major long-term improvements over current conditions |
| Number of Municipalities with Riparian Area Bylaws / Policies | Programmatic | Municipal<br>Watershed | 100% of municipalities in the watershed | May be combined with wetlands bylaws/policies<br>Should address setbacks for Environmental Reserve, riparian health, etc. |
| Awareness among residents and/or farmers | Social | Watershed | e.g., 30% increase over 10 years | Will require standardized, statistically random surveys |
| Riparian Workshop Attendance | Social | Watershed<br>Municipal | Increase in number of people attending workshops | Requires compilation of baseline information on workshop attendance |
| % of Farms reporting grassed buffer strips BMP | Programmatic | Watershed | 50% of farms report the use of grassed waterways by 2016 | Requires more than doubling from 2006 baseline numbers |

### Land Use

A wide range of land use activities associated with agriculture, industry, urban areas, and forestry pose risks to water quality, aquatic ecosystem health, and other watershed values when not managed and mitigated appropriately. Draft management goals and outcomes for land use are provided below.

| DRAFT MANAGEMENT GOALS | DRAFT OUTCOMES FOR LAND USE |
|---|---|
| LG1. Land uses are located and managed in ways that do not result in unacceptable impacts to water quality, water quantity and aquatic ecosystem health | LO1. Public and private lands are managed with source water protection as a high priority |
| | LO2. Ecological infrastructure (including wetlands, riparian areas, alluvial aquifers, native vegetation, steep slopes) is conserved and integrated when planning and managing land uses |
| | LO3. Particular attention is paid to the headwaters and other highly sensitive areas when planning and managing land uses |
| LG2. Planning, approval and management of land use and human activities in the watershed are aligned to achieve regional watershed management objectives | LO4. The RDRWA collaborates with provincial and municipal government agencies and other groups to facilitate efficient resourcing and delivery of watershed protection programs and services |
| | LO5. Cumulative effects management, risk mitigation, and integrated land management principles are applied to land management decisions |

| | |
|---|---|
| | LO6. Partnerships between individuals, community groups, businesses and government agencies are cultivated to achieve plan goals and objectives |
| LG3. Educational opportunities are provided to identify ways to contribute to a healthy watershed | LO7. Watershed functions and ecological services are better understood by residents, governing agencies, First Nations and stakeholders |
| | LO8. Appropriate actions to maintain a healthy watershed environment are taken by individuals, municipalities, developers, industry, farms, etc. |
| | LO9. People recognize that a healthy economy depends on a healthy watershed |
| LG4. Knowledge of land uses and watershed functions increase over time | LO10. Knowledge of how land uses impact the watershed is enhanced, as well as Beneficial Management Practices to mitigate impacts |

The tables below specify draft targets and indicators for land use. The first table specifies targets and indicators for natural land cover, surface linear density, and livestock intensity. The second table specifies targets and indicators for impervious areas, focused on those parts of the watershed undergoing urbanization. The third table specifies a range of recommended programmatic and social indicators.

| **Area** | **Natural Land Cover (%)** | **Surface Linear Density ($km/km^2$)** | **Livestock Intensity (average kg phosphorus / ha / year)** | |
|---|---|---|---|---|
| | | | **Baseline** | **Notes** |
| Entire Watershed | >44% | 0.40 | 4.4 | - Maintain baseline conditions if feasible<br>- Implement BMPs for all livestock operations<br>- Carefully manage livestock access and BMPs within areas with the highest risk of contaminant mobilization (see Chapter 6) |
| Upper Headwaters | >87% | 0.25 | 0.7 | |
| Lower Headwaters | >37% | 0.82 | 6.0 | |
| Central Urbanizing | >24% | 1.26 | 8.4 | |
| Central Agricultural | >23% | 0.83 | 3.8 | |
| Dry Grasslands | >63% | 0.51 | 2.4 | |

| **Sub-watershed** | **Impervious Area** | |
|---|---|---|
| | **Baseline Estimate** | **Targets (%)** |
| Waskasoo | 4-5% | <10% |
| Blindman | 1.5-2.5% | <5% |

| Grouping | Indicator | Target |
|---|---|---|
| Municipal | Percentage of municipalities in the watershed that have adopted a policy, guideline, or bylaw for watershed conservation, addressing avoidance of ecological infrastructure, landscape connectivity, and relevant BMPs (e.g., stormwater management including discharge rates and annual volume targets for urban areas, agricultural practices in rural municipalities, etc.) | 100% of municipalities |
| | Percentage of municipalities in the watershed that have taken steps to minimize consumption of land for permanent urban or industrial land uses within their Municipal Development Plan (MDP) or through other means | 100% of municipalities |
| | Percentage of municipalities that require Erosion and Sediment Control (ESC) Plans be planned, designed, and implemented for new developments, including random inspections by qualified staff | 100% of municipalities |
| | Percentage of municipalities in the watershed that have adopted a performance management system (e.g., inventories, indicators, targets) to evaluate progress towards watershed management goals and potential "stop work" orders for non-compliance | 100% of municipalities |
| | Number of Low Impact Development (LID) stormwater projects installed | e.g., Increase over time (potentially partner with the ALIDP to measure and report on quantities) |
| | Percentage of Inter-Municipal Development Plans that address watershed management and landscape connectivity principles | 100% of Inter-Municipal Development Plans in the watershed |
| | Percentage of municipalities with water conservation management plans | 100% of municipalities |
| Provincial Regulatory Bodies | Percentage of decisions made by provincial regulatory bodies that include steps to address, as applicable: (i) watershed cumulative effects, (ii) erosion and sediment control plans, (iii) Low Impact Development, and (iv) Integrated Land Management principles | 100% of all land use decisions made by provincial regulatory bodies incorporate these considerations |
| Watershed Stewardship Groups | Amount of support to local WSGs including programs, funding, in-kind and technical support, policy development, etc. | Increase amount of financial support provided to WSGs |
| | # restoration and conservation pilot projects undertaken by WSGs | Increase the number of restoration and conservation pilot projects undertaken by WSGs |
| | Number of workshops undertaken by WSGs and attendance | e.g., 3 workshops per year with attendance of >30 people at each workshop |
| Agriculture | % of farms using grassed buffers as a BMP<br>(see Riparian Chapter) | >50% of farms reporting use of grassed buffers by 2016 |
| Gravel / Sand Extraction Industry | Ratio of pit registrations to reclamation certification applications for pits under the *Code of Practice for Pits*<br>*(# reclamation applications : # of pit registrations)* | Improve from baseline (1:13)<br>Draft target is 1:10 in short term and 1:5 in long term |
| | Support the implementation of the new provincial aggregate policies | 100% support and implementation of new provincial policies |

| Grouping | Indicator | Target |
|---|---|---|
| Oil and Gas Industry | Number of operators certified and actively using the ISO 14001 Environmental Management System or similar standards | 100% of oil and gas operators certified |
| | Number of operators conducting annual reviews of standard operating procedures for possible changes due to new legislation and policies, BMPs, or recommendations from new applied research | 100% of oil and gas operators conducting annual reviews |
| | Number of pipeline operators implementing proactive, aggressive monitoring systems to detect structural issues in a manner that will considerably reduce the risk of future spills and/or blowouts | 100% of pipeline operators implementing pipeline monitoring systems |
| Forestry | Number of major forestry operators certified to CSA –Z809 Forest Certification Standard or ISO 14001 | 100% of all forestry certified |
| | Annual review of Operating Ground Rules for possible changes supported by new legislation and policies, BMPs, or recommendations from new applied research | 100% |
| All sectors | Awareness among landowners of riparian issues increases | e.g., 30% increase over 10 years |

### Watershed Sensitivity Mapping

A qualitative GIS overlay mapping exercise was conducted to help identify parts of the watershed most sensitive to potential surface water contamination. The summary map created is intended to be used as a tool at multiple scales to identify sensitive parts of the landscape. Possible users include Watershed Stewardship Groups, municipal governments, the Red Deer River Watershed Alliance, the provincial government, and all industries and stakeholders involved with the implementation of watershed BMPs. The data created by this tool can also be applied for finer-scale, sub-watershed or industry-specific applications.

### Summary

This report provides a foundation for strategies related to wetlands, riparian areas, and land use to protect and enhance the Red Deer River Watershed. All information in this report is based on available data, and is intended for broad regional watershed-scale visioning purposes. It may need to be re-evaluated for site-specific applications. Targets are also expected to be refined over time in a process of adaptive management.

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ABMI – Alberta Biodiversity Monitoring Institute

AESRD – Alberta Environment and Sustainable Resource Development

ATPR – Alberta Tourism, Parks and Recreation

BMP – Beneficial Management Practice

BRBC – Bow River Basin Council

CAESA – Canada-Alberta Environmentally Sustainable Agriculture

CAPP – Canadian Association of Petroleum Producers

CCME – Canadian Council of Ministers of the Environment

CPESC – Certified Professional in Erosion and Sediment Control

DEM – Digital Elevation Model

DO – Dissolved Oxygen

ER – Environmental Reserve

ESA – Environmentally Significant Area

ESC – Erosion and Sediment Control

GIS – Geographic Information System

IBHI – Index of Biotic and Hydrologic Integrity

IBI – Index of Biotic Integrity

ILM – Integrated Land Management

IWMP – Integrated Watershed Management Plan

LID – Low Impact Development

LiDAR – Light Detection and Ranging

MGA – Municipal Government Act

MSP – Municipal Sustainability Planning

NAWMP – North American Waterfowl Management Plan

O2 – O2 Planning + Design Inc.

P - Phosphorus

PPWB – Prairie Provinces Water Board

RDRWA – Red Deer River Watershed Alliance

RHI – Riparian Health Inventory

RTFI – Recreation and Tourism Features Inventory

STP – Soil Test Phosphorus

TAC – Technical Advisory Committee

TDC – Transfer of Development Credits

TDS – Total Dissolved Solids

TDP – Total Dissolved Phosphorus

TN – Total Nitrogen

TP – Total Phosphorus

TSS – Total Suspended Solids

WCO – Water Conservation Objective

WEPP – Water Erosion Prediction Project

WESPUS – Wetland Ecosystem Services Protocol for the United States

WID – Western Irrigation District

WPAC – Watershed Planning and Advisory Council

WQO – Water Quality Objective

## ACKNOWLEDGEMENTS

This report was prepared by O2 Planning + Design with support from LimnoLogic Solutions

The following individuals are acknowledged for their input on shaping the contents of this draft:

Alan Dolan, Anne-Marie Anderson, Gerard Aldridge, Chris Teichreb, Phil Boehme, Dug Major, Trevor Wallace, Andy Jedrych, Lorri Hamilton, Ian Jarvis, Thierry Fisette, Shari Clare, Vance Buchwald, Lane Seely, Geniene Sabila, Sandi Riemersma, Shane Gabor, Pascal Badiou, Tracy Scott, Norine Ambrose, Kelsey Spicer-Rawe, Kelsey Kure, Markus Thormann, Brad Wiebe, Kevin Gagne, Bill Shaw, Brandon Leask, Terrina Perley, Brad Wiebe, Jan Simonson, Lindsay Stephens and stakeholders and members of the public who participated in workshops, presentations and meetings or who responded through an online response form.

RDRWA received funding for this work through project funds and in-kind support provided by Alberta Environment and Sustainable Resource Development as well as support from numerous provincial, municipal and other organizations.

# 1. INTRODUCTION AND CONTEXT

The Red Deer River Watershed Alliance (RDRWA) was formed to promote watershed health and the good use and proper management of water in the Red Deer River watershed. It was designated as the Watershed Planning and Advisory Council (WPAC) for the Red Deer River watershed under the Government of Alberta's *Water for Life Strategy* in September 2005. The fundamental goal under the *Water for Life Strategy* (GOA, 2003; GOA, 2008a) is to ensure sustainable management of the province's water resources so Albertans are assured of:

- Safe and secure drinking water supply
- Healthy aquatic ecosystems
- Reliable quality water supplies for a sustainable economy

As indicated in Alberta's *Water for Life Strategy,* WPACs are responsible for *"leading watershed planning, developing best management practices, fostering stewardship activities within the watershed, reporting on the state of the watershed, and educating users of the water resource."*

Phase 1 of the planning process was completed in 2009 when the RDRWA released its State of the Watershed Report. Phase 2 is to develop an integrated watershed management plan (IWMP) for the Red Deer River basin.

The terms of reference as approved by the RDRWA Board of Directors state that the objectives of the IWMP are:

- To set targets and thresholds for water quality, land use, biological, and water quantity indicators as reported in the State of the Watershed Report
- The process of identifying targets and thresholds allows stakeholders to work out mutually acceptable solutions for the protection, restoration, and/or maintenance of the health of the individual sub-watersheds as well as the Red Deer River watershed as a whole
- To make recommendations such as Beneficial Management Practices, market-based instruments, monitoring strategies, future research priorities that may eventually be reflected in policies
- To provide information and guidance to stakeholders in developing their action plans to implement recommendations of the IWMP
- To provide decision makers with the relevant information specific to the Red Deer River watershed essential for its effective protection, restoration, and/or maintenance as a healthy watershed

## 1.1 Study Scope and Objectives

The RDRWA's vision is that the IWMP will achieve or exceed requirements under government regulations. Moreover, management efforts will be directed towards maintaining current conditions where they are good, and improving conditions where they have deteriorated because of human activities.

Land use, riparian areas, and wetlands are three interrelated components that provide the focus of the second component of work on the IWMP initiated by the RDRWA in 2012. Surface water quality was the first component, which was addressed during 2011 and early 2012 (Anderson 2012). As all components are intimately related, this report tried to ensure that links and interrelationships were consistent.

The RDRWA commissioned O2 Planning + Design Inc. (O2) to prepare a background study to support the development of this component of the IWMP. Working with the project manager and facilitator, Alan Dolan of Alan Dolan & Associates, O2 has prepared a comprehensive yet focused background technical report on wetlands, riparian areas, and land use for the Red Deer River watershed. One of the principal aims was to ensure these elements are comprehensively described and mapped using the best available information and data. The study also aims to define outcomes, proposed indicators, and potential quantitative targets for managing wetlands, riparian areas, and land use in the basin at multiple scales. In achieving this, O2 has aimed to build on and complement the information in the State of the Watershed Report (Aquality, 2009). This background information is intended to be a useful input to the IWMP, which ultimately will help meet the RDRWA's vision that:

***"The Red Deer River Watershed will be healthy, dynamic and sustainable through the efforts of the entire community."***

## 1.2 Technical Team Input

The RDRWA expanded its Technical Advisory Committee (TAC) by assembling additional Technical Team members who were consulted for their expertise in each of the topics and familiarity with the Red Deer River basin (Appendix A). Separate Technical Teams were assembled for each topic area (riparian areas, wetlands, and land use).

Engagement and input from the Technical Teams took the form of a survey, distributed during July and August of 2012, as well as a series of workshops held in late August and early September 2012 to discuss key management issues, data sources, and potential priority areas to focus the work. A draft was circulated for review in late October / early November followed by additional workshops, prior to a presentation of the report to the public and broader stakeholders.

## 1.3 Report Structure

This report is structured as a series of chapters. Chapter 1 provides a synthesis of the background and context of the study. Chapter 2 provides some additional background on watershed geography, hydrology, and water quality, in order to set the context for integrating this study with other IWMP components. Chapter 3 focuses on wetlands, Chapter 4 deals with riparian areas, and Chapter 5 addresses land use in the context of watershed management. Each of these three chapters discusses the background context, baseline data and maps, appropriate outcomes and target values for indicators, management implications, recommendations related to monitoring and data acquisition, research needs, and suggested Beneficial Management Practices for different stakeholder groups. The report concludes with Chapter 6, which describes a Geographic Information Systems (GIS) overlay mapping technique that identifies the overall sensitivity of the watershed to potential source water contamination risks that may be present. Chapter 7 provides a brief conclusion and summary of findings.

# 2. Background on the Red Deer River Watershed

The Red Deer River State of the Watershed Report (Aquality, 2009) includes more detailed descriptions of the watershed. A brief synthesis of some key themes is provided below to provide context for this study.

## 2.1 Geography and Ecosystems of the Red Deer River Watershed

The Red Deer River watershed, with a drainage area of over 49,000 $km^2$, is the largest sub-basin of the South Saskatchewan River Basin. It includes over 55 urban centres and 18 rural municipalities. The headwaters originate in Banff National Park and the Rocky Mountains. As it drains eastwards, the watershed enters the heavily forested Foothills and Boreal Mixedwood landscapes.

The rolling Central Parkland Natural Sub-region dominates areas downstream from Gleniffer Lake. Here, a mosaic dominated by farmland is interspersed with small remnant patches of aspen forests, shrubs, wetlands, and some native grasslands. Eastern portions of the watershed are situated in the drier southeastern part of Alberta and the Grasslands Natural Region. This includes the iconic "dinosaur country" in the river valleys, characterized by badlands and cottonwoods in the floodplain. Agricultural operations, native grasslands, and networks of oil and gas developments characterize much of the eastern parts of the watershed. The Red Deer River enters the Province of Saskatchewan 8 km from the river's confluence with the South Saskatchewan River.

Major tributaries in the watershed include the Panther River, James River, Medicine River, Little Red Deer River, Blindman River, Dogpound Creek, Rosebud River, Three Hills Creek, Kneehills Creek, and Berry Creek. Sizeable lakes include Gleniffer, Sylvan, Gull, Buffalo, and Sullivan Lakes.

Considerable amounts of irrigation infrastructure and associated return flows enter the Red Deer River from both the Western Irrigation District (WID) and the Eastern Irrigation District (EID). Although both the WID and the EID draw their source water from the Bow River, about half the irrigation water from the WID is returned to the Red Deer River through the Serviceberry Creek and Rosebud River systems, while about 60% of the return flows from the EID enter the Red Deer River through the Matzhiwin Creek and Manson Creek tributaries.

## 2.2 Summary of Land and Resource Use in the Watershed

Multiple uses occur in many parts of the watershed, including forestry, crop and livestock agriculture, oil and gas, petrochemical industries, coal mining, aggregate mining, utility corridors, urban development, country residential development, recreation and tourism. Agriculture, including both annual cropping and livestock, dominate central portions of the watershed, as well as areas surrounding Brooks. There are about 13,000 farms in the Red Deer River watershed, and about 43% of the watershed is used to grow crops (Aquality, 2009). Urban populations are centrally concentrated in the City of Red Deer. Oil and gas activities, including well sites and pipeline networks, occur throughout the watershed, but are concentrated north and northeast of Brooks, in the County of Stettler, and Clearwater County west of the Town of Eckville.

Land use and resource development activities can pose risks to aquatic health, due to loadings of nutrients, pathogens, sediment, salts, pesticides, pharmaceuticals, and other contaminants into waterways. Intensive or improperly managed land uses can also impact riparian areas and wetlands and associated ecosystem services, including water filtration, erosion control, water storage and supply, carbon storage, biodiversity support, and recreational opportunities (Braumann et al., 2007).

**WHAT ARE ECOSYSTEM SERVICES?**

Ecosystem services are the benefits people obtain from ecosystems. Values are intrinsic to ecosystem services. These values can be either monetized or expressed using non-market evaluations.

Ecosystem service assessments provide a means to measure and evaluate trade-offs between various alternative scenarios of resource use and land use change (Braumann et al., 2007).

**The cumulative effects of land use and resource extraction pose risks to aspects of both water quantity and water quality that are of concern to the IWMP.**

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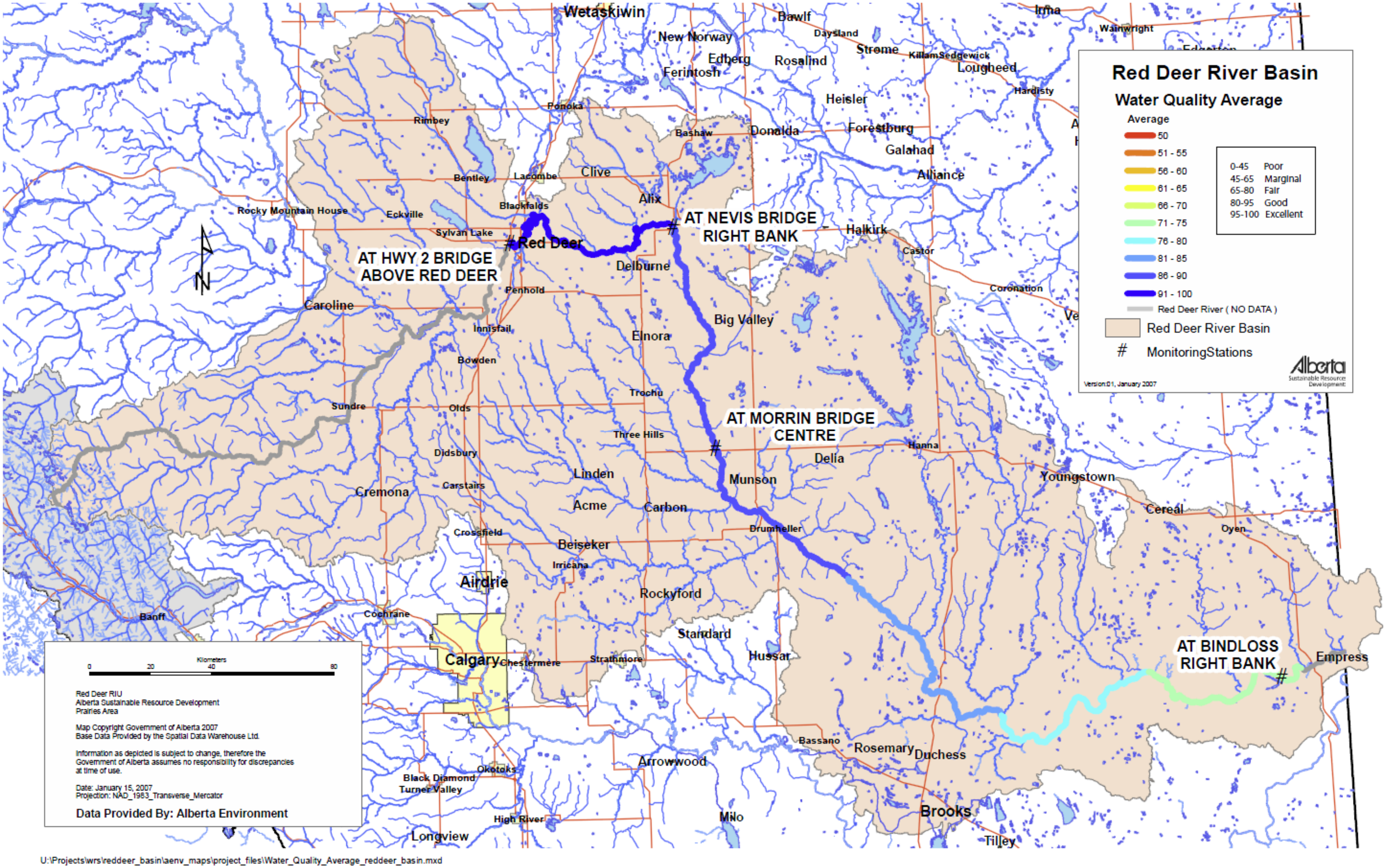



**Figure 1. Map of Water Quality Index Scores (Average) by Reach in the Red Deer River** (*Source: Alberta Environment 2007)*

## 2.3 Summary of Water Quality Conditions in the Red Deer River

Generally, water quality conditions in the Red Deer River mainstem deteriorate from upstream (west) to downstream (east)[1]. Although some of these changes are natural, some are the result of human activities in the basin. Historical reach conditions reported below are based mainly on the Alberta River Water Quality Index (RWQI) ratings from 1996-2004. The RWQI provides ratings for water quality based on a wide range of water quality indicators, including nutrients, dissolved oxygen, bacteria, metals and pesticides. Ambient concentrations are compared to available guidelines for the most sensitive use. Often, but not always, protection of aquatic life is the most sensitive use; for example recreation and irrigation are the most sensitive uses for bacterial quality.

Information from other water quality reports has been incorporated where appropriate (Aquality, 2009; Anderson, 2012). More detailed information on water quality, including identification of reach specific issues within the Red Deer River mainstem, indicators and draft Water Quality Objectives (WQOs) can be found in Anderson (2012) and Aquality (2009)[2].

### REACH 1: Headwaters to Sundre

Regular water quality sampling at Sundre in the uppermost part of the Red Deer River has only recently started. Limited historical data suggests that water quality is of high quality in this reach, although bacterial counts and total phosphorus levels can be high especially during periods of runoff. Recent oil pipeline spills in this reach in 2008 (Pembina Pipeline Corporation) and 2012 (Plains Midstream) have highlighted some water quality concerns due to hydrocarbons.

### REACHES 2 & 3: Sundre to City of Red Deer (Hwy 2)

In this reach, overall water quality conditions are typically “good” to “excellent.” Historically, guidelines have been exceeded at times for phosphorus (particularly during spring) as well as for some heavy metals (e.g., copper, lead), and bacteria. Pesticides are detected sometimes in these reaches. Total phosphorus has also increased over time, likely due to agriculture, wastewater inputs and urban stormwater runoff. Significant deteriorating trends were determined at this site for bacterial indicators and dissolved oxygen (Anderson 2012).

### REACH 4: City of Red Deer (Hwy 2) to Nevis

In this reach, overall water quality conditions are generally “good” (Figure 1) and sub-indices for bacteria and metals range typically from “good” to “excellent.” However, nutrient and pesticide sub-indices range from “fair” to “good” with some guideline exceedences for nutrients. The Red Deer River at Nevis experiences peaks in nutrient concentrations (TP and TN) in April to May that coincide with peak runoff events. Water is well oxygenated at Nevis and guidelines for the protection of aquatic life are met. Some exceedences of guidelines were reported for Al, Cu, Fe and Hg. Significant deteriorating trends were determined at this site for *E. coli*, TN and ammonia-N for the period from 1987 to 2010 (Anderson 2012). This timeframe does not incorporate ambient data following major upgrades at the Red Deer Wastewater Treatment Plant. Some major industrial outfalls occur in this reach near Joffre. Some hydrocarbons (phenols) have been measured and exceedences in Al and Zn relative to freshwater aquatic life guidelines have been measured as well (Aquality 2009).

### REACH 5: Nevis to Morrin

Overall, water quality conditions are generally considered “good” to “fair” in this reach. However, sub-index values for nutrients have ranged from “poor” to “good” and the pesticides sub-index has ranged from fair to good. Peaks in TP and TN concentrations occur during the months of April through July and coincide with spring runoff and precipitation events. Significant decreases in TP and TDP were reported at Morrin and

[1] Protecting water quality is important for all water bodies in the basin, not just the Red Deer River mainstem; however, there is insufficient data to focus the analysis on all individual water bodies in the basin

[2] The summary of issues may not completely reflect water quality issues during major runoff events (e.g., spring freshet, large storms)

reasons for improvements remain to be investigated. Some oxygen depletion has been evident at the Morrin station although most (98%) measurements, particularly those outside of winter, are in compliance with guidelines. Some exceedences of guidelines were reported for Al, Cu, Fe and Hg at Nevis site and for Al, Fe, Mn, Cr and Ni at Morrin (Aquality2009; Anderson 2012).

**REACH 6a: Morrin to Jenner (includes Drumheller)**

Historically, water quality conditions in this reach have been considered "good." AESRD recently established a long-term monitoring station at Jenner. Due to insufficient data, water quality objectives have not yet been proposed for this site (Anderson 2012). Available data shows that TSS, TDS, TN and TP concentrations begin to increase in this reach along with increases in concentrations of several metals. The Red Deer River flows through the highly erodible Badlands, which may contribute suspended solids and associated contaminants to the river. Irrigation return flows from the Western Irrigation District (WID) and the Eastern Irrigation District enter this reach of the river, representing a partial diversion from the Bow River Basin as well as potential water quality concerns.

**REACH 6b: Jenner to Bindloss**

In this reach, water quality is mostly considered "fair." Compliance with guidelines decreased for all sub-indices. The nutrient sub-index was considered "marginal." Concentrations of TN and TP are higher at Bindloss compared to upstream. Based on TP levels, the trophic status of the river changes from mesotrophic to eutrophic. DO levels were relatively high at Bindloss but occasional low winter levels have occurred in the past, with some concentrations below chronic and acute guidelines. Several metals were substantially higher than upstream locations, including Fe, Mn, and Al. Other metals that occasionally did not meet guidelines included: Cd, Cr, Cu, Pb, Ag, and Zn. Higher suspended solid levels (TSS) have been reported in this reach compared to the upper reaches (Cross, 1991). Increases in metals and other parameters are believed to reflect increased sedimentation attributed to local geology (Bearspaw formation) and the Badlands, and sediment re-suspension in this reach (Anderson, 1996). Significant deteriorating trends were reported for TN, ammonia-N, TDS and NO2+NO3-N (Anderson 2012).

**Water Quality Objectives**

Reach-specific water quality objectives were established for key water quality parameters based on historical (1987 – 2010) data (Anderson 2012); stations for which objectives were developed are shown in Figure 5.

Establishing WQOs is important for managing successive river reaches. The basic philosophy incorporated in the objectives is to maintain conditions where they are good and to improve conditions where human activities have caused water quality to degrade. Typically, exceedences of guidelines for the most sensitive use are a trigger for enhanced water quality management. Hence WQOs also help protect all uses of river water (i.e., protection of aquatic life, source water protection of drinking water supplies, livestock watering, irrigation, industry, aesthetics, and recreation). These in turn support the *Water for Life* outcomes (e.g., see Table 2)

**Table 2. Water Uses and Associated Water for Life Outcomes** *(Anderson 2012)*

| Uses | Water for Life Outcomes |
|---|---|
| Protection of Aquatic Life | Healthy Aquatic Ecosystems |
| Raw Water for Drinking Water Supply | Safe, secure drinking water supply |
| Livestock Watering | Quality water supply for a sustainable economy |
| Irrigation | Quality water supply for a sustainable economy |
| Industry | Quality water supply for a sustainable economy |
| Aesthetics | Quality water supply for a sustainable economy; Healthy aquatic ecosystems |
| Recreation | Quality water supply for a sustainable economy; Healthy aquatic ecosystems |

## 2.4 Summary of Water Quantity Conditions in the Red Deer River

Water quantity issues, including average flows and extremes, are influenced by land cover, land use, consumptive use and climate as discussed in Chapter 5 and 6 of this report. A synthesis of water quantity in the watershed is provided below.

Water flows in the Red Deer River vary considerably over the year (Figure 2) and seasonally (Figure 3). Annual average flows are approximately 70 $m^3/s$ throughout most of the river (Aquality, 2009), although maximum and minimum flows span a wide range (Figure 3). Much of the water flow is generated in the headwaters, where snowfall and rainfall are higher and evapo-transpiration lower than in the rest of the watershed. In fact, over 50 % of the total water yield in the Red Deer River originates from the Rocky Mountains and Foothills, which represent only a small fraction of the watershed (Kienzle & Mueller, 2010). Physical structures, in particular the Dickson Dam and Gleniffer Lake Reservoir, have altered the hydrologic regime of the river.

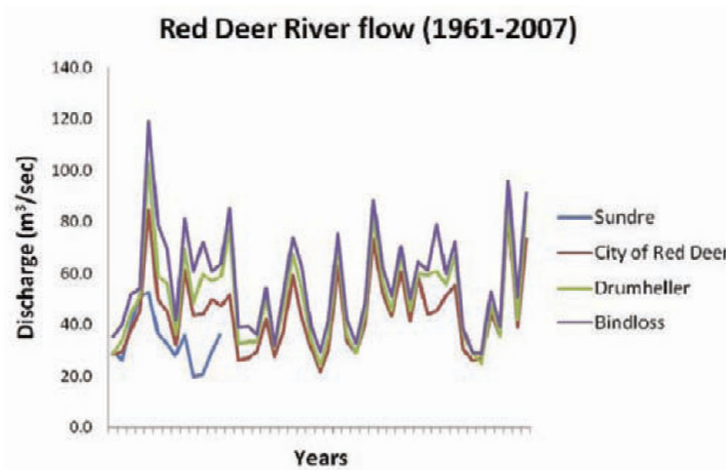



**Figure 2. Red Deer River Average Annual Flows (1961-2007)** *(Aquality, 2009)*

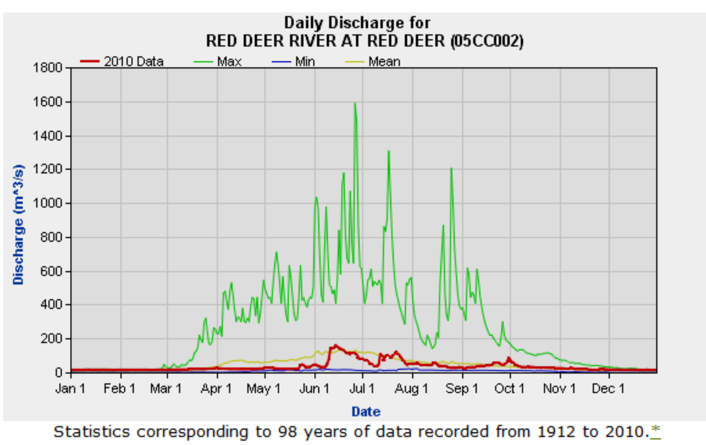



**Figure 3. Red Deer River Daily Discharge: max., min., and mean values** *(Environment Canada, 2010)*

Flooding is an ever-present threat, with the highest flood risk occurring from late April to mid-June, particularly in the headwaters upstream from the Dickson Dam. Flooding typically occurs when snowmelt in the headwaters coincides with heavy spring rainfall.

Drought is a threat as well. The droughts of the “Dirty Thirties” are well known. More recently, major droughts were experienced in 1979, 2001, and 2002. In a longer-term context, tree ring and lake diatom studies indicate severe, prolonged droughts have occurred repeatedly across the region in the past (Sauchyn et al., 2002) Figure 4). The potential for future severe droughts remains a concern for the watershed.

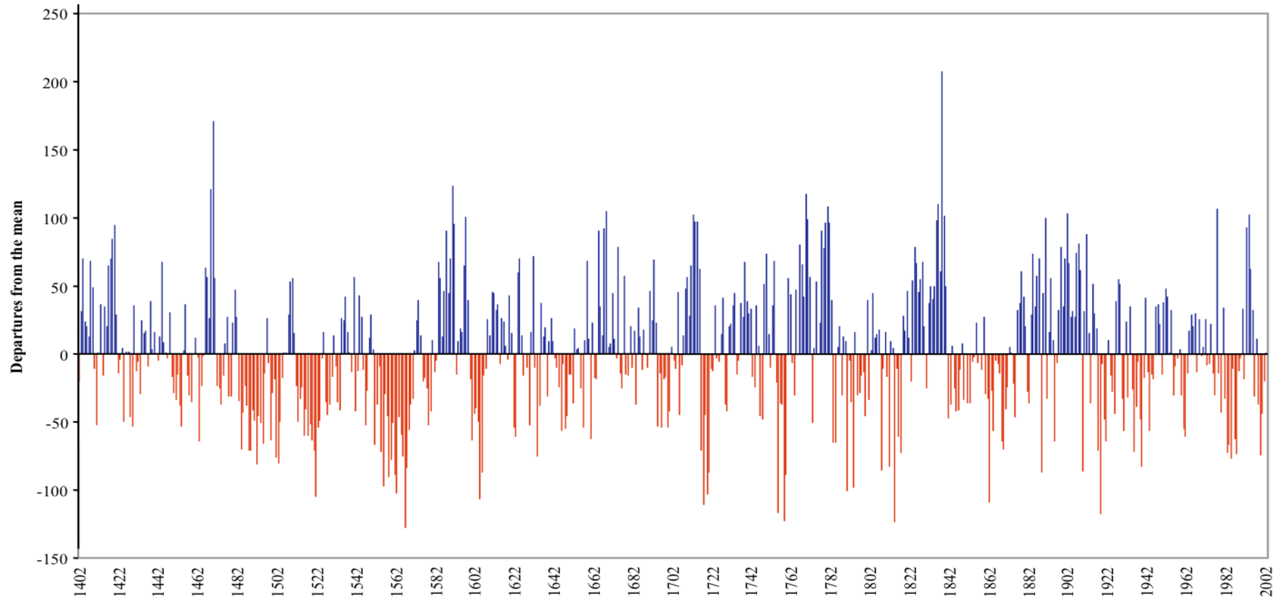



**Figure 4. Reconstruction of South Saskatchewan River Flows: 1402-2004 based on paleoclimate** *(Axelson et al., 2009)*

There are over 700 active licences that divert up to a maximum of 220,660 $dam^3$/year of water from the Red Deer River (Aquality, 2009). Allocations are relatively low in comparison to the natural flow of over 2 million $dam^3$/year (Environment Canada, 2010). One recent analysis showed the Red Deer River's licensed allocation represents 5% of the median flow at Dickson Dam, and 18% of the median flow near Bindloss. This is fairly low compared to other rivers in southern Alberta. Nonetheless, consumptive water uses still pose a risk to in-stream flow needs for fish, aquatic life, and other uses during low-flow periods and major droughts.

The largest licensees by sector include (Aquality 2009):

- *Urban municipalities:* 28% (62,435 $dam^3$/year) (although return flows are high for this use)
- *Crop irrigation:* 22% (48,491 $dam^3$/year): (this represents the largest consumptive water use)
- *Oil/gas/petrochemicals:* 12% (25,500 $dam^3$/year)
- *Cooling purposes:* 11% (24,875 $dam^3$/year)

Expansion of water licensing in the Red Deer River is currently not constrained by the provincial moratorium on licences in the South Saskatchewan River Basin. However, the Master Agreement on Apportionment between Alberta, Saskatchewan, and Manitoba administered by the Prairie Provinces Water Board (PPWB) does create long-term constraints for new licences. Alberta must deliver a percentage of flow to the downstream provinces over the long-term. Since there is currently high consumptive water use in the Bow and Oldman Rivers, which also drain into the South Saskatchewan River system, the Red Deer River flows currently help balance water volumes supplied downstream. In the short- to medium-term, the largest potential new consumptive use is the "Special Areas Water Supply Project," which proposes to divert water to the driest parts of the Red Deer River watershed, primarily for livestock watering and irrigation.

Water Conservation Objectives (WCOs) for the Red Deer River were established in 2007 under section 15(1) of the *Water Act* to meet instream objectives and minimum flows in the Red Deer River sub-basin. This includes separate WCOs for three different reaches (AENV, 2007a).

## 2.5 Outcomes, Indicators and Targets: Background Context, Problems and Issues

Outcomes, indicators, and targets are important to synthesize information on watersheds, which contain many complex, interrelated variables. Indicators are also important to craft feasible monitoring and management programs. For a WPAC, indicators are critical to measure an organization's progress towards meeting its vision, as well as specified outcomes and goals. This contributes to a performance management system that gauges success through time.

Throughout the watershed planning and implementation process, indicators and targets should be selected, refined, and modified to reflect changing conditions and priorities. As the watershed planning process proceeds, a measureable target is set for each indicator, which allows for measuring progress and ultimately reaching the target (USEPA, 2008).

Watershed management plans should aim to provide a set of environmental, programmatic, and social indicators.

### Definitions

**Outcomes** are the desired future conditions that guide the development and implementation of an organization's recommendations.

**Indicators** are measurable surrogates for end points of value to the public. Indicators measure progress towards achieving the desired outcomes.

**Targets** are specific, quantitative values assigned to indicators that reflect a desired outcome.

### 2.5.1 *Environmental Indicators*

Environmental indicators are based on observed variables of concern in the watershed, as well as sources of degradation that contribute to impacts on the aquatic environment. For example, water quality conditions supporting designated water uses in the Red Deer River main stem are important. Equally important are the land use patterns and practices that potentially influence receiving water quality conditions.

AESRD has stated that Watershed Planning and Advisory Councils (WPACs) and Watershed Stewardship Groups (WSG) should select a number of assessment techniques for watershed indicators at several spatial scales (AENV, 2008). This should begin at the largest spatial scale of assessment, which relies on existing information and remote sampling techniques, and progresses towards finer scales, where field-based surveys are required to sample small-scale variables (Fausch et al., 2002; AENV, 2008).

Previous work in the watershed listed 20 recommended indicators in four major categories, including indicators and metrics related to riparian areas, wetlands and land use (Aquality, 2008) (Table 1). The State of the Watershed Report also synthesized both existing condition indicators and ecological risk indicators for each of 15 sub-watersheds in the basin (Aquality, 2009).

The Technical Advisory Committee (TAC)'s review of *Data Gaps in Watershed Health Indicators* in May 2011 was also reviewed as a source of information to determine the scope (RDRWA, 2011).

**Table 1. Select Indicators in the State of the Watershed Report for Riparian Areas, Wetlands, and Land Use** *(Aquality, 2008)*

| Indicator | Metrics |
|---|---|
| Wetlands | • Area (ha) of intact natural wetlands<br>• Area (ha) of reclaimed/restored wetlands<br>• Area (ha) of drained wetlands |
| Riparian Health | • Aerial videography (riparian health assessment)<br>• Cows and Fish Riparian Health Inventories |
| Livestock and Grazing | • No. of head per hectare<br>• Manure production (tonnes) |
| Urban, Rural, and Recreational Development | • Urban vs. rural population<br>• % of hectares of watershed/sub-watershed developed as urban area, rural subdivision or for recreational purposes |
| Linear Development / Fragmentation | • No. of road crossings in a given area<br>• % of watershed with linear development (i.e., % covered by roads, pipelines, cut lines, etc.) |
| Oil and Gas Activity | • # of wells (active, decommissioned, and abandoned) per given area |
| Land Cover | • % cover of trees, shrubs, grassland, bare soil, etc. |

## Factors to consider when selecting watershed indicators

(USEPA, 2008; Davenport, 2003)

**Validity:**

- Is the indicator related to your goals and objectives?
- Is the indicator appropriate in terms of geographic and temporal scales?

**Clarity:**

- Is the indicator simple and direct?
- Are the methodologies consistent over time?

**Practicality:**

- Are adequate data available for immediate use?
- Are there any constraints on data collection (e.g., costs, available technology)?

**Clear Direction:**

- Does the indicator have clear action implications depending on whether change is good or bad?

### 2.5.2 *Programmatic and Social Indicators*

Technical watershed reports can often neglect or overlook "softer" *programmatic and social indicators,* which are important to establish and track in addition to environmental indicators (Davenport, 2003). *Programmatic indicators* can be defined as representing actions taken intended to achieve a goal. Examples include:

- Number of people attending workshops or educational events
- Number of municipalities adopting riparian, wetland, or watershed protection bylaws or policies
- Number of physical installations of Low Impact Development (LID) Beneficial Management Practices

*Social indicators* measure changes in social or cultural practices, such as increased awareness of watershed issues, and behavioural changes that lead to the implementation of management measures, increased stewardship, and less risk of water quality impacts. Examples of social indicators include:

- Rates of citizen participation in watershed restoration activities
- Knowledge and/or attitudes among agricultural producers and other landowners

### 2.5.3 *Indicators, Targets and Geographic Context*

Targets and management objectives must differ in a watershed in response to natural and anthropogenic spatial patterns. The Headwaters, Central Parkland, and Grassland landscapes of the Red Deer River watershed differ substantially from one another, and consequently require different targets and management approaches. In addition, more pristine areas with intact natural assets require different targets than landscapes with substantial human activity. Additionally, targets must be easily communicated for the broad understanding and application of watershed management planning objectives.

With this in mind, this project defined a set of five watershed-based landscape units to help frame indicators and targets in a simple yet geographically valid way. Criteria applied in defining boundaries included the defined sub-watershed boundaries (Aquality, 2009), Natural Regions and Sub-Regions (NRC, 2006), primary land management issues and land use patterns, and the location of water quality monitoring stations (Table 2).

**Table 2. Watershed-Based Landscape Units Defined**

| **Watershed Landscape Unit** | **Rationale** | | | |
|---|---|---|---|---|
| | **Sub-Watersheds** | **Natural Regions / Sub-Regions** | **Primary Land Uses** | **Coordination w/ WQ Monitoring Stations** |
| A. Upper Headwaters (3,775 km$^2$) | - Based on Panther and James sub-watersheds | - Primarily Rocky Mountains and Foothills | - Forestry<br>- Recreation | - Entirely upstream from Gleniffer Lake WQ monitoring station |
| B. Lower Headwaters (7,503 km$^2$) | - Based on Raven, Medicine, Little Red Deer sub-watersheds (including Fallen Timber Creek) | - Primarily Dry Mixedwood, some Central Parkland | - Agriculture<br>- Oil and gas<br>- Recreation | - Upstream from Red Deer at Hwy. 2 WQ monitoring station |
| C. Central Urbanizing (2,829 km$^2$) | - Includes Blindman River, Waskasoo | - Primarily Central Mixedwood Natural, some Central Parkland | - Concentrated urban development (e.g., Red Deer, Blackfalds, Penhold, Sylvan Lake, Gull Lake)<br>- Agriculture<br>- Petrochemical industry | - Upstream from Nevis WQ monitoring station |
| D. Central Agricultural (18,300 km$^2$) | - Includes Buffalo, Threehills, Kneehill, Rosebud, Michichi sub-watersheds | - Central Parkland in upper portions, Foothills Fescue and Northern Fescue in southernmost portions | - Agriculture | - Not ideal based on location of Morrin WQ station |
| E. Dry Grasslands (17,802 km$^2$) | - Includes Berry, Matzhiwin, and Alkali sub-watersheds | - Primarily Dry Mixed Grass | - Oil and gas<br>- Pasture / native prairies<br>- Some irrigated agriculture | - Upstream from Bindloss-however the Jenner station could also be used to further study/separate influences from the Alkali vs. Berry/Matzhiwin sub-watersheds |

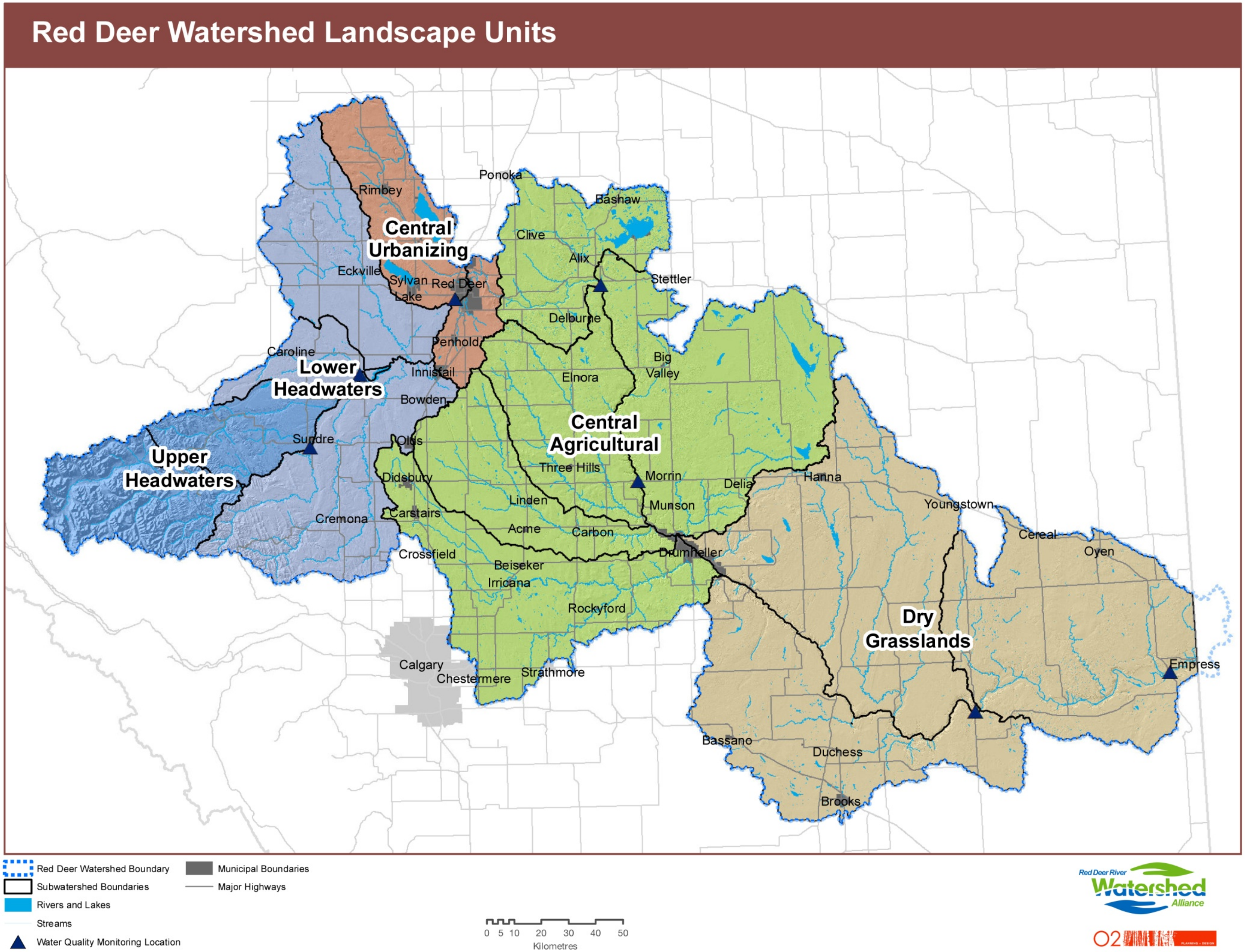



**Figure 5.** Map of Defined Watershed-Based Landscape Units

### 2.5.4 *Targets and Cumulative Effects Management*

Cumulative effects are the result of multiple activities occurring on a landscape through time and space. The federal practitioners' guide defines cumulative effects as *"changes to the environment that are caused by an action in combination with other past, present and future human actions*"(Hegmann et al., 1999). Cumulative effects tend to occur because of mismatches in the scale at which impacts accumulate and the scale at which decisions are made. The consequences of human activities often appear insignificant on an individual project-by-project basis, but accumulate to levels of significance when broader or different scales of time and space are considered (Kingsley, 1997).

Cumulative impacts are rarely linear, and are more often characterized by sudden non-linear shifts, critical thresholds, and surprises (Folke et al. 2004). Ecosystems are complex, dynamic, and adaptive systems, and rarely follow simple, predictable, linear changes through time. Long periods of stability, punctuated by abrupt, rapid, non-linear change to an alternative state are characteristic features of most ecosystems. These "surprises" are caused by complex interactions between ecosystem resilience and the cumulative effects of multiple stressors. Often, ecosystems are resilient to a certain level of stressors and will show little change. However, if multiple stressors are crowded in space and time, a sudden "trigger" or critical threshold can be surpassed, causing the ecosystem to "flip" into an alternative state. Well-documented examples of these "non-linear" changes include shifts from clear water to turbid water conditions in temperate lakes (Carpenter et al., 1999)[3] and shifts from hard corals to macroalgae in coral reef ecosystems (Hughes, 1994).

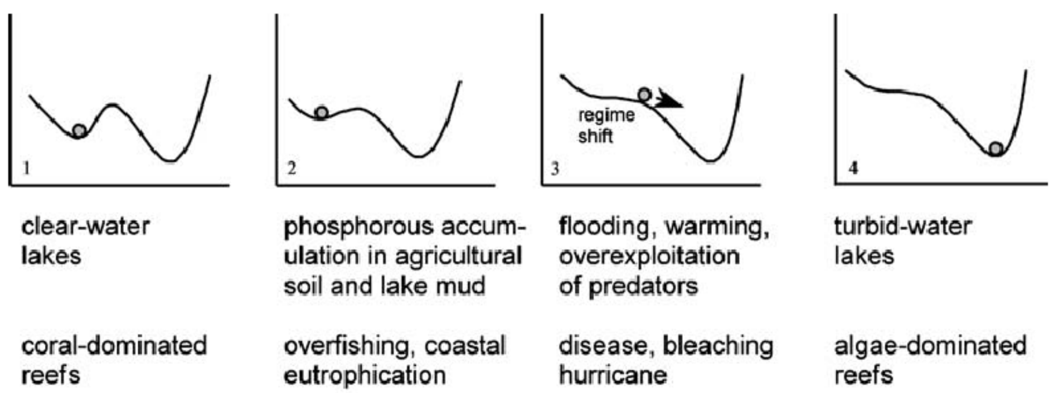



**Figure 6. Ecosystem Regime Shifts: initial state (1), causes (2), triggers (3), and alternate state (4)** *(Source: Folke et al. 2004)*

It can be very difficult to predict what combination of cumulative effects will cause a sudden non-linear change. However, once an ecosystem has "flipped" into a degraded state, it can be difficult and sometime even impossible to restore it back to its former condition.

[3] However, in cold boreal lake environments, natural oscillations between clear and turbid regimes can also occur (Bayley et al., 2007)

### 2.5.5 ***Targets and Management Responses***

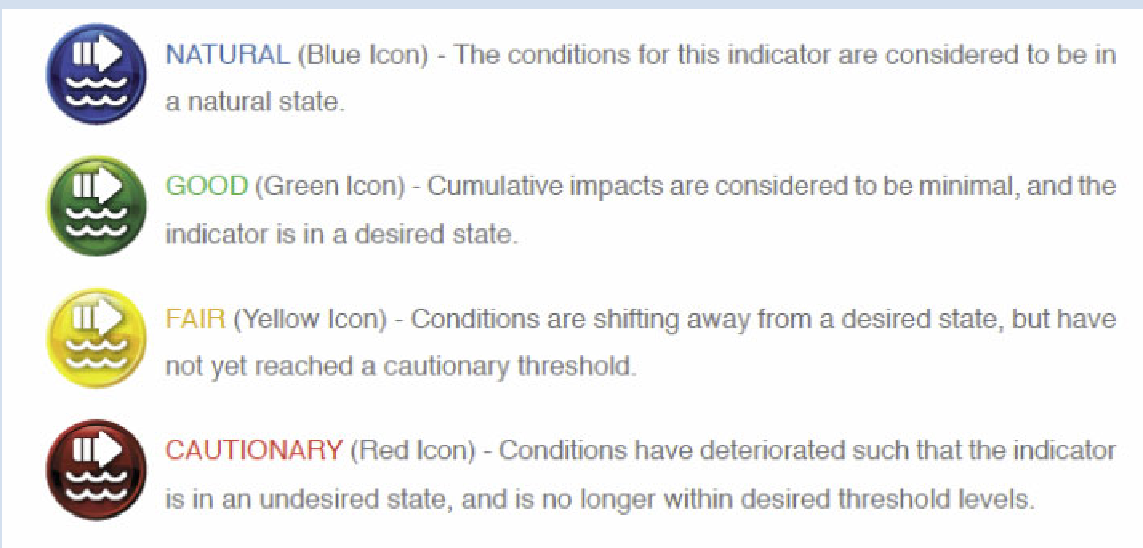
Management responses need to be driven by and linked to established indicators and targets specifying the desired level, or range, an indicator must achieve or maintain through time. The aim is to be proactive to help avoid reaching potential critical thresholds where undesirable conditions and unacceptable environmental, social, or economic impacts occur. Determining the appropriate target value for an indicator often requires a blend of science, planning, and social values. This is because *ecological* thresholds, defined as a critical value at which sudden, non-linear and often irreversible change occurs (Folke et al., 2004) are notoriously difficult to quantify and predict (Figure 6). Data gaps and incomplete information are also a challenge when formulating targets. The natural range of variability in environmental conditions must also be considered carefully.

**However, in the absence of perfect scientific knowledge, planning exercises still require management targets.** Targets must be set by integrating existing knowledge and data, expert analysis, and socioeconomic considerations. Adaptive management frameworks are also useful. Effective adaptive management requires testing of assumptions, and iterative analysis through time to refine or change targets as necessary in response to new data and information.

**BRBC Reporting on Watershed Condition Indicators, Cumulative Effects and the Land Use Framework**

Cumulative effects management frameworks, including those related to surface water and groundwater, are being included in the regional plans under development for the provincial *Land-use Framework*. Each regional plan will identify specific limits and triggers for selected indicators. **The RDRWA could contribute to this process by developing a set of watershed-based cumulative effects indicators for further consideration in the Red Deer Regional Plan.**

The Bow River Basin Council (BRBC) has established colour-coded values to report on watershed condition indicators linked to as much relevant and recent data as possible as follows (BRBC, 2010):



NATURAL (Blue Icon) - The conditions for this indicator are considered to be in a natural state.

GOOD (Green Icon) - Cumulative impacts are considered to be minimal, and the indicator is in a desired state.

FAIR (Yellow Icon) - Conditions are shifting away from a desired state, but have not yet reached a cautionary threshold.

CAUTIONARY (Red Icon) - Conditions have deteriorated such that the indicator is in an undesired state, and is no longer within desired threshold levels.

# 3. WETLANDS

This chapter focuses on wetlands. Included is a definition of wetlands and wetland typologies in the watershed, as well as wetland functions and services (Section 3.1). Existing baseline wetland mapping for the watershed is provided in Section 3.2. Section 3.3 provides draft outcome statements, followed by proposed indicators and targets for wetlands in Section 3.4. Section 3.5 discusses management implications and recommendations, including future research needs and key Beneficial Management Practices to focus the development of the IWMP and future efforts.

> *"Wetlands combine the beauty of aesthetic form and ecological functions in ways that make them a critical issue in land use planning"* (France, 2003)

## 3.1 Wetland Definitions, Functions and Services

Wetlands are transitional environments intermediate between aquatic and terrestrial ecosystems. They consist of areas temporarily, seasonally or permanently covered by shallow water. Wetlands have characteristic wetland soils and are dominated by hydrophytic ("water-loving") vegetation (Stewart & Kantrud, 1971). Wetlands can be defined as: *" Land that is saturated with water long enough to promote wetland or aquatic processes as indicated by poorly drained soils, hydrophytic vegetation and various kinds of biological activity which are adapted to a wet environment"* (National Wetlands Working Group, 1988). The Canadian Wetland Classification System defines five general classes of wetlands: bog, fen, marsh, swamp, and shallow water.

In the Red Deer River Watershed, "prairie pothole" wetlands are the most common wetland type. These form in landscape depressions within small, independent drainage basins overlying glacial till (Figure 7). Dominant water inputs of prairie wetlands include snowmelt runoff, wind-blown snow, and direct summer precipitation (Fang & Pomeroy, 2010). The open-water area of prairie wetlands varies considerably between seasons and years in response to cycles of drought and deluge (van der kamp & Hayashi, 2003). Water quality in prairie wetlands varies considerably depending on landscape position, with widely varying salt concentrations typically observed over scales as small as 1 to 10 $km^2$ (van der Kamp & Hayashi, 2009). AESRD uses the Stewart and Kantrud (1971) wetland classification system for prairie wetlands, which includes the following classes:

- **Class I – Ephemeral Ponds** (wetland low prairie zone only)
- **Class II – Temporary Ponds** (includes a wet meadow zone)
- **Class III – Seasonal Ponds and Lakes** (includes a shallow marsh zone)
- **Class IV – Semi-permanent Ponds and Lakes** (includes a deep marsh zone)
- **Class V – Permanent Ponds and Lakes**
- **Class VI – Alkali Ponds and Lakes** (high in salts)
- **Class VII – Fen (Alkaline Bog) Ponds** (very uncommon in the region)

The Stewart-Kantrud classification system is based primarily on water permanence; however, accurate classification relies heavily on field observations of diagnostic wetland plants.

The Red Deer River Watershed includes a diversity of other wetland types. Oxbow wetlands or floodplain marshes are common in many riparian areas adjacent to streams and rivers, including along the Medicine River (Figure 8). Shallow water lacustrine fringe wetlands occur at the margins of many lakes (Figure 9). Bogs and fens occur primarily in the headwaters of the watershed, concentrated in the Lower Foothills and Dry Mixedwood Natural Sub-regions, where they constitute over 6% of the landscape (Turchenek & Pigot, 1988) (Figure 10). Bogs and fens are considered peatlands, which contain a thick layer (>40 cm) of partially decomposed organic matter. Bogs, which are primarily rain and snow fed, are acidic, peat-accumulating wetlands dominated by *Sphagnum* moss (Mitsch & Gosselink, 2007). Fens are peat-accumulating wetlands that receive groundwater input from surrounding mineral soils and support marsh-like vegetation or trees and muskeg.


**Figure 7. Landscape with a Diversity of Prairie Pothole Wetlands, near Rumsey, AB**


**Figure 8. Riparian Oxbow Wetlands, Medicine River Sub-Watershed near Markerville, AB**


**Figure 9. Lacustrine Fringe Shallow Water Wetland, Pine Lake, AB (Threehills Sub-Watershed)**

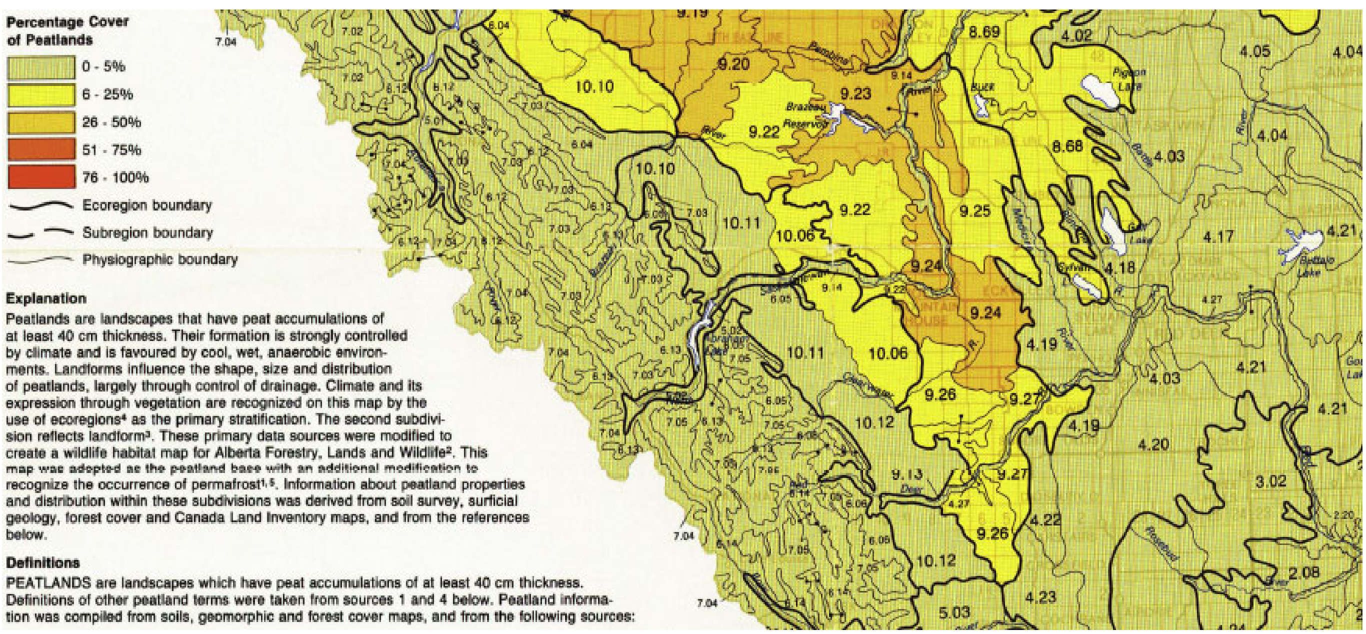



**Figure 10. Peatlands occur in the Upper Headwaters** *(e.g., landscape units 9.26 and 9.27 above) (Turchenek & Pigot, 1988)*

### 3.1.1 *Functions and Services of Wetlands*

Wetlands provide many functions and ecosystem services in a watershed[4], as summarized below. However, it should be kept in mind that the functions and services of any individual wetland depend on many factors, including wetland type, size, morphometry, soils, organic matter, climate and hydrologic regime, vegetation, season, landscape position, and the degree of use of wetland ecosystem services by human beneficiaries (Preston & Bedford, 1988; Adamus, 2011; Gustavson & Kennedy, 2010).

#### Water Quality Improvement

Wetlands help maintain and improve water quality by removing and storing sediment, phosphorus (P), nitrogen (N), pathogens, pesticides, and other contaminants (Johnston et al., 1990; Mitsch & Gosselink, 2007)[5].

Wetlands can considerably reduce P through plant and/or microbial uptake, mineralization, and adsorption/ precipitation (Mitsch & Gosselink, 2007; Wang & Mitsch, 1998). In constructed wetlands with very high P concentrations in influent, reductions of 64-95% are possible (USEPA, 1993; Vymazal & Kropfelova, 2008; White & Bayley, 2001). P retention by natural wetlands is also important, but varies widely (Mitsch, 1992). The role of wetlands in N removal is also very important (Mitsch & Gosselink, 2007; Arheimer & Wittgren, 1994). Nitrate retention by wetlands can be up to 87%, whereas ammonium retention can be up to 76% (Gabor et al., 2004). Wetlands also filter sediment by up to 98% and a wide range of other contaminants, particularly if wetland riparian areas are intact (Gilbert et al., 2006; Gergel et al., 2002; Gabor et al., 2004).

#### Water Storage and Supply

Water storage by wetlands provides many supporting and regulating ecosystem services upon which all other wetland ecosystem services depend. A recent study in Alberta east of Calgary examined water storage and supply of wetlands. The study found that the >6,500 wetlands scattered across the 274 $km^2$ pilot study area contained over 36 million $m^3$ of water storage capacity (O2, 2011a). This is almost twice the volume of Pine Lake.

Cattle and wildlife in agricultural areas often make use of water stored in wetlands. Small-scale irrigation of golf courses, open spaces, and crops are also potential uses of water stored in wetlands. Small wetlands can also contribute to crop and hay production by providing high moisture capture in the spring.

#### Flood Reduction

Wetlands absorb water during floods, creating a “sponge” effect that delays peak flows. By storing and gradually releasing water, wetlands attenuate downstream flooding and reduce bank erosion. On a cumulative basis, wetlands on the landscape substantially decrease downstream peak flows (Hey & Phillippi, 1995; Zedler & Kercher, 2005; Yang et al., 2008; O2, 2011a). Conversely, draining wetlands increases flood risk downstream, especially if cumulative wetland losses in a watershed through time are substantial[6].

#### Drought Buffering

Wetlands can provide a valuable source of water as well as livestock forage during drought. In addition, many wetlands continue to supply aquifers and small tributaries with water during drought and dry seasons (Baker & van Ejik, 2006; Pollock et al., 2003; Westbrook et al., 2006). Peatlands in the upper headwaters of the Red Deer River are likely to be particularly important in this respect.

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[4] Functions are the natural processes that maintain ecosystems; services are outputs of ecosystems that benefit people (AESRD, 2011)

[5] Wetlands do show source-sink phenomenon, and in some cases (e.g., high flows) wetlands also act as a source of nutrients

[6] One study in a SW Manitoba prairie watershed found wetland losses between 1968-2005 increased peak flows by 18%. Restoration scenarios indicated that restoring 465 ha of wetlands over time would decrease peak flows by over 11% (Yang et al., 2008).

### Groundwater Recharge

Many wetlands recharge and maintain local and regional groundwater supplies. Although net recharge is often small (1-3 mm/year), there is evidence that over long time periods, small pothole wetlands are a key source of recharge to regional prairie aquifers (Hayashi et al., 1998). Groundwater recharge by wetlands is also related to drought buffering, as it can lead to higher base flows and improved distribution of seasonal and inter annual flows in streams and rivers (Gilbert et al., 2006).

### Recreational, Scenic, and Aesthetic Values

Wetlands can provide numerous opportunities for tourism and recreation, including bird watching, nature photography, hunting, fishing, walking, and other activities (Boyer & Polasky, 2004). Related to this are aesthetic and scenic values. Property values in proximity to wetlands are often used as a proxy for aesthetic values; for example, Foley (2007) found that residents in Bridlewood Creek in Southwest Calgary were willing to pay a premium to live close to the local community wetland. The ecosystem services pilot east of Calgary found that house values increased by up to $5,000 per house if they were located adjacent to a wetland (AESRD, 2011).

### Biodiversity Support

Wetlands are hotspots of biodiversity with high primary production (Reddy & DeLaune, 2008). Wetlands provide habitat for aquatic invertebrates, amphibians and reptiles, waterfowl, songbirds, raptors, mammals, pollinators, and native plants (Adamus, 2011; Mitsch & Gosselink, 2000). Many floodplain and lacustrine fringe wetlands also provide critical nursery habitat for fish (Graff & Middleton, 2002).

Prairie pothole wetlands have been identified as extremely important to breeding waterfowl in North America. Approximately 40-75% of North America's duck population relies on prairie potholes as breeding habitat (CPPIF, 2004). Prairie potholes are also an important staging area for migrating shorebirds. Saline wetlands and wetlands surrounded by mud flats and pebbled areas often provide habitat for rare and specialized species, including nationally endangered species such as piping plover. Vegetated riparian areas adjacent to wetlands are important habitat for many bird, mammal, and amphibian species (Huel, 2000; CPPIF, 2004). Wetlands in the Boreal Plain (west portion of the watershed) have also been identified as important for waterfowl in a North American context.

### Carbon Sequestration / Climate Regulation

Wetlands, particularly peatlands, store considerable carbon (Reddy & DeLaune, 2008). Although many wetlands also produce methane ($CH_4$), a greenhouse gas, current knowledge indicates drainage or alteration of wetlands releases carbon to the atmosphere. Estimates relevant for prairie potholes in the Red Deer River watershed indicate that wetland drainage decreases soil organic carbon by 89 tonnes/ha; this is equivalent to 326 tonnes of $CO_2$ equivalent (DUC, 2011). Conversely, restoring prairie pothole wetlands sequesters carbon, even when accounting for $CH_4$ emissions, with sequestration estimates of 3.3 tonnes of $CO_2$eq/ha/year over an approximate 30-year period (Badiou et al., 2011). Therefore, wetland conservation and restoration can play a role in slowing global climate change.

Wetlands can also regulate local climate. For example, in Florida it was shown that wetlands in the landscape reduced frost damage by moderating low temperatures (Marshall et al., 2003). Evapo-transpiration from wetlands can also increase local air humidity.

**Other Services:** Other ecosystem services provided by wetlands include food production (e.g., wild rice, cranberries, fish), cultural and spiritual values, scientific and educational values, fuelwood production, furs and pelts, peat production[7], genetic resources[8], nutrient cycling, erosion control, avoidance of reservoir sedimentation and dredging costs, potential biological control of insect pest species, and passive bequest and existence values.

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[7] Peat harvesting for horticultural uses occurs west of Olds, AB (Dr. Maria Strack, personal communication)

[8] Genetic resources could be used for medicine / pharmaceutical research, genes for plant resistance, ornamental species, etc.

### 3.1.2 *Economic Valuation of Wetland Ecosystem Services*

There are a variety of methods available to translate wetland ecosystem services into economic values (Gustavson & Kennedy, 2010; Brander et al., 2006). Table 3 summarizes recent research on this topic. However, ecosystem service benefits are highly context specific as they relate to how the environment is used and valued by people (AESRD, 2011; Ruhl et al., 2007; O2, 2009a). There are also some ecological values that can be difficult to value in the marketplace, so caution is required when interpreting this information.

**Table 3. Sample Wetland Economic Valuation Estimates in Published Literature**

| Location | Type of Wetland Values Evaluated | Value ($/ha/year) |
|---|---|---|
| Lower Fraser Valley, B.C. | Waste treatment, flood protection, wildlife viewing, hunting and fishing | $5,800 to $24,400<br>(Olewiler, 2004) |
| Global average estimate | Gas regulation, flood regulation, water supply, erosion control, waste treatment, habitat, food production, raw materials, recreation, culture | $19,580<br>(Costanza et al., 1997) |
| New Jersey | Water regulation, water supply, habitat, aesthetic values, recreation | $21,485<br>(Liu et al., 2010) |
| Black River, Ontario | Phosphorus removal, nitrogen removal, biodiversity, carbon sequestration, recreation | $1,319/ha<br>(Pattison et al., 2011) |
| Shepard Slough Study Area, southern Alberta | Flood control, water filtration, carbon storage, recreation, aesthetic and property values | $56,000/ha<br>(AESRD, 2011) |

## 3.2 Baseline Wetland Data and Mapping

Existing information on wetland cover and wetland density was synthesized into maps of wetland cover and wetland density. A discussion of wetland loss in the watershed is also provided in this section.

### 3.2.1 *Wetland Cover*

The provincial merged wetlands inventory was obtained from AESRD and queried to summarize information on wetland cover. A map of average wetland cover for each sub-watershed is shown in Figure 15. Statistics are shown in Appendix B. Highlights and general trends for wetland cover for the Red Deer River Basin include:

- Wetland cover in the entire Red Deer watershed is estimated at 7.5%
- The Michichi sub-watershed has the highest overall wetland cover (13.7%), due to the dominant knob and kettle topography with numerous wetland basins isolated from the regional drainage network
- The Medicine sub-watershed has the second highest overall wetland cover (13.6%), due primarily to the numerous fens in the upper part of the watershed
- The Waskasoo and Little Red Deer sub-watersheds have the lowest wetland cover (3.6%), likely due to natural landscape factors as well as historical drainage for agriculture and urban development
- In the Little Red Deer sub-watershed, there appears to be an area of over 1,000 $km^2$ in the uppermost part of the watershed where wetlands have not been mapped, suggesting that this may be a data gap requiring further investigation[9]

[9] It is possible that wetlands in the Little Red Deer watershed are in fact as high as 5%

### 3.2.2 *Wetland Density*

A map of wetland density (number of wetlands/$km^2$) is shown on Figure 13. This map tends to highlight local areas with many small wetlands (e.g., south part of Rosebud sub-watershed).

The procedure applied to conduct this mapping was a simple numeric count of wetlands per Alberta Township System (ATS) section. The input ATS section grid was processed to remove all road allowances and clipped to the Red Deer Watershed boundary. The geometry of each section was recalculated after clipping to ensure that the area in $km^2$ of partial sections (cut off by Watershed boundary) was updated. Portions of larger wetlands occupying more than one section were counted as individual wetlands within each section for the purposes of this analysis. An intersect operation was performed between the clipped section grid and the provincial merged wetland inventory. The results were summarized as the count of wetlands per $km^2$ and mapped as colour coded section grid footprints.

### 3.2.3 *Wetland Types*

Figure 11 shows the distribution of wetland types in the watershed based on the provincial merged wetlands inventory. Overall, marsh wetlands are the dominant wetland type in the watershed, although these are concentrated in the prairie pothole landscapes of the Central Agricultural and Dry Grasslands landscape units (Appendix B). Peatlands are dominated by fens in the watershed, with both fens and bogs restricted to the upper and lower headwaters and the upper Blindman River sub-watershed.

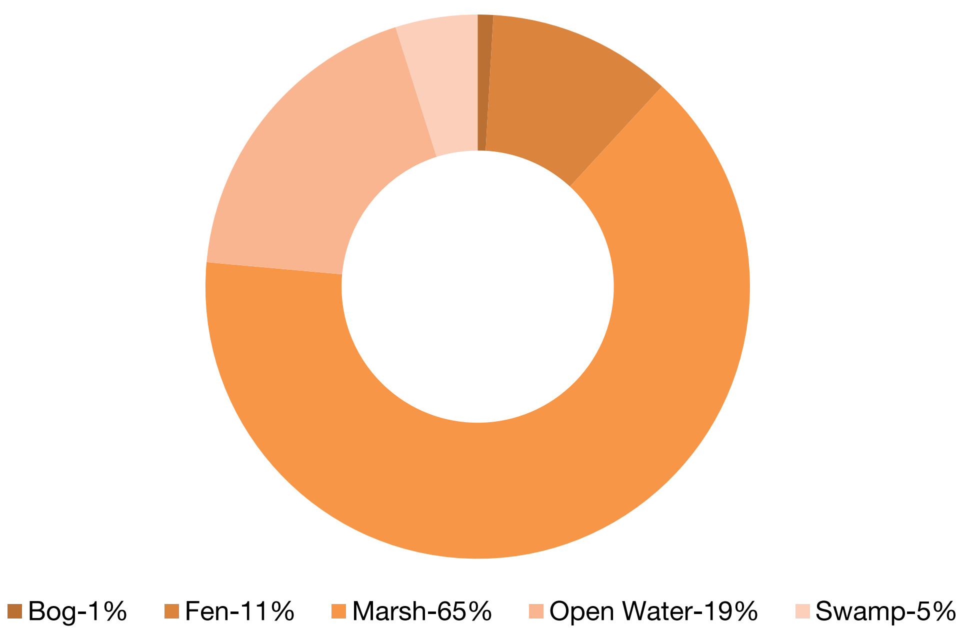


**Figure 11. Wetland Types in the Red Deer River Watershed (% of all wetland area)**

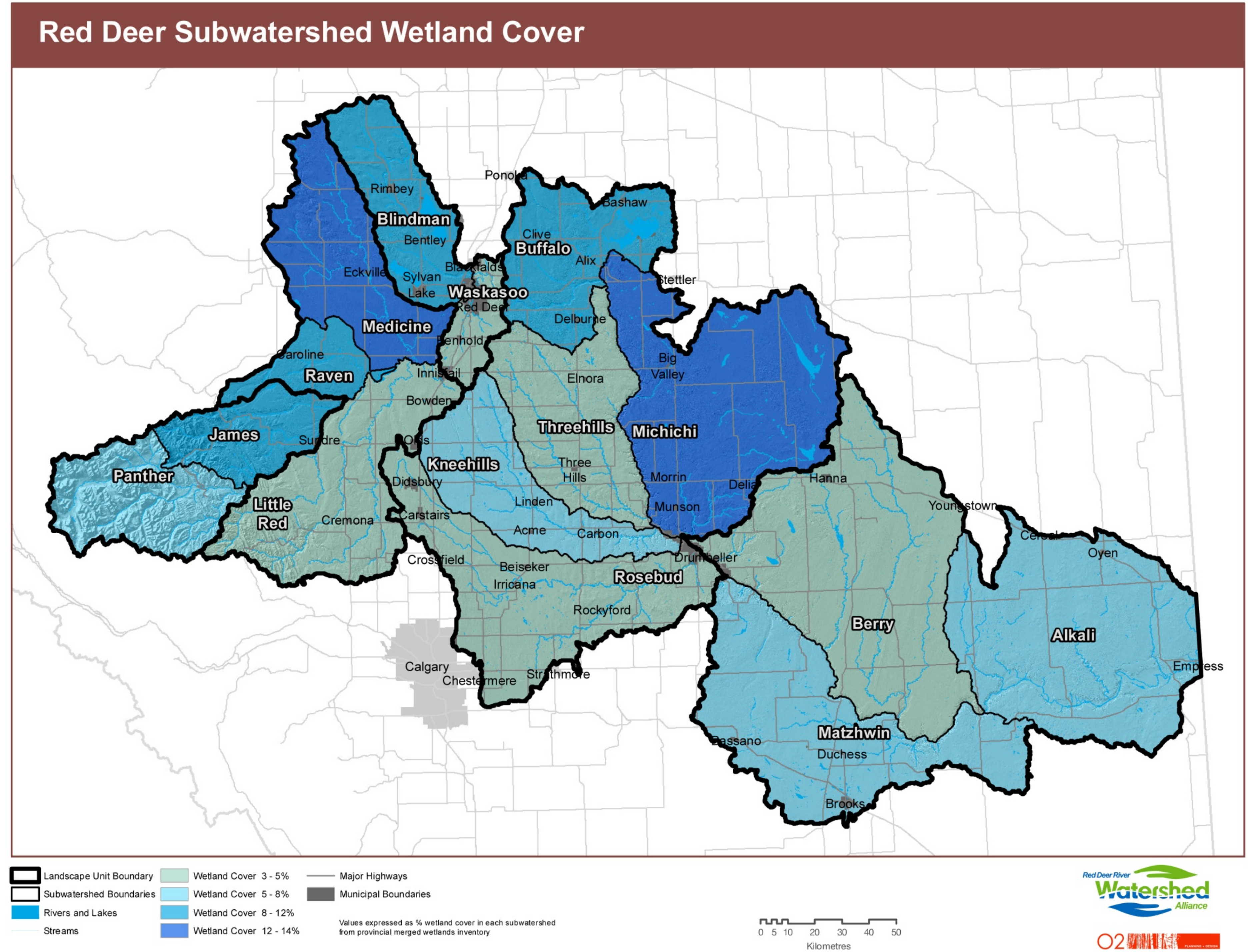


**Figure 12. Map of Wetland Cover (%) By Sub-Watershed**

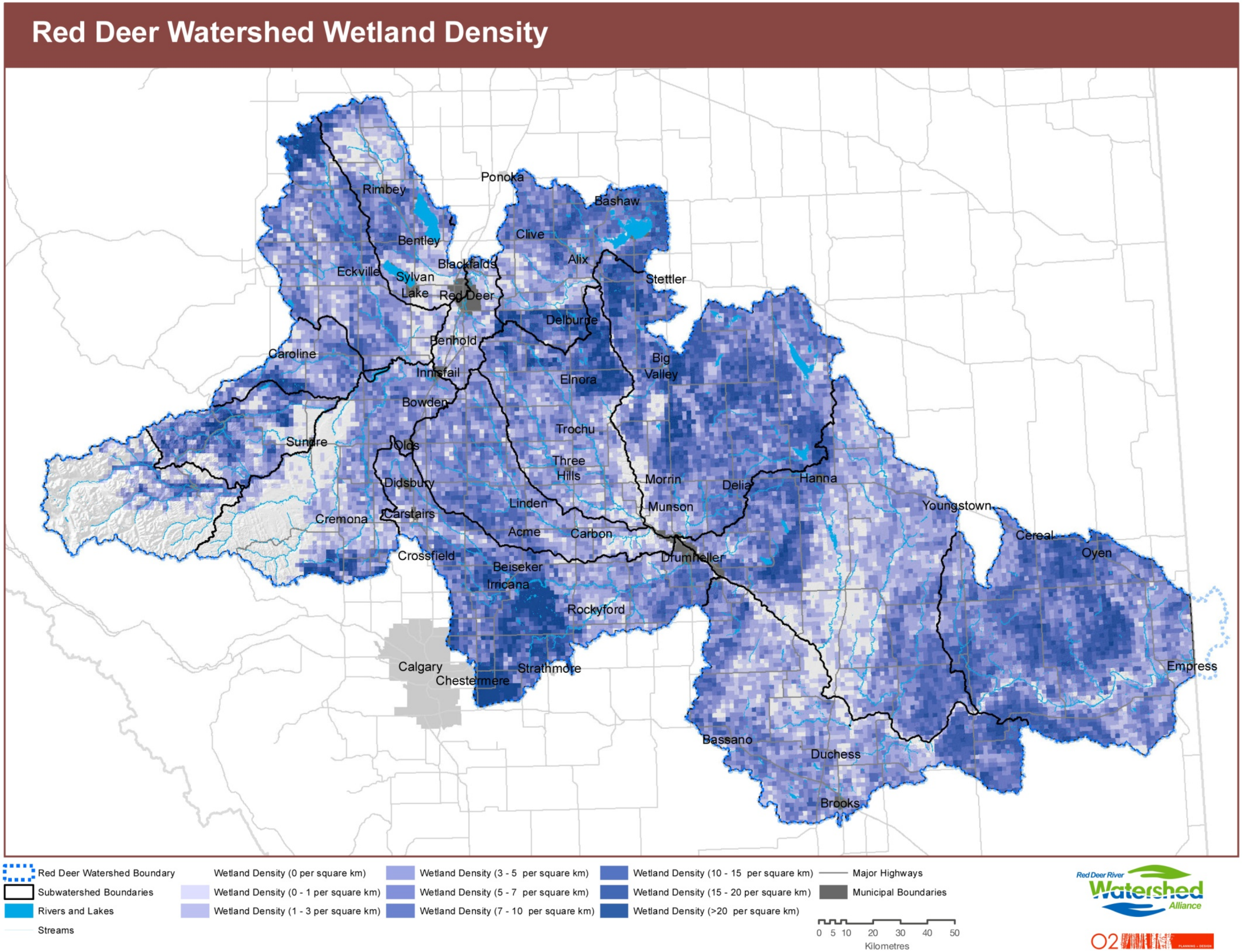


**Figure 13.** **Map of Wetland Density**

### 3.2.4 *Wetland Loss*

There is no comprehensive, accurate database of drained or lost wetlands in the watershed. However, the federal government completed wetland monitoring sample transects in Alberta, with 17 monitoring transects in the Red Deer River Watershed (Watmough, 2008; Aquality, 2009). Overall, findings from 1985-2001 included:

- 7% of the total sampled wetland area in the Red Deer Watershed was considered lost or severely degraded as a result of human activities during the 16 year period
- Sampled transects in the watershed had a mean wetland area loss of 7% with a range of -36% to +2% for the entire sample
- 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

In a longer-term context, the scale of wetland loss is only partially understood, but is estimated to be significant. The Prairie Ecozone in Canada has experienced the greatest historic loss of wetlands in the country (60-80%), while 10-20% of wetlands have been lost in the Boreal Plain Ecozone further west (TetrES Consultants Inc., 2006). Alberta-specific estimates show that approximately 64% of wetlands have been lost to date in the agricultural "White Area" (settled area) of the province, with current annual losses estimated at between 0.3 % and 0.5 % of remaining wetland area (AESRD, 2012). The scale of wetland loss or impacts in the public "Green Area" of the province is unknown, but has likely increased due to development *(Alberta Water Council – Recommendations for a New Alberta Wetland Policy).*

A variety of activities and land uses pose risks of further wetland loss and impacts in the watershed. These include but are not limited to:

- Wetland drainage or encroachment for agriculture or urban developments
- Agricultural or urban runoff into wetlands and associated pollution
- Oil and gas development (e.g., new well pads, hydrocarbon spills from pipelines, exploration)
- Aggregate mining (e.g., sand, gravel)
- Highways and infrastructure corridors
- Climate change including higher temperatures and increased drought risk (Sauchyn et al., 2007)

## 3.3 Red Deer Watershed Wetland Goals and Outcomes

Draft management goals and associated draft outcomes related to wetlands for the Red Deer River IWMP process are outlined below.

**Table 4. Draft Goals and Outcomes for Wetlands in the Red Deer Watershed**

| DRAFT MANAGEMENT GOALS | DRAFT OUTCOMES FOR WETLANDS |
|---|---|
| WG1. Wetlands as well as their functions and ecosystem services are protected, restored, or enhanced<br><br>WG2. Wetlands contribute to maintaining or improving surface water quality and other watershed management objectives (e.g., water conservation, flood damage minimization, biodiversity) | WO1. No further net loss of wetland area and functions |
| | WO2. Restore lost or degraded wetlands where feasible and beneficial |
| | WO3. Where ecologically significant wetland complexes exist, maintain or restore associated upland areas to retain or enhance landscape connectivity |
| | WO4. Maintain core ecological functions and services of wetlands (e.g., water storage, flood control, biodiversity support, climate regulation, etc.) through planning of compatible adjacent land uses |
| WG3. Landowners, governments, and other stakeholders are active stewards of wetland environments | WO5. The values and functions of wetlands are recognized by all stakeholders when making decisions and taking action |
| | WO6. Wetlands are conserved and managed by all stakeholders based on a watershed stewardship approach |
| WG4. Knowledge of wetlands is improved | WO7. Knowledge of wetlands in the watershed is enhanced, including distribution, functions, and services of wetlands and interrelationships with surrounding areas and society |

## 3.4 Proposed Indicators and Targets for Wetlands

This section discusses and proposes indicators and draft targets for wetlands in the Red Deer River watershed. Wetland targets are intended to provide a general gauge for conditions over the landscape. Appendix A also provides additional information on site-specific wetland indicators that should also be considered when developing the IWMP. In all cases, a clear justification for the proposed indicators and targets is provided. In addition, the indicators have been crafted to measure progress towards the draft outcomes in Table 4.

### 3.4.1 *Wetlands Indicator #1: Wetland Cover*

More wetlands in the landscape are generally associated with greater watershed health and more wetland-related ecosystem services (Gergel et al., 2002; Maltby, 2009). Environment Canada guidelines recommend a minimum of 10% wetland cover in each watershed and at least 6% in each sub-watershed (EC, 2004). Published science-based landscape-scale thresholds for wetland cover in temperate watersheds include:

- **3% to 7%:** adequate flood control and water quality services (Mitsch & Gosselink, 2000)
- **7%:** flood control (Hey & Phillippi, 1995) (Mississippi River case study)
- **3.4 to 8.8%:** nitrogen control (Mitsch et al. 1999) (Mississippi River case study)
- **15%:** phosphorus retention (Wang & Mitsch, 1998) (Great Lakes Basin case study)

Table 5 provides proposed targets for wetland cover, which is based primarily on current baseline wetland cover as well as the above literature review. Except for phosphorus retention, current wetland cover in the basin is within the range recommended for specific services.

**Table 5. Proposed Targets for Wetland Cover**

| Landscape Unit and Nested Sub-Watersheds | Existing Wetland Cover (%) | Proposed Wetland Cover Targets (%) | Municipality |
|---|---|---|---|
| **Entire Watershed** | 7.5 | >7.5 | |
| **Upper Headwaters** | 8.5 | >8.5 | |
| James | 10.9 | >10.9 | Mountainview Cty, Clearwater Cty, Red Deer Cty, MD of Bighorn |
| Panther | 5.4 | >5.4 | Improvement District No 9, Clearwater Cty, MD of Bighorn No 8 |
| **Lower Headwaters** | 8.5 | >8.5 | |
| Little Red | 3.6 | >3.6 | Mountainview Cty, Red Deer Cty, MD of Bighorn, MD of Rocky View |
| Raven | 11.3 | >11.3 | Clearwater Cty, Red Deer Cty, Mountainview Cty |
| Medicine | 13.6 | >13.6 | Clearwater Cty, Red Deer Cty, Lacombe Cty, Ponoka Cty, Wetaskiwin Cty |
| **Central Urbanizing** | 8.9 | >8.9 | |
| Waskasoo | 3.6 | >3.6 | Red Deer Cty, Lacombe Cty |
| Blindman | 10.7 | >10.7 | Red Deer Cty, Lacombe Cty, Ponoka Cty, Wetaskiwin Cty |
| **Central Agricultural** | 6.2 | >6.2 | |
| Michichi | 13.7 | >13.7 | Starland Cty, Special Area No 2, Stettler Cty, Paintearth Cty |
| Rosebud | 4.8 | >4.8 | Mountainview Cty, Wheatland Cty, Kneehill Cty, MD of Rocky View |
| Kneehills | 5.2 | >5.2 | Mountainview Cty, Kneehill Cty, Red Deer Cty, MD of Rocky View |
| Threehills | 4.4 | >4.4 | Kneehill Cty, Red Deer Cty |
| Buffalo | 10.8 | >10.8 | Lacombe Cty, Stettler Cty, Ponoka Cty |
| **Dry Grasslands** | 5.7 | >5.7 | |
| Berry | 4.4 | >4.4 | Starland Cty, Special Area No 2, Special Area No 3 |
| Matzhwin | 6.7 | >6.7 | Newell Cty, Wheatland Cty, Cypress Cty |
| Alkali | 6.4 | >6.4 | Cypress Cty, Special Area No 2, Special Area No 3, MD of Acadia |

Targets exceeding existing baseline conditions have been specified to highlight the importance of wetland restoration. The watershed-wide target is > 7.5% wetland cover. To account for variability in natural conditions and land use patterns in different areas, targets for landscape units and sub-watersheds have been proposed[10].

[10] All targets should be interpreted and applied with care, as they are based on existing baseline data inventories, and data gaps may be present. In addition, numbers are area-wide averages. Finer-scale targets could be specified using other boundaries (i.e., sub-sub-watersheds, soil parent material types, townships, or even quarter sections)

Existing wetland cover in some areas may be insufficient to achieve desired outcomes such as phosphorus retention and high downstream water quality. For example, in some areas where wetlands have been drained, and there are large contributing areas with agricultural land uses upstream from the former wetland, it may be judicious to restore wetlands on a local scale to as high as 15% of the landscape in order to prevent eutrophication downstream. However, further more detailed research would be required to identify appropriate areas for such initiatives.

### 3.4.2 *Wetlands Indicator #2: Peatland Cover*

Peat-forming bogs and fens are rare in the Red Deer River watershed and occur in the hydrologically important headwaters. Therefore, they are particularly worthy of conservation for a variety of services related to water quantity and timing (e.g., contribution to baseflow), water quality, and biodiversity values. Moreover, current science and engineering approaches are unable to restore peat-forming bogs and fens. Therefore, although wetland avoidance is important for all wetlands, it is particularly important for peatlands, since for these wetland types, “no net loss” requires 100% avoidance. Notably, peatlands occur almost exclusively in the upper watershed. Basin-wide, peatlands make up less than 1% of the landscape, but are over 6% of the Upper Headwaters and over 3% of the Lower Headwaters.

As a target, **peatland cover should be maintained in the James, Panther, Little Red, Raven, Medicine, and Blindman sub-watersheds[11]** (see Appendix B for specific quantitative values)**.**

### 3.4.3 *Wetlands Indicator #3: Municipalities with Wetlands Conservation Bylaws or Policies*

All municipalities in the watershed can play a leadership role in promoting and ensuring wetland conservation and restoration within their boundaries, through the creation of wetland conservation guidelines, policies, overlay zones, and/or bylaws based on no further net loss of wetland area. The target should be for 100% of municipalities to have formally adopted a bylaw, policy, and/or guideline related to wetland conservation.

### 3.4.4 *Wetlands Indicator #4: Awareness of Residents and/or Farmers*

Knowledge of wetland functions and services among landowners and/or watershed residents should be considered as an indicator. Potential indicators and targets could include an increase in measured awareness of wetlands issues, using pre- and post-education surveys (e.g., 30% increase in measured awareness over 10 years).

### 3.4.5 *Summary of Proposed Wetlands Indicators and Targets*

Proposed indicators and targets for wetlands in the Red Deer River watershed are summarized in Table 6.

[11] Sustainable extraction of peat for horticultural purposes can be accommodated in this framework as it is not a permanent peatland loss

**Table 6. Summary of Proposed Indicators and Targets for Wetlands**

| *Indicator* | *Type of Indicator* | *Scale of Analysis* | *Targets* | *Notes* |
|---|---|---|---|---|
| **Key Recommended Indicators** | | | | |
| Wetland Cover (%) | Environmental | Watershed | >7.5% | Greater than baseline conditions to achieve no net loss outcome |
| | | Landscape Units and Sub-watershed | e.g., >13.6% in Medicine sub-watershed | |
| Peatland Cover (%) | Environmental | Landscape Units | e.g., >6.0% in Upper Headwaters | Greater than baseline conditions |
| Municipalities with Wetland Conservation/ Restoration Bylaws or Policies | Programmatic | Watershed<br>Municipal | 100% of all municipalities in the watershed | May be combined with riparian bylaws/policies<br>Should address avoidance, Environmental Reserve, compensation, setbacks, inter-municipal collaboration, etc. |
| Awareness of all stakeholders (residents, farmers, developers, etc.) | Social | Watershed | e.g., 30% increase over 10 years | Will require standardized and statistically random surveys |
| **Additional Indicators for Consideration** | | | | |
| Wetland Density | Environmental | Watershed | Baseline (4.3 wetlands/$km^2$) | Maintain baseline conditions is suggested<br>Requires further research |
| | | Landscape Units | e.g., 3.0 wetlands / $km^2$ in the Lower Headwaters | |
| Wetland Sizes and Shapes | Environmental | Site-specific | Maintain current distribution of wetland sizes and shapes | When restoring wetlands >2.0 ha, include small islands and complex shorelines |
| Wetland Location | Environmental | Site-specific | Wetlands should be as close as possible to other wetlands for connectivity | Wetlands in the headwaters, floodplains, etc. are the most important |
| Wetland Riparian Buffer Widths | Environmental | Site-specific | Provincial guidelines<br>100 m is ideal for biodiversity conservation | A 500 m setback from wetlands containing trumpeter swan breeding habitat may be necessary |
| Wetlands and Adjacent Upland Habitats | Environmental | Site-specific | 5 parts natural upland: 1 part wetland (where biodiversity values are very important) | Important in ESAs (e.g., Mikwan-Goosequill-Hummock Lakes) |
| Wetland Functions and Ecosystem Services | Environmental | Site-specific | Compensation wetlands have similar functions / services as disturbed wetlands | Useful for the compensation process to help ensure no net loss of wetland functions |
| Wetlands Avoidance Within the Regulatory Process | Programmatic | Watershed | Increase over current status quo | Applications for disturbance to environmentally significant wetlands (mapped ESAs) are rejected |
| Wetlands Avoidance Outside the Regulatory Process | Programmatic | Watershed | Avoidance is demonstrated and documented by industry | Requires industry-led processes to document avoidance |

## 3.5 Management Implications and Recommendations

The following recommendations relate specifically to the management, conservation, and restoration of wetlands for consideration in the IWMP. Recommendations are listed under three categories: monitoring + data acquisition, research needs, and recommendations related to key Beneficial Management Practices (BMPs).

### 3.5.1 *Monitoring and Data Acquisition*

The following are the priorities for improved monitoring and data acquisition:

- ***Improve the Current Wetlands Inventory.*** A single, high resolution wetlands database representing a standardized and replicable inventory method to delineate wetlands is required, to enable accurate identification of wetland boundaries and the capability to conduct trend analyses over time. The current database appears to contain some data gaps, and the inventory was created by merging a number of inventories with different methods, from different years, and at different resolutions.
- ***Conduct a Drained Wetlands Inventory.*** A comprehensive drained wetlands inventory will help to determine sub-watersheds and specific locations where extensive drainage has occurred to help target current and future restoration efforts. As this is likely to be a large task for the entire watershed, this could be staged to address specific high-priority areas first (e.g., NAWMP priority landscapes, areas at high risk of being impacted, etc.).
- ***Identify Ecologically and Hydrologically Significant Wetlands.*** Regionally significant high priority wetlands should be identified and prioritized for conservation. The provincial-scale identified Environmentally Significant Areas (ESAs) (Fiera, 2009), the Aquatic Environmentally Significant Areas map (AESRD, 2011), and the NAWMP target landscapes could be used as inputs, but should be refined in the context of the Red Deer watershed. "Indispensable" wetlands that should be avoided or conserved in all circumstances should be identified.
- ***LiDAR and Drainage Basin Definition.*** Collection of LiDAR and delineation of wetland contributing areas using appropriate software (e.g., Whitebox) is also recommended. As this may be a very large project if performed across the entire watershed, targeting of key areas with known water quality issues may be a more feasible, smaller project.
- **Integrate Wetlands Indicators within an Integrated Monitoring and Reporting System** (see Section 5.6.1 for more details)

### 3.5.2 *Research Needs*

The following are the recommended research needs to improve knowledge, understanding, and management of wetlands in the watershed:

- ***Long-Term Wetland Monitoring Program.*** Long-term research of wetlands in the watershed should be initiated to collect the necessary baseline scientific understanding for more detailed models and other research recommendations below.
- ***Investigate Wetlands Targets In a Nested Hierarchy of Scales.*** Watersheds exist in a nested hierarchy of scales. Therefore, when assessing and reporting on wetland targets, it would be desirable to examine finer sub-watershed scales than those shown in this report.
- ***Hydrologic Study on Wetlands.*** Hydrologic studies to improve understanding of the value of wetlands to overall water balance in the Red Deer Watershed are required (e.g., quantify wetland roles in flood mitigation, seasonal distribution of flows, drought mitigation, etc.). The influence of wetlands on the mainstem Red Deer River would need to be separated from that of other water bodies as well as endorheic "non-contributing areas" with no surface outlet to the Red Deer River watershed drainage network. Groundwater / surface water interactions should also be analyzed. The ratio of wetland basin contributing areas to wetland sizes should also be a component of this research.

- ***Integrate ecological research with economic models.*** Many quantitative science-based models of wetland functions are not adaptable to reliable economic valuation. This requires improved integration of ecological research with economic models on wetland valuation to better direct future research needs supporting decision-making in Canada (Gustavson & Kennedy, 2010). By necessity, addressing this issue will require coordinated research by academia and the provincial government.
- ***Regionally-calibrated wetland function models***. Local reference standards for wetland functions in the watershed would be required to place individual wetland functions in context (Adamus, 2011; Gustavson & Kennedy, 2010). This would help to bridge the divide between site-specific wetland science studies (e.g., IBHI) and broad-scale, cost-effective screening tools (Gustavson & Kennedy, 2010).
- ***Review and Harmonize Municipal Policies and Plans.*** Municipal land use bylaws, municipal development plans, and inter-municipal development plans should be compiled, reviewed, and compared to best practices. Tools should also be developed that are easy to apply in the context of the watershed rather than just individual parcels of land.
- ***Ensure Coordination and Integration of Wetlands with Other Watershed Considerations.*** Ensure wetland management is integrated with other key management objectives, such as water quality, biodiversity, open space and quality of life in the IWMP. This requires that the effects of wetlands on water quality and water flows are integrated into a state-of-the-art scientific water quality model to evaluate the achievement of environmental outcomes under various management and engineering options. A water quality model for the Red Deer River is currently being coordinated by AESRD (Chris Teichreb, personal communication).

### 3.5.3 *Suggested Key BMPs for Wetlands*[12]

**Protection and Conservation Tools**

*The bed and shore of permanent wetlands are Crown lands, even if surrounded by private lands*

- All industries including the agricultural sector and governments should aim to avoid impacting wetlands
- Effective compliance and enforcement of existing / future regulations and policies is critical
- Establish new municipal or provincial parks and protected areas for wetland areas
- Develop municipal bylaws and plans for wetlands and effective implementation strategies
- Develop wetland restoration programs for private landowners including financial incentives and grants, technical support, and advice (e.g., see the Government of Manitoba's Wetland Restoration Incentive Program as a template) (GOM, 2010)
- Develop and apply additional tools such as conservation easements, tax benefits, market-based instruments under the *Land Stewardship Act,* etc. to promote wetland conservation

**Compensation Considerations**

- Where impacts on wetlands are unavoidable, ensure compensation occurs
- Locate compensation wetlands as close to the original wetland as possible, and within the same sub-watershed or landscape unit
- Create new wetlands that provide comparable functions to the original wetland[13]

[12] More detailed reviews and international case studies of wetlands BMPs can be found in pages 4-97 to 4-114 of: (RDRWA, 2009)
[13] Consider size, shape, riparian buffer, etc. as outlined in Appendix A

- Create a wetland mitigation bank and market to enhance the availability of wetland offset credits

**Specific BMPs**

- Maintain and restore wetland riparian buffers as large as possible and ensure they contain healthy, natural vegetation
- Manage livestock access to wetlands with a variety of tools including temporary or permanent fencing and alternative livestock watering systems (e.g., solar, cattle nose pump, etc.)
- Ensure that land use practices adjacent to wetlands minimize runoff of nutrients, pesticides, sediment, pathogens, and other contaminants (see Land Use Chapter 5.0 for more detail)
- Address recreational impacts on wetlands with indirect measures (signage, education) and direct measures (e.g., access control, boardwalk siting, design, facilities, surveillance)

**Education**

- Develop education strategies targeting loss / drainage of wetlands in agricultural and urban contexts
- Educate all audiences on economic and social benefits of wetlands, including how wetlands can enhance development, as opposed to being at their expense
- Identify, involve, document, and mobilize support for wetland conservation among multiple sectors of society — waterfowl hunters, conservationists, landowners on flood plains, recreationists, etc.)

# 4. RIPARIAN AREAS

This chapter focuses on riparian areas. Included is a definition of riparian areas, as well as descriptions of the functions and services they provide (Section 4.1). Existing baseline riparian area mapping for the watershed is provided in Section 4.2. Section 0 provides draft outcome statements, followed by proposed indicators and targets for the Red Deer River Watershed in Section 4.4. Section 4.5 discusses management implications and recommendations, including future research and monitoring needs and key BMPs to help focus the IWMP.

## 4.1 Riparian Area Definitions, Functions, and Services

The Alberta Riparian Habitat Management Society (Cows and Fish) defines riparian areas as: *"the portions of the landscape strongly influenced by water, and are recognized by hydrophytic (water-loving) vegetation along rivers, streams, lakes, springs, ponds and seeps."*

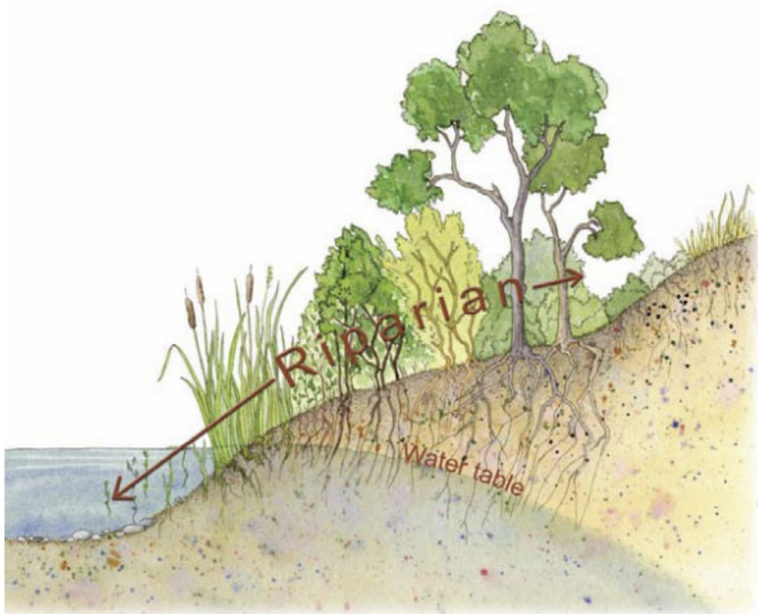


**Figure 14. Diagrammatic Representation of a Riparian Area** *(Fitch & Ambrose, 2003)*

The Alberta Water Council Riparian Land Conservation and Management Project Team, Draft "Riparian Lands" Definition is slightly expanded as follows:

*"Riparian areas are transitional areas between upland[1] and aquatic ecosystems. They have variable width and extent both above and below ground. These lands are influenced by and/or exert an influence on associated water bodies[2], which includes alluvial aquifers[3] and floodplains[4], when present. Riparian lands usually have soil, biological, and other physical characteristics that reflect the influence of water and/or hydrological processes."*

*[1]For the purpose of this definition, "upland" is considered to be the land that is at a higher elevation than the alluvial plain or stream terrace or similar areas next to still water bodies, which are considered to be "lowlands"*

*[2]A water body is any location where water flows or is present, whether or not the flow or the presence of water is continuous, intermittent or occurs only during a flood, and includes but is not limited to wetlands and aquifers (generally excludes irrigation works) (Source: Water Act).*

*[3]For the purpose of this definition, alluvial aquifers are defined as groundwater under the direct influence of surface water (GUDI).*

*[4]For the purpose of this definition, floodplain is synonymous with flood risk area. The flood risk area is the area that would be affected by a 100-year flood. This event has a one percent chance of being equaled or exceeded in any year.*

### 4.1.1 *Functions and Services of Riparian Areas*

The importance of riparian areas far exceeds their relatively small area. Some of the most important functions provided by healthy, well vegetated riparian areas include bank stability, water quality improvement, flood mitigation, provision of wildlife habitat and movement corridors, fish habitat support, forage production, recreational opportunities, aquifer recharge, and aesthetic amenities.

There are three main types of streams: perennial streams, which generally flow throughout most of the year; intermittent streams, which have a distinct channel that usually flow after rain or snowmelt and are dry for most of the year; and ephemeral streams, which are typically unmapped, have little to no channel development, and flow only during or immediately after rainfall or snowmelt. Riparian areas associated with all of these are important, although the intermittent and ephemeral streams are not always recognized as important and are often not mapped accurately.

**Bank Stability and Erosion Control**

Healthy riparian vegetation provides bank stability, slows floodwaters, traps sediment, and prevents sediment mobilization into waterways (Griffin & Smith, 2004; Dunne & Leopold, 1978; Waters, 1995). Dense woody riparian vegetation reduces flow velocities and boundary shear stresses on floodplain surfaces during overbank flows. Where woody vegetation is sparse and the bank slope sufficiently steep, the floodplain surface is vulnerable to high rates of erosion during floods. One study has shown that dense shrubs reduce the boundary shear stresses on floodplain surfaces by up to three orders of magnitude (Griffin & Smith, 2004). By reducing the velocity of sediment-bearing storm flows, sediments can also settle out of the water, and deposit on riparian lands instead of being carried downstream (BRBC, 2012).

Not all riparian sites in the watershed support trees and shrubs. Deep-rooted grasses of prairie riparian areas can also reduce bank erosion, particularly for lower order streams with low banks and a gentle grade (Lyons et al., 2000). Around lakes and ponds, riparian areas also dissipate energy from wave action (AENV, 2008).

Therefore, bank stability provided by riparian areas is integral for water quality improvement by controlling total suspended solid (TSS) concentrations and related contaminants adhering to particles suspended in the water column, in addition to maintaining stream channel shape and profile.

**Non-Point Source Pollution Filtration**

Riparian areas improve water quality by filtering a wide range of non-point source contaminants originating via overland and subsurface flow, including nitrogen, phosphorus, many pesticides, heavy metals, and hydrocarbons (Mayer, 2006; Braumann et al., 2007; Worrall et al., 2003). The effectiveness of riparian buffers at filtering water depends on the contaminant, as well as the width and condition of the riparian area, vegetation type, soils, proximity to groundwater, slope, and season (Lyons et al., 2000). The thickness and characteristics of the upper soil "duff" layer of decaying leaves and twigs is particularly important to slow terrestrial runoff and allow infiltration of water and subsequent pollutant removal processes (France, 1997). Wooded riparian areas tend to be better than grassy areas in assimilating nitrogen, whereas grassy riparian areas are often better at assimilating phosphorus, although heavy inputs of phosphorus can overwhelm and saturate the riparian zone over time (Lyons et al., 2000).

**Water Quality Improvement: Temperature**

Shade and cover provided by riparian vegetation moderates water temperature considerably, particularly in small (low order) streams. This can help to support cold and cool water fish species populations. Even modest changes in temperature can affect fish by altering insect production, egg incubation, fish rearing, migration, and susceptibility to disease (MacDonald et al., 2003).

**Flood Mitigation**

Riparian lands can reduce peak flows and flood damage. As floodwaters move through a vegetated area, plants resist flow and dissipate energy (Griffin & Smith, 2004). Retaining healthy natural riparian areas as open spaces also helps prevent developments from locating in harm's way, reducing property damage during floods.

### Groundwater Recharge

Riparian areas can recharge shallow groundwater alluvial aquifers that help maintain stream flow and water quality during low flow periods. Where water infiltrates and recharges alluvial aquifers, this contributes to higher base flows and improved distribution of seasonal and annual flows in streams and rivers (Gilbert et al., 2006; Spinello & Simmons, 1992).

### Forage Production

Riparian areas can be a very important agricultural forage resource when managed appropriately and sustainably (e.g., timing restrictions, appropriate stocking densities). One study in central Alberta found that riparian production is as much as 77% greater than native rangelands (deMaere, 2002). Forage production in riparian areas also tends to be higher in healthy sites than in unhealthy sites (Desserud et al., 2006).

### Biodiversity

Well-vegetated riparian areas provide benefits to biodiversity in amounts disproportionate to their surface area. Approximately 80% of Alberta's species use riparian areas as all or part of their life cycle requirements (AENV, 2008). Greater moisture availability, proximity of microhabitats, adjacency of water and terrestrial vegetation, presence of specialized species, and the provision of movement and dispersal corridors are the key factors explaining this high biodiversity (Hilty et al., 2006; Forman, 1995; Bennett, 1999; O2, 2007).

In the eastern part of the watershed (Dry Grasslands landscape unit), tree and shrub species such as poplar, spruce, birch, willow and river alder are unique to the riparian valleys. In this area, cottonwoods that require flooding and silt deposition for seed germination often thrive in riparian areas and provide a striking contrast to the dry badlands on the slopes of the river valley system (CPPIF, 2004; O2, 2007; Samuelson & Rood, 2004).

Riparian habitat in the watershed is important for many mammal, bird, fish, insect, and plant species. Mammal species using riparian areas in the watershed include moose, mule deer and white-tailed deer, as well as elk and grizzly bear in the headwaters. Riparian-associated listed and at-risk bird species found in the watershed include piping plover, ferruginous hawk, peregrine falcon, loggerhead shrike, and yellow rail (Aquality, 2009). Riparian areas support fish habitat by providing cover, shade, and microhabitats. In wooded riparian areas, coarse woody debris and root wads are important. Undercut banks, favoured by many species of fish including brown trout, are more likely in grassy riparian areas (Lyons et al., 2000). Healthy riparian areas are important for all fish, and are particularly important in the Upper Headwaters where they support cold-water fish species such as bull trout, which are concentrated in tributaries such as Pinto Creek (Fitzsimmons, 2012).

### Recreation and Aesthetics

Riparian areas are important sites for recreation and tourism activities, including bird watching, nature photography, hunting, fishing, walking, and other activities. In addition, the linear corridor-like nature of riparian areas makes them well suited to link landscapes and communities together with adjacent trail systems. These trail systems can promote active lifestyles as well as alternative modes of transportation that have a range of economic, social, and environmental benefits (Driver et al., 1991). Riparian "ribbons of green" in the landscape provide important visual diversity and an aesthetically pleasing landscape (O2, 2011b). The provision of aesthetically pleasing green space in riparian areas increases adjacent property values (ARPA, 2007). However, recreation can also impact riparian areas due to trail erosion, and the introduction of impervious surfaces and manicured lawns.

### 4.1.2 *Riparian Buffers and Riparian Setbacks*

Riparian areas are highly variable in width depending on the local, site-specific context (see definitions above). Riparian *setbacks* are areas based on policy criteria (e.g., 50 m fixed-width buffers). Riparian setbacks may not protect the full extent of the riparian zone, which varies in width.

In Alberta, several guidelines for riparian setbacks have been created at different times by different agencies. *"Stepping Back from the Water*" (released by the province in April 2012) is a guidebook with an emphasis on conserving riparian areas in Alberta's settled region (AEW, 2012). It emphasizes water quality benefits of riparian areas, and recommends discretionary setbacks as specified below in Table 7.

**Table 7. Provincial (AEW 2012) Recommended Effective Widths for Vegetated Filter Strips[14]**

| Type of Water Body | Substrate | Width | Modifiers | Notes |
|---|---|---|---|---|
| **Permanent Water Bodies** Lakes, Rivers, Streams, Seeps, Springs<br>Class III - VII Wetlands | Glacial till | 20m[9] | If the average slope of the strip is more than 5%, increase the width of the strip by 1.5 m for every 1% of slope over 5% | Slopes > 25% are not credited toward the filter strip |
| | Coarse textured sands & gravels, alluvial sediments | 50m[10] | None | Conserve native riparian vegetation and natural flood regimes |
| Ephemeral and Intermittent Streams, Gullies | Not specified | 6m strip of native vegetation or perennial grasses adjacent to the stream channel crest[11] | If the average slope of the strip is more than 5%, increase the width of the strip by 1.5 m for every 1% of slope over 5% | Maintain continuous native vegetation cover along channels and slopes |
| Class I & II Wetlands | Not specified | 10m strip of willow and perennial grasses adjacent to water body[12] | None | Maintain and conserve native wetland or marshland plants on legal bed and shore |

Separate provincial guidelines exist for riparian setbacks established as Environmental Reserve (ER) during the process of municipal subdivision, in the ASRD document *"Recommended Guidelines for Minimum Environmental Reserve / Easement Widths*" (ASRD, 2007). This includes standard recommended widths for reservoirs, lakes, large rivers, and small rivers, and additional factors based on hazards such as floodplain, erosion prone areas, escarpments, and steep slopes.

For the agricultural industry, the federal *Field Manual for Buffer Design for the Canadian Prairies* (Stewart et al., 2010) was developed to assist in locating and designing vegetated buffers in prairie landscapes, to maximize environmental returns from vegetated buffers while minimizing loss of cropland. The focus of the manual on grassing of ephemeral drainage systems to minimize pollution during spring snowmelt is commendable. The manual specifies minimum buffer widths for addressing sediment and dissolved phosphorus as follows:

- 5 m for sediment trapping and spray drift interception
- 10 m for 50% reduction in dissolved phosphorus
- 20 m for 80% reduction in dissolved phosphorus

The forestry industry is subject to separate guidelines on riparian buffer strips, as outlined in the Alberta Timber Harvest Planning and Operating Ground Rules (ASRD 2008). These generally include 100m setback requirements for lakes and large permanent (>5 m wide) streams, 10-30 m setbacks for small permanent and intermittent streams, and 15m for ephemeral streams (ASRD, 2008).

It should also be noted that riparian buffers for wildlife corridor functioning tend to be wider than for water quality benefits (Bentrup, 2008).

[14] The AEW (2012) recommended widths cites supporting literature including Vidon and Hill (2006), Gharabaghi et al. (2006), Liu et al. (2008)

## 4.2 Baseline Riparian Data and Mapping

This section presents maps and statistics of baseline riparian area extent and condition in the watershed. Included is an assessment of the integrity of variable width riparian areas, riparian health derived from aerial videography, and riparian health derived from field site visits.

### 4.2.1 *Land Use in Variable Width Riparian Areas*

Riparian areas are naturally variable in width. At some sites, the functional riparian zone is narrow (e.g., 3 m) and the transition to upland habitat is rapid and abrupt. Conversely, riparian zones are often very wide along low-gradient meandering streams with oxbows or unconfined alluvial stream segments.

In many cases, mapping a fixed-width buffer around streams is the only choice permitted by time and resource constraints (Bentrup & Kellerman, 2004). However, fixed-width buffer approaches result in inaccurate maps of riparian lands (Aunan, 2005).Cost distance approaches using digital elevation models and local calibration is the recommended approach to delineate riparian areas (Dilts et al., 2010; Hemstrom, 2002).

Fortunately, a recent variable width riparian model was completed in Alberta using a cost distance approach. Furthermore, this model has been calibrated to local factors in the Red Deer River watershed, including natural subregion, stream type, and other factors (Caslys, 2010). As the accuracy of this layer has been estimated at about 90% (Caslys, 2010), it was considered to be highly suitable for use in this project. Please note that the results of the Caslys study were released by the province in geospatial format with the name “Lotic Riparian Polygons-Digital Elevation Model (DEM).” Sample variable width riparian outputs for areas within the watershed (1:10,000 scale) are shown on Figure 15.

To roughly estimate the intactness and integrity of riparian areas, O2 obtained the 2011 satellite-derived crop inventory produced by Agriculture Canada. Using a raster-to-vector conversion and several other GIS tools, the approximate extent of the following 4 class types within the variable width riparian areas was calculated[15]:

- Urban areas
- Croplands
- Hay and pasture[16]
- Natural land cover (including forests, shrublands, wetlands, grassland/rangeland, barren rock, and water classes)

A sample map output of riparian land classification at a scale of 1:10,000 is provided in Figure 16. Full statistical results are shown in Appendix B. A map of the amount of natural riparian areas in each sub-watershed is shown in Figure 17.

*Note that this analysis is based on available remote sensing data inputs that may have spatial accuracy errors and potential classification errors. Actual on-the-ground conditions may vary and site-specific applications will likely require field verification.*

[15] Appendix B provides more details on methods

[16] Hay/pasture was kept separate due to the perennial nature of vegetation in these areas and lower chemical inputs

# Riparian Corridor Land Use Analysis

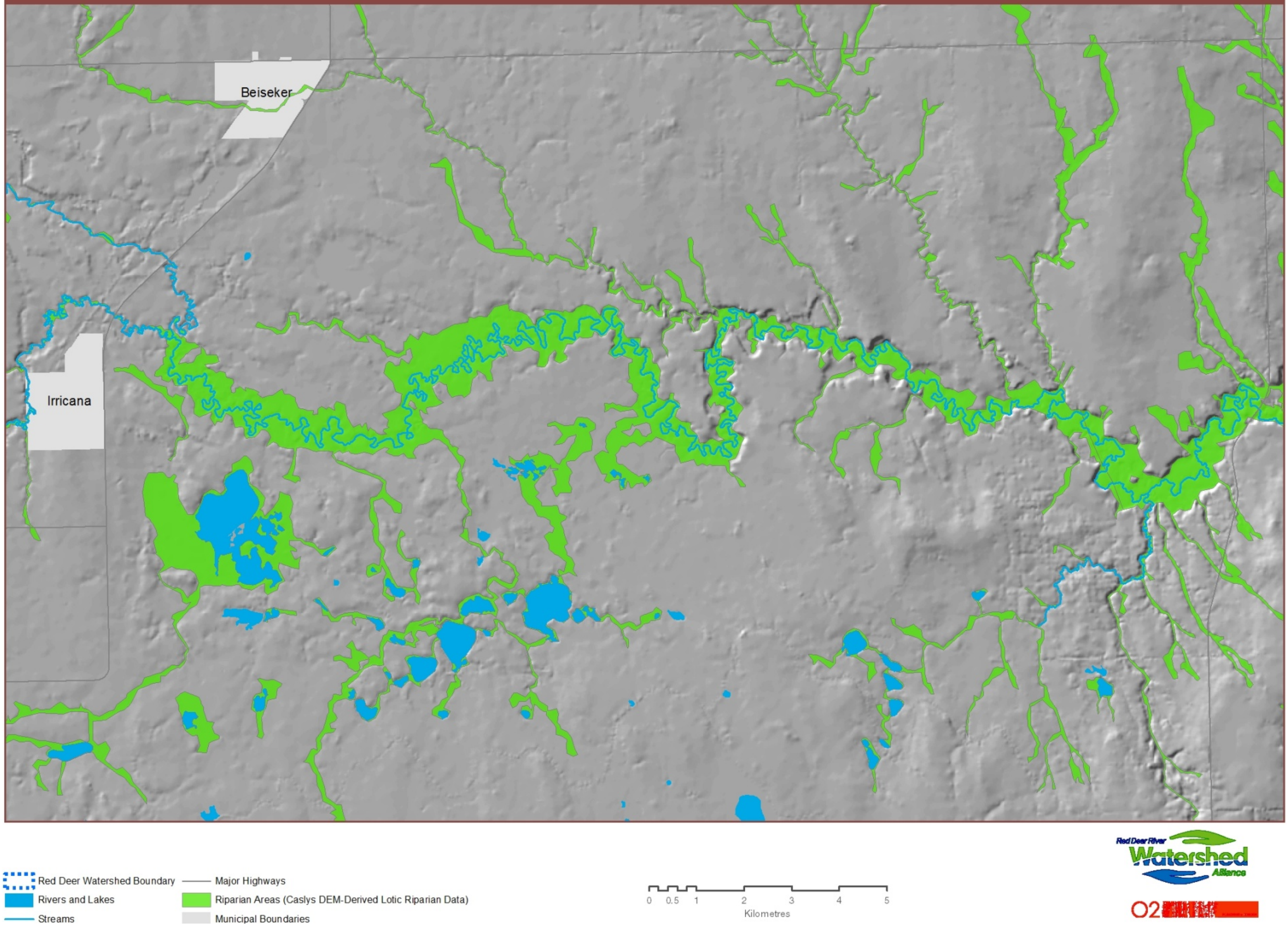


**Figure 15. Map of Provincial Variable Width Riparian Area Layer, Rosebud River near Beiseker**

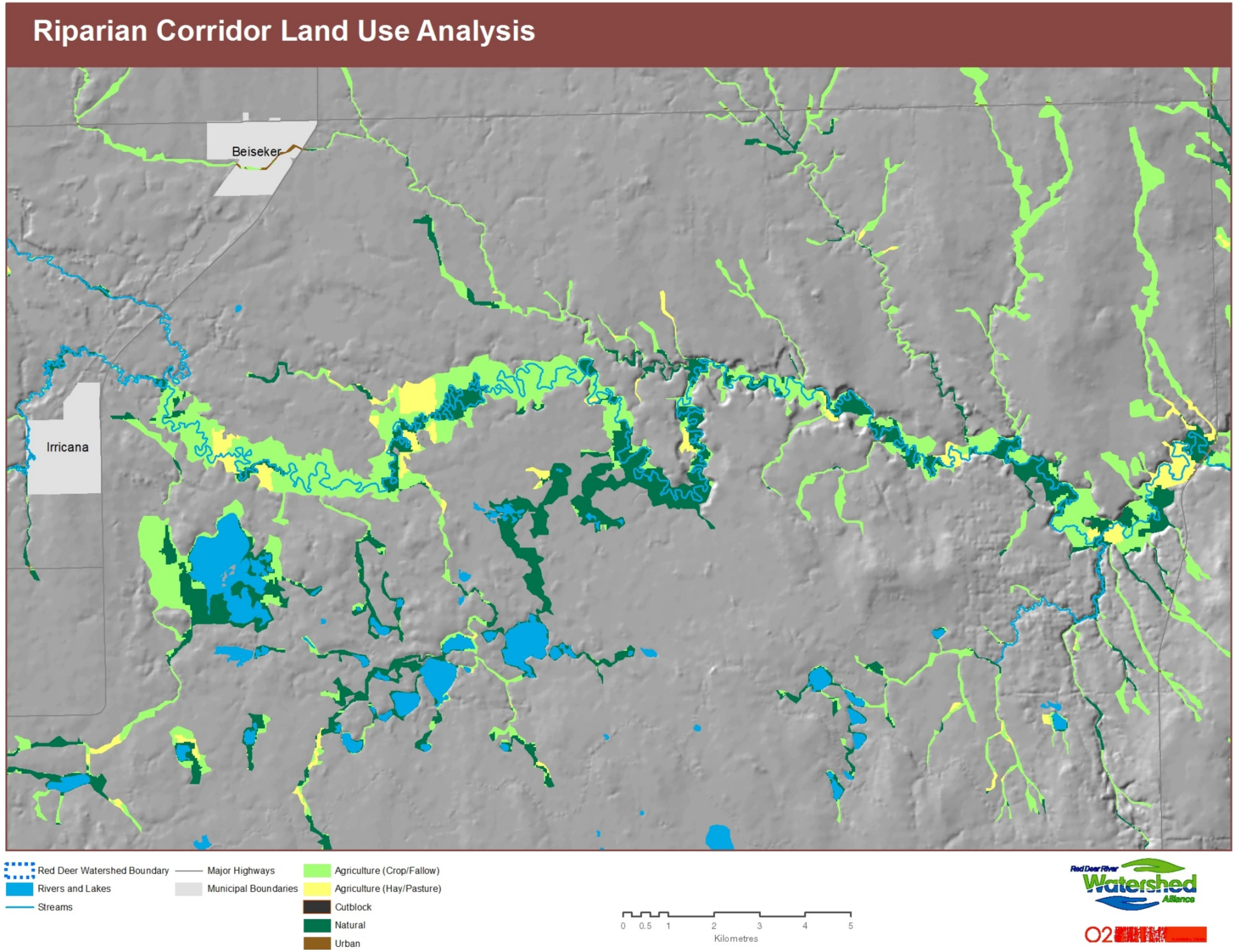


**Figure 16.** **Map of Riparian Land Use Classification, Rosebud River near Beiseker**

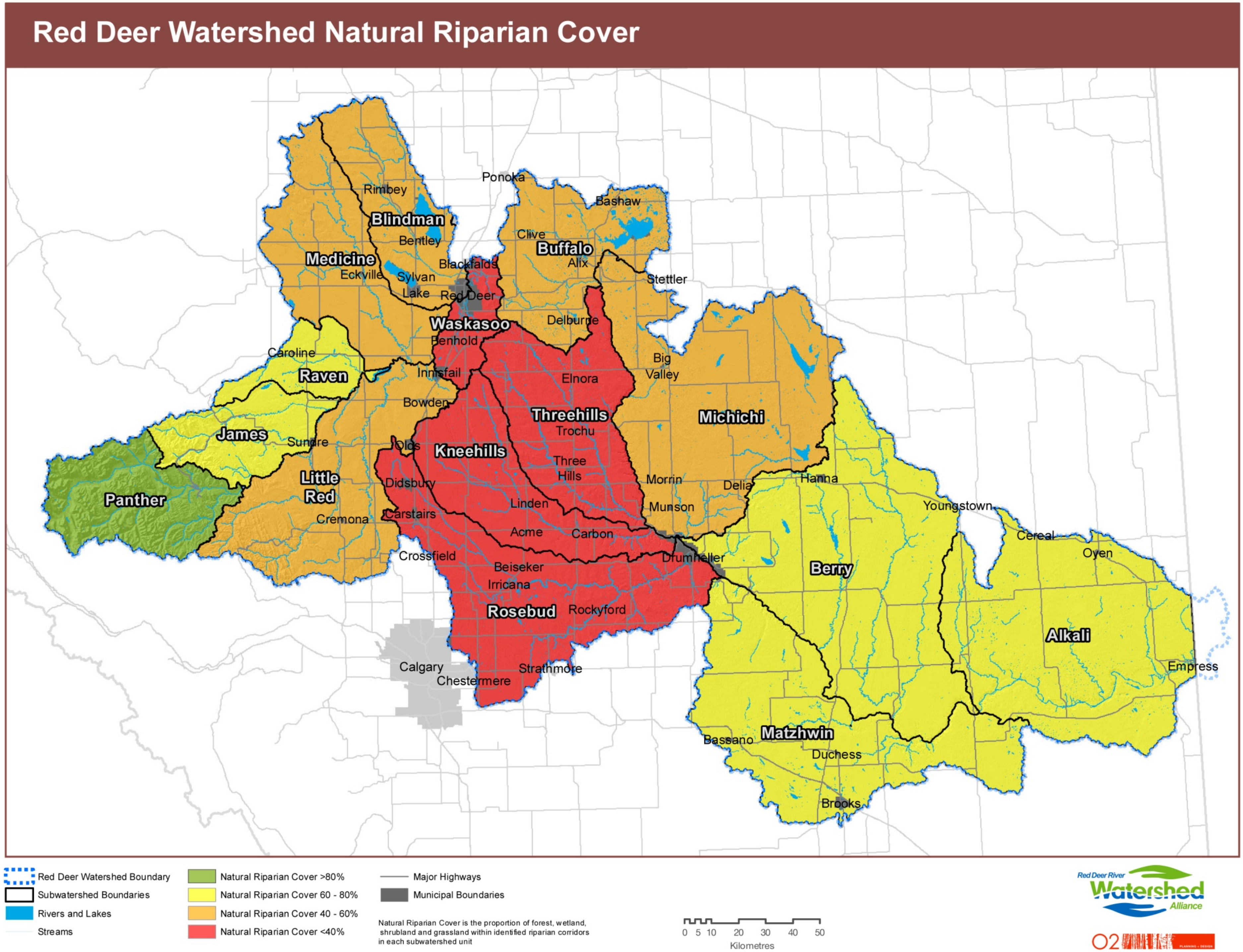


**Figure 17.** **Map of % Natural Riparian Areas by Sub-Watershed**

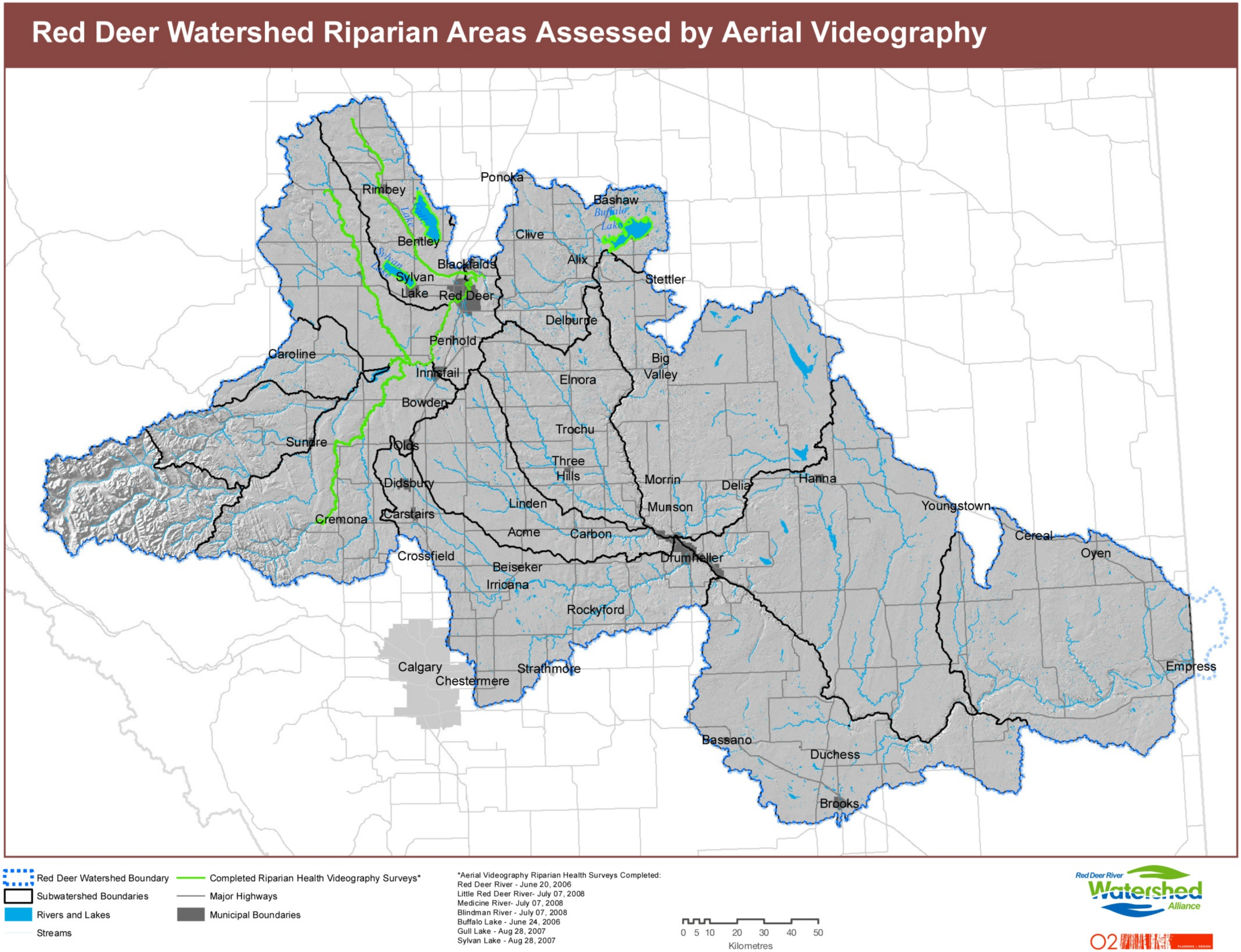


**Figure 18.** **Map of Locations Where Aerial Videography Riparian Health Surveys Have Been Completed**

### 4.2.2 *Riparian Health*

Healthy riparian areas are well-vegetated, with abundant plant growth, deep-rooted species, few invasive weeds or disturbance-caused species, little bare ground or altered banks, and natural hydrologic regimes (Fitch et al 2001).

In the Red Deer River watershed, riparian health has been assessed using two different methods: aerial videography, and field-based site assessments. These are both reviewed below.

#### *4.2.2.1 Riparian Health and Integrity from Aerial Videography*

Riparian health assessment with aerial videography involves flying over a water body and recording the shoreline with a video camera. The video is georeferenced with a GPS. A specialist reviews the video footage and assigns sections of the shoreline to one of three categories: "Good," "Fair," or "Poor." Parameters used to assign scores include vegetation cover, community structure/composition, site stability, land use, flood control structures, etc.[17]

In the watershed, several riparian health assessments using aerial videography have been completed by AESRD for both rivers and lakes. Figure 18 maps locations in the watershed where aerial riparian videography assessments were recently conducted from 2006 to 2008. Table 8 summarizes the results.

**Table 8. Riparian Health and Integrity Videography Assessments in the Watershed**

| River / Lake | Total Length Assessed | Riparian Health Scores | | |
|---|---|---|---|---|
| | | Good / Healthy | Fair / Moderately Impaired | Poor / Highly Impaired |
| **Rivers** | | | | |
| Red Deer River | 164 km (Gleniffer Lake to E. of Red Deer) | 28% | 32% | 40% |
| Medicine River | 213 km | 14% | 23% | 63% |
| Blindman River | 195 km | 11% | 21% | 67% |
| Little Red Deer River | 226 km | 46% | 27% | 26% |
| **Lakes** | | | | |
| Sylvan Lake | 37 km | 51% | 7% | 42% |
| Gull Lake | 53 km | 36% | 35% | 29% |
| Buffalo Lake | 130 km | 34% | 29% | 37% |

*Includes right and left banks for streams

Among the rivers sampled using videography, the Little Red Deer River has the healthiest riparian areas of all rivers, whereas the Blindman River is the least healthy. Yet many highly impaired riparian zones were observed in all systems, ranging from 26% for the Little Red Deer to 67% for the Blindman River.

Those areas where riparian health has been assessed represent a small fraction of the entire watershed. Lower order riparian areas are the most numerous in the watershed and are often the most heavily impacted. These areas have much greater potential to mobilize contaminants into the watershed if not managed carefully (Forman, 1995; Dunne & Leopold, 1978).

[17] As videography is a broad-scale assessment, limitations exist in accurately identifying some parameters such as individual plant species, components of the riparian area distant from the bank, etc.

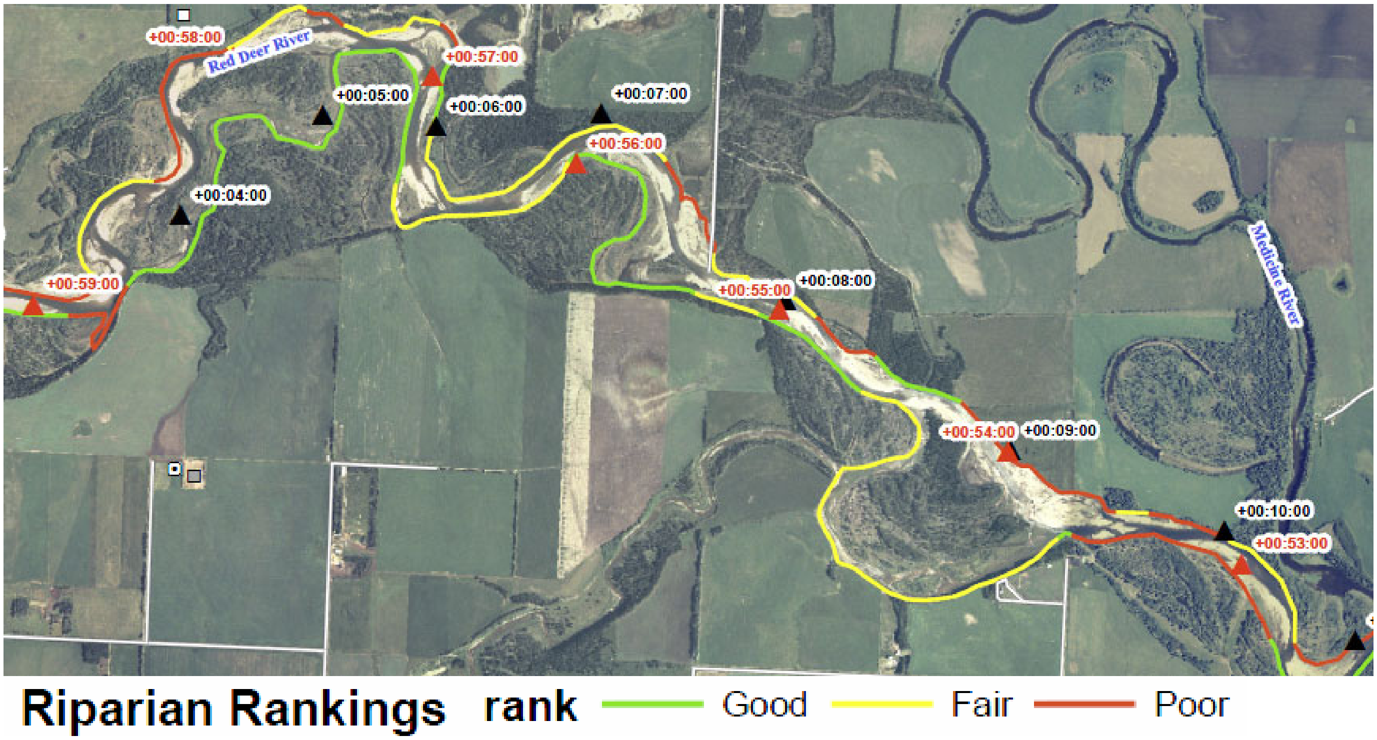


**Figure 19. Aerial Videography Riparian Health Results Along the Red Deer River**
*Source: ASRD + ACA (2006)*

#### *4.2.2.2 Riparian Health Inventory Field Surveys*

The Riparian Health Index Inventory (RHI) used by Cows and Fish in Alberta combines several field-based parameters characterizing riparian site conditions and ecological function based on vegetation health (e.g. cover, invasive species, degree of browsing, etc.), soil health (e.g. compaction, bare ground, etc.), and hydrology/geomorphology (e.g. incisement, etc.) into one composite index.

Approximately 80 parameters are measured to provide a comprehensive and detailed evaluation of riparian health. Field survey assessments for riparian health are completed on foot by trained professionals from the Alberta Riparian Habitat Management Association Society (Cows and Fish). These assessments are time-consuming and require specialized training. Riparian assessments inventories have been completed primarily based on requests from landowners, communities and municipalities throughout within the watershed. Overall riparian health scores are broken down into three categories as follows:

- **Healthy (80-100% score range):** Little to no impairment of any riparian functions
- **Healthy with problems (60-79% score range):** Some impairment to riparian functions due to management or natural causes
- **Unhealthy (<60% score):** Severe impairment to riparian functions

A coarse summary of riparian health was completed by Cows and Fish for a presentation in October 2010 for the RDRWA. Those results were as follows: between 1999 and 2010, 213 riparian health inventories in the Red Deer River watershed were completed across 314 km of streambank and shoreline on 38 different waterbodies in 16 different municipalities. Ten lentic (standing water) sites and 203 lotic sites (95% of all RHI sites) were included. Summary results for all sites were:

- **Healthy:** 24.8%
- **Healthy, but with Problems:** 48.5%
- **Unhealthy:** 26.7%

Although the Cows and Fish program is an excellent initiative with a strong educational focus, the voluntary nature of sampled sites means that these summary statistics do not necessarily reflect the overall trend for the watershed. For example, poor stewards of the land are unlikely to ask for an assessment to be completed, resulting in a non-random sample.

Due to landowner confidentiality, specific geographic information on RHI polygons cannot be shared. However, sample sites in the Red Deer watershed are most heavily concentrated along the Medicine River and Red Deer River and the Central Agricultural area east of the Red Deer River (Cows and Fish, 2008).

Although there are limited sample sizes, riparian health conditions deteriorate from upstream to downstream along the Red Deer River mainstem, as shown by the following (Cows and Fish, 2005):

- *Upper Headwaters Upstream of Gleniffer Lake:* 6/6 RHI sites (100%) rated “healthy” (>80% score)
- *Gleniffer Lake to Nevis:* 3 sites (75%) rated “healthy” (>80% score), 1 site rated “healthy with problems” (60-79% score)
- *Nevis to Bindloss:* 1 site rated “healthy” (>80% score), 6 sites (86%) rated “healthy with problems” (60-79% score)
- *Bindloss to Saskatchewan border:* 2 sites rated “healthy with problems” (60-79% score)

A report on RHI site assessments for 15 inventories along the Rosebud River within Wheatland County has also been recently compiled (Cows and Fish, 2012). Highlights include:

- The average health score of 74% compares favourably to the provincial average of 69%[18]
- Of 15 sample sites, 7 (47%) are in proper functioning condition (*healthy),* 7 sites (47%) are functional at risk *(healthy, but with problems)* and one site (7%) rated non-functional (*unhealthy*)

***COTTONWOODS IN THE LOWER WATERSHED***

In the eastern lower reaches of the watershed, cottonwoods that require flooding and silt deposition for seed germination provide important biodiversity and visual diversity values. Several Cows and Fish riparian surveys in this area indicate that cottonwood regeneration varies from fair to poor, due to a combination of browse pressure and hydrologic limitations, including the operation of the Dixon Dam upstream (AENV 2007b).

[18] However, fish biologists recently working in the Rosebud River recently reported that many riparian areas are heavily impacted

## 4.3 Red Deer Watershed Riparian Area Goals and Outcomes

Draft management goals and associated draft outcomes related to riparian areas for the Red Deer River IWMP process are outlined below.

**Table 9. Draft Goals and Outcomes for Riparian Areas in the Red Deer River Watershed**

| DRAFT MANAGEMENT GOALS | DRAFT OUTCOMES FOR RIPARIAN AREAS |
|---|---|
| RG1. Riparian areas and their related functions and ecosystem services are protected or restored<br><br>RG2. Riparian areas contribute to maintaining or improving surface water quality and other watershed management objectives | RO1. Riparian ecosystems and associated adjacent upland areas are kept intact and ecologically functional |
| | RO2. Sustain or improve riparian areas |
| | RO3. Core ecological functions of healthy riparian lands are maintained (e.g., bank stability, water quality protection, water storage and flood mitigation, biodiversity, fish habitat support, etc.) |
| | RO4. Invasive plant species are reduced, particularly in riparian lands adjacent to watercourses and water bodies |
| RG3. Landowners, governments, and other stakeholders are active stewards of riparian areas | RO5. The values and functions of wetlands are recognized and considered by stakeholders when making decisions and taking actions that may affect riparian areas |
| | RO6. Riparian areas are conserved and managed by multiple stakeholders |
| RG4. Knowledge of riparian areas is improved over time | RO7. Enhanced knowledge and understanding of:<br>- Distribution of variable width riparian areas<br>- Functions and services of riparian areas as well as how to conserve and manage for these<br>- Importance of the composition, structure and health of upland areas adjacent to riparian areas |

## 4.4 Proposed Indicators and Targets for Riparian Areas

This section proposes indicators and targets for riparian areas in the Red Deer River watershed. All indicators and targets selected were based on coordination with the outcome statements above. Included are descriptions of recommended indicators and associated targets. Additional information on riparian area indicators and targets, including several site-specific considerations, are provided in Appendix A.

### 4.4.1 *Riparian Indicator #1: Riparian Areas with Perennial Vegetation Land Cover*

Existing undisturbed natural riparian areas should be left intact and protected from further encroachment. Land uses within riparian areas should be converted to more sustainable forms to restore lost riparian areas. For example, perennial hay cover in riparian areas is typically far more desirable than crops.

For these reasons, as well as the critical importance of riparian areas to watershed health, targets for intact riparian areas were based on the amount of all riparian areas containing perennial vegetation land cover (natural cover + hay and pasture). To determine draft targets, the following criteria were defined and used to establish targets:

- Existing natural riparian land cover is maintained
- Half the crops currently in riparian areas are converted to hay and tame pasture
- An additional 1% of existing lost riparian areas are restored back to natural conditions

The resulting indicator values using the above criteria are listed in Table 10. The proposed watershed-wide target is 82% of riparian areas with perennial vegetation, an increase of 18% from current baseline conditions. To account for variability in natural conditions and land use patterns, more specific targets for landscape units have been proposed (Table 10). Such targets would be highly desirable for watershed management, although they may not be met for some time (e.g., by 2030).

**Table 10. Proposed Targets for Riparian Areas With Perennial Vegetation Land Cover**

| Watershed-Based Landscape Unit | % of All Riparian Areas with Perennial Land Cover (Natural + Hay or Pasture) | Change from Baseline Required |
|---|---|---|
| Entire Watershed | 82% | +18% |
| Upper Headwaters | 97% | +8% |
| Lower Headwaters | 85% | +17% |
| Central Urbanizing | 77% | +22% |
| Central Agricultural | 76% | +25% |
| Dry Grasslands | 92% | +9% |

*More detailed tables for each of the 15 sub-watersheds can be found in Appendix B

### 4.4.2 *Riparian Indicator #2: Riparian Health Scores*

“Healthy” riparian areas provide the widest range of ecosystem services and could form the basis of an idealistic target. However, in certain cases, more pragmatic targets must be set in combination with benchmark conditions. Natural events including floods, fire, drought, insects, etc. can affect the measured health status of riparian areas, so expecting all riparian areas to be scored as "healthy" may be unrealistic due to the natural range of variability. Taking these factors into account, as well as existing baseline information and data gaps, preliminary targets for this indicator are specified below in Table 11. These should be considered as long-term targets for watershed health, and the ability to reach these may be affected by landowner practices, program funding, and natural flood events.

It is recommended that either the aerial videography method or the Cows and Fish RHI method could be applied to monitor riparian health over time. Both of these methods have strengths and weaknesses. For example, the aerial videography is more appropriate at the reach scale, whereas the RHI method is more appropriate at the site scale. Aerial videography can provide continuous inventories of entire reaches at comparatively low cost for equivalent field survey efforts, whereas the RHI method includes more detailed site-specific variables and may capture observations that are not possible from the air. As a result, the use and integration of both indicators may the best approach moving forward. However, neither of these methods is currently capable of adequately summarizing and monitoring trends accurately at the watershed scale, which requires other approaches as recommended in riparian indicator #1 above.

More aggressive targets could be contemplated, but would require the voluntary participation of many landowners (including incentives from local and provincial governments), and continued, cooperative efforts by municipalities, agencies, organizations and programs such as Cows and Fish, Watershed Stewardship Groups (WSGs), Alberta Agriculture (e.g., Growing Forward program), etc. Additional information and considerations related to riparian health are provided in Appendix A.

**Table 11. Proposed Targets for Riparian Health[19]**

| River | Score | Baseline | Target |
|---|---|---|---|
| Watershed-Wide (Estimate) | Good/ Healthy | 25% | 30% |
| | Fair / Healthy With Problems | 49% | 55% |
| | Poor / Unhealthy | 27% | 15% |
| Red Deer River (Gleniffer Lake to Red Deer) | Good/ Healthy | 28% | 50% |
| | Fair / Healthy With Problems | 32% | 30% |
| | Poor / Unhealthy | 40% | 20% |
| Medicine River | Good/ Healthy | 14% | 30% |
| | Fair / Healthy With Problems | 23% | 40% |
| | Poor / Unhealthy | 63% | 30% |
| Blindman River | Good/ Healthy | 11% | 30% |
| | Fair / Healthy With Problems | 21% | 35% |
| | Poor / Unhealthy | 67% | 35% |
| Little Red Deer River | Good/ Healthy | 46% | 60% |
| | Fair / Healthy With Problems | 27% | 20% |
| | Poor / Unhealthy | 26% | 20% |

*Riparian health can be measured with either aerial videography or site-based RHI field assessments, according to resources, programming, need, and scale. For example, the Cows and Fish program could be used to provide rough estimates at the watershed-scale (although there are scale mismatch and sampling issues to be aware of), whereas monitoring of reach-specific targets may be more appropriate using aerial videography.

Additional information and considerations related to riparian health are provided in Appendix A.

### 4.4.3 *Riparian Indicator #3: Municipalities with Bylaws / Policies on Riparian Protection*

All municipalities in the watershed should develop and adopt a bylaw, policy, or guidelines on riparian areas including information on setbacks, riparian health, priorities for conservation, etc. These could potentially be combined with a wetland bylaw or policy as well.

[19] Attention was placed on setting targets for lotic (fluvial) systems. In addition, targets have only been specified for the mainstem of rivers previously assessed using this method.

### 4.4.4 *Riparian Indicator #4: Awareness Among Residents and/or Farmers*

It is recommended that surveys of landowner and/or watershed residents to measure / quantify awareness of riparian functions and management issues should be conducted periodically to determine if education and outreach efforts are having the desired effects over time in increasing awareness and stewardship.

A cheaper potential metric that also may help to gauge interest and engagement may be to measure attendance at workshops.

### 4.4.5 *Riparian Indicator #5: Farms Reporting Implementation of Grassed Waterways*

The federal Agricultural Census measures the number of farms reporting the use of “grassed buffer strips” on their property surrounding streams and other water bodies. It is recommended that this be examined periodically over time. This can be achieved by downloading the Census Agricultural data in GIS format and processing to determine an estimate of the total proportion of farms in the watershed implementing this BMP, which is critical for riparian health. All permanent and intermittent waterways require riparian area protection to help protect the quality of aquatic environments.

In 2006, the baseline estimated value was 1,800 farms reporting the use of grassed buffer zones around water bodies. As there are well over 10,000 farms in the watershed, this is a rate of less than 20%. Accordingly, it is considered highly desirable and potentially achievable that this figure could more than double with sufficient education and stewardship initiatives. The 2011 census results will also be released in geospatial format in spring 2013 and could be examined to determine if recent trends can be uncovered.

**Table 12. Summary of Proposed Indicators and Targets for Riparian Areas**

| Indicator | Type of Indicator | Scale of Analysis | Targets (Summary) | Notes |
|---|---|---|---|---|
| **Key Recommended Indicators** | | | | |
| % Riparian Areas with Perennial Vegetation Land Cover | Environmental | Watershed | 82% | Will require shifting approximately half of all crops to hay in riparian areas |
| | | Landscape Units | e.g., >85% in Lower Headwaters | |
| Riparian Health Scores from Aerial Videography | Environmental | Reach-specific | e.g. >30% "Healthy" along Medicine River | Will require major improvements from current conditions over the long-term |
| Number of Municipalities with Riparian Area Bylaws / Policies | Programmatic | Municipal<br>Watershed | 100% of municipalities in the watershed | May be combined with wetlands bylaws/policies<br>Should address setbacks for Environmental Reserve, riparian health, etc. |
| Awareness among residents and/or farmers | Social | Watershed | e.g., 30% increase over 10 years | Will require standardized, statistically random surveys |
| Riparian Workshop Attendance | Social | Watershed<br>Municipal | Increase in number of people attending workshops | Requires compilation of baseline information on workshop attendance |
| % of Farms reporting grassed buffer strips BMP | Programmatic | Watershed | 50% of farms report the use of grassed waterways by 2016 | Requires more than doubling from 2006 baseline numbers |
| **Additional Indicators for Consideration** | | | | |
| % of 1st and 2nd order Riparian areas with Perennial Vegetation Land Cover | Environmental | Watershed | >75% | 1st and 2nd order streams are critical |
| | | Landscape Units | e.g., >95% in Upper Headwaters | Headwaters are critical |
| Riparian Health Inventory (RHI) Scores (Cows and Fish) | Environmental | Watershed | e.g., 30% "Healthy" (+5%) | Limitations for trend analyses at watershed scale |
| | | Site-specific | Maintain or improve on current conditions at the site scale | "Healthy" for all sites is an ultimate long-term target |
| Width of Riparian Setbacks | Environmental | Site-specific | Provincial guidelines (AEW 2012)<br>100 m recommended | Larger setbacks may be required for major river valley corridors |
| Connectivity of Riparian Areas | Environmental | Site-specific | Maximize riparian connectivity<br>Restore disconnected areas | More quantitative landscape connectivity metrics can be derived using GIS if desired |
| Vegetation Diversity | Environmental | Site-specific | Diverse mixture of native plant types | Redundant with RHI score recommended above |

## 4.5 Management Implications and Recommendations

The following recommendations relate specifically to the management, conservation, and restoration of riparian areas for consideration in the IWMP. Recommendations are listed under three main categories: monitoring and data acquisition, research needs, and recommendations related to key Beneficial Management Practices (BMPs).

### 4.5.1 *Monitoring and Data Acquisition*

The following have been identified as priorities for consideration in monitoring and data acquisition:

- **Lower Order Streams.** Due to the importance (and often neglect) of lower order streams, a more refined analysis to measure land use patterns in lower order (first and second order) streams could be conducted, compared to land use trends in higher order streams, and used to refine proposed targets (Table 29) and associated management and farmer outreach efforts.
- **Flow Accumulation Modelling to Identify Potential Ephemeral Streams.** Many of the small ephemeral streams in Alberta remain unmapped in provincial hydrographic databases. Flow accumulation modelling using high resolution GIS DEM inputs can help indicate the locations of intermittent and ephemeral streams; however for highly accurate maps, ground truthing is required during flood events and this is likely to be prohibitive in cost.
- **Lentic Riparian Areas.** The provincial DEM-derived riparian areas maps only address lotic (flowing-water) riparian areas. Lentic (standing water) riparian areas are generally not included unless they are part of a flow-through pond or small lake. Additional analysis would be required to map and analyze lentic riparian areas and associated land uses.
- **Cows and Fish Riparian Health Data.** The Cows and Fish RHI field data could be summarized and reported on as separate distinct units (i.e. sub watersheds) for the purpose of target-setting. Additional resources would enable Cows and Fish to complete a more detailed summary of “average” scores for the Red Deer River mainstem and for sub-watersheds with sufficient sampling (e.g., Medicine River, Rosebud River), and the 5 watershed landscape units defined in this report.
- **Investigate Provincial Grazing Lease Riparian Health Data.** Public Lands staff are required to monitor range and riparian (where applicable) health on provincial rangelands, but only on a 10 year interval. Therefore, much of the data may be out of date, unless done recently. It may still be useful for the WPAC to expend future efforts collating and summarizing this information including potential trend analyses over time.
- **Additional Aerial Surveys for Riparian Health.** These have only been conducted for a limited subset of the Red Deer River mainstem as well as some key tributaries upstream of Red Deer. Additional survey effort may be desirable depending on cost and utility, integration with other program needs, etc. In addition, to track changes and potential success of initiatives over time, currently assessed areas should be re-flown at a specified interval (e.g., every 10 years?) to track and monitor health over time[20].
- **Integrate Riparian Indicators in an Integrated Monitoring and Reporting Framework** (see Section 5.6.1 for more details)

[20] As an indicator this would likely be useful but there may be several limitations due to the methods applied.

### 4.5.2 *Research Needs*

The following are the recommended research needs to improve knowledge, understanding, and management of wetlands in the watershed:

- ***Investigate Riparian Targets in a Nested Hierarchy of Scales.*** Watersheds exist in a nested hierarchy of scales. Therefore, when assessing and reporting on riparian area targets, it would be desirable to examine finer sub-watershed scales than those shown in this report.
- ***Investigate and Ground Truth the Riparian Maps.*** The variable-width boundaries and associated land uses are both based on remote sensing data and GIS modelling. Some field surveying to verify the accuracy of these map products may be required to increase confidence in the results.
- ***Integrate ecological research with economic models.*** Many quantitative science-based models of riparian functions are not adaptable to reliable economic valuation. This requires better integration of ecological research with economic models on riparian area valuation to better direct future research needs supporting decision-making. By necessity, addressing this issue will require coordinated research by academia and the provincial government.
- ***Regionally-calibrated riparian function models***. Local reference standards for riparian functions in the watershed (e.g., phosphorus control, sediment control, etc.) may be required.
- ***Ensure Coordination and Integration of Riparian areas with Other Watershed Considerations.*** Ensure wetland management is integrated with other key management objectives, such as water quality, biodiversity, open space and quality of life within the IWMP. This requires that the effects of riparian areas on water quality and water flows are integrated into a state of the art scientific water quality model to evaluate the achievement of environmental outcomes under various management and engineering options. This is currently being undertaken on contract for the Red Deer River watershed through AESRD (Chris Teichreb, personal communication).
- ***Remote Sensing Tools for Riparian Areas.*** The Alberta Terrestrial Imaging Centre at the University of Lethbridge is currently working with the North Saskatchewan Watershed Alliance to develop a remote sensing monitoring system for wetlands, riparian areas, and permanent vegetation for Alberta's "White" area, with the prototype system developed for the Vermilion River watershed. Effective determination of riparian area health using a suite of remote sensing tools may hold great promise for lower-cost, regional scale, repeatable methods of measuring watershed health related to riparian areas.
- ***Review and Harmonize Municipal Policies and Plans.*** Municipal land use bylaws, municipal development plans, and inter-municipal development plans should be reviewed and compiled and compared to best practices.
- ***Compensation Program for Riparian Areas?*** The province has an extensive system for compensation payments and associated restoration in cases where wetlands are disturbed within the regulatory process. Riparian areas are as important as wetlands, so perhaps the province should examine a conservation offset system for disturbed riparian areas as well. This may require some policy-based research to make the case for this and examine feasibility, institutional mechanisms, project risks, etc.

### 4.5.3 *Suggested BMPs*

The RDRWA has conducted detailed reviews and international case studies of BMPs for riparian areas (RDRWA, 2009)(pages 4-80 to 4-94). Key BMPs synthesized and highlighted for this report include:

**Protection and Conservation Tools**

- All industries, including agriculture, and governments should aim to avoid development or resource extraction in or directly adjacent to local variable-width riparian areas and associated steep slopes
- Effective compliance and enforcement of existing / future regulations and policies is critical
- Establish new municipal or provincial parks and protected areas for riparian areas
- Develop municipal bylaws, plans, and policies for riparian areas including detailed variable setback width policies, riparian management categories, and permitted and restricted activities in each management zone.
- Reconnect severed linkages in the riparian network where possible
- Develop riparian restoration programs for private landowners, including financial incentives and grants, technical support, and advice (e.g., see the *Field Manual on Buffer Design for the Canadian Prairies* as a source of information)
- Develop and apply additional tools such as conservation easements, tax benefits, and market-based instruments under the *Land Stewardship Act* to promote riparian area conservation among landowners
- Where riparian impacts are completely unavoidable, investigate potential compensation elsewhere in the same sub-watershed
- Collaborate with other landowners and surrounding jurisdictions to address shared issues

**Specific BMPs**

- Maintain and restore riparian buffers as large as possible that contain healthy natural vegetation
- Within riparian areas, convert crops to perennial hay cover or agroforestry operations as appropriate
- Carefully manage livestock access to riparian areas with a variety of tools, including rotational grazing, time controlled grazing (avoid moist conditions), appropriate stocking rates, temporary or permanent fencing, and alternative livestock watering systems (e.g., solar, cattle nose pump)
- If cropping in riparian areas does occur, ensure annual crop stubble is left near or in the riparian zone during fall, winter and spring, or that fall cereals are used as an alternative
- Consider wetland retention ponds for farmland with tile drainage systems, because riparian buffers will be ineffective for nutrient retention, particularly if pipes bypass the riparian zone and discharge directly into streams
- Reduce the occurrence of invasive plants and weeds in riparian areas

- Limit loss of riparian areas due to hard engineering infrastructure (rip rap, gabions) and channelization by avoiding placement of infrastructure in vulnerable areas and using “soft” bioengineering techniques as an alternative
- Convert riparian areas that are developed as industrial or commercial uses to open spaces if and when such opportunities arise during redevelopment and/or brownfields remediation
- Address recreational impacts on riparian areas with both indirect measures (signage, education) and direct measures (e.g., access control, trail sighting and design, facilities, bylaws, surveillance)

**Education**

- Develop an education strategy specifically to target riparian areas in agricultural areas, using lessons learned from surveys on producer knowledge of riparian areas and functions (Cows and Fish, 2002)
- Educate all audiences on the economic and social benefits of conserving riparian areas, including how riparian areas can enhance development, as opposed to being at the expense of development
- Educate, inform and engage the community and users of these areas to assist in improving riparian health and developing riparian management strategies
- Promote community action events that tackle riparian issues and give the public the opportunity to directly improve riparian health (e.g., weed pulls, clean-up days, etc.)
- Develop community monitoring programs that involve local user groups and residents (Cows and Fish, 2012)
- Provide appropriate training for municipal staff to understand wetland and riparian goals during application review processes
- Communicate with all stakeholders during the development of planning documents and seek early and regular input into the process

# 5. LAND USE

This chapter summarizes land use activities in the Red Deer Watershed and issues related to watershed management. Included are summaries of how land use is integrally related to watershed values and conditions (Section 5.2). Existing baseline information on land use in the watershed is provided in Section 5.3. Section 5.4 provides draft outcome statements, followed by proposed targets, strategies, and actions related to land use discussed in Section 5.5. Section 0 discusses management implications and recommendations, including future research needs and suggested key Beneficial Management Practices that are required to focus the development of the IWMP and future implementation efforts.

## 5.1 Land Use Definitions and Relationships With Watershed Ecosystem Services

The provincial government defines land use as: "*All uses of land, such as crops, forestry, conservation, recreation, tourism, oil and gas, mining, utility corridors, transportation, cities and towns, industrial development, etc."* (GOA, 2011). Land use has also been defined *"any human use of land that alters it from its natural state"* (Sisk, 1998).

Land uses and natural areas in the watershed form a mosaic of interacting landscape elements. Depending on land use type, location and intensity along with cumulative effects from all other land uses there is the potential for land use to negatively impact ecosystem services in the watershed. Conversely, ecosystem services enhance and contribute to productive and valuable land uses (O2, 2009a). For example, riparian areas and wetlands provide water filtration, erosion control, water storage and supply, carbon storage, biodiversity support, and recreational opportunities (Braumann et al., 2007).

Improper locations or management practices associated with land uses can negatively impact important aquatic ecosystems, including riparian areas, wetlands, lakes, and rivers. More specifically, key risks that land uses may pose to watersheds include:

- Loss of hydrologic functions and ecosystem services due to loss and/or impact of land uses on:
    - Wetlands
    - Riparian areas
    - Alluvial aquifers
    - Natural uplands (e.g., forests, native grasslands)
    - Headwaters
- Increased risk of erosion and sedimentation
- Increased loadings of contaminants to local waterways (e.g., total suspended solids, phosphorus, nitrogen, pesticides, pathogens)
- Negative impacts to the quantity and timing of river flow due to:
    - Consumptive water uses (e.g., irrigation)
    - Irrigation return flows and inter-basin transfers from irrigation canals
    - Increased impervious cover changing the volume and timing of water flow
    - Construction of dams and creation of impoundments
- Impacts on groundwater quantity or quality (the focus of the next Background Technical Report for the IWMP)
- Negative impacts on biodiversity
- Loss of cultural amenities and valuable natural landscapes that contribute to quality of life

## 5.2 Land Use Risks to Watershed Values

The Technical Advisory Committee (TAC) for the RDRWA previously identified a range of categories for land use issues in the watershed that formed the basis for the land use subsections below. Land use type including relationships to watershed values are summarized below. Note that additional information on *where* land uses occur in the Red Deer River watershed has been summarized in the subsequent section (5.3), whereas the following section focuses on the actual risks of each individual land use to the watershed.

### 5.2.1 *Urban Development*

Intensive residential, commercial, and industrial land uses in urban in urbanized areas can influence local hydrology and water quality (Table 13). Construction from ongoing development is a particular concern, as it can release large quantities of sediment. Erosion rates from unmitigated construction sites are typically hundreds of times higher than pre-development conditions, and can be up to 1000 times higher during major runoff events (City of Calgary, 2001).

Developments and associated roads, parking, rooftops, and other impervious surfaces result in higher peak stormwater runoff (Figure 20). Residential subdivision developments can generate up to ten times more runoff than predevelopment (City of Calgary 2005), leading to increased risk of flooding and erosion downstream. Water quality in urban stormwater runoff is typically poor, with high Total Suspended Solids (TSS), high nutrients (nitrogen, phosphorus[21]), and increased concentrations of salts, bacteria, pesticides, metals, and hydrocarbons (Forman et al., 2003; O2, 2009b). Stormwater detention ponds mitigate some but not all of these impacts.

**Table 13. Effects of Urban Land Use on Hydrology**

| Land Use/ Land Cover Change | Impacts on Hydrological Processes[1] | | Red Deer River Watershed Context |
|---|---|---|---|
| | *Decreased* | *Increased* | |
| Loss of wetlands, creeks, and riparian areas | - Water storage<br>- Flood control<br>- Infiltration<br>- Base flow<br>- Erosion control | - Stormwater drainage<br>- Peak flows<br>- Water pollution | Most former wetlands in urban areas such as Red Deer, Olds, and Innisfail have been lost to development |
| Increase in impervious areas in industrial, commercial, and residential land uses | - Evaporation<br>- Groundwater recharge<br>- Interflow / baseflow<br>- Natural drainage | - Stormwater drainage<br>- Peak flows<br>- Water pollution | Since the 1950s, urban development has significantly increased impervious surfaces, although increases have been small in the context of the entire watershed |
| Loss of topsoil, soil structure (e.g., compaction), and vegetative cover | - Water retention<br>- Erosion control | - Peak flows<br>- Potable water demand for lawns/gardens<br>- Water pollution | Many current land development practices lead to loss of topsoil and vegetative cover |

*Sources: (Ackerman & Stein, 2008) (CWP, 2001) (Gergel & Turner, 2002) (Snyder & Goetz, 2005)*

Studies have shown imperviousness to be a key indicator of urban land use impacts on watersheds. As imperviousness increases so do negative impacts to channel stability, water quality, and stream biodiversity (Leitao & Ahern, 2002) (CWP, 2001).

[21] Phosphate fertilizers applied to urban lawns and open spaces constitute a considerable source of phosphorus on a per hectare basis in Alberta's watersheds (AESRD, 2012). Excess phosphorus and nitrogen can create eutrophic conditions not suitable for fish and other aquatic biota.

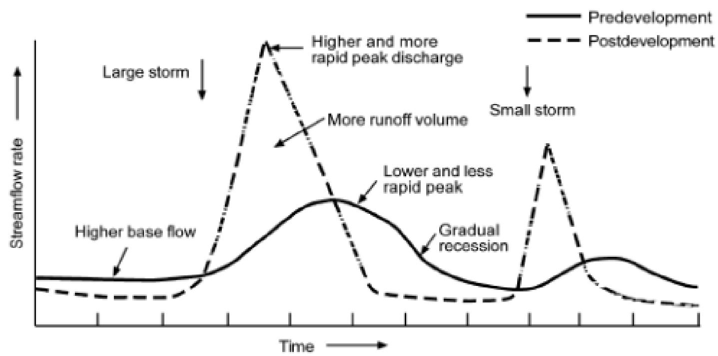


**Figure 20.** **Changes to Stream Hydrology in Urban Areas**
*Source: (Schueler, 1992)*

### 5.2.2 *Rural Development*

Increasingly, rural areas are developing business parks and commercial developments, which take on the density and servicing of uses typically considered only urban in the past. This includes many business parks, industrial parks, and commercial areas in rural municipalities. Many of the impacts discussed above in 5.2.1 apply to these types of developments. This is particularly the case for industrial parks, which in Alberta often have imperviousness values >80%, as well as commercial areas, which although smaller in size typically have imperviousness values >90% (O2, 2009b).

Rural acreages can also impact watersheds through:

- Local losses / impacts on wetlands, riparian areas, and introduction of impervious land cover
- Septic systems can be a source of nutrients, pathogens, and other contaminants (e.g., cleaning products, personal care products, pharmaceuticals) with the amount of risk depending on location, design, construction, operation, and management
- Use of lawn and garden care products
- Increased pet and small-farm animal density (e.g. horses, llamas)
- Large areas of low density sprawl of rural acreages leads to higher overall watershed imperviousness at broad scales and greater overall impacts compared to high density urban land use (Jacobs & Lopez, 2009; USEPA, 2005)

### 5.2.3 *Agriculture*

Agricultural activities in the watershed can impact watershed health. Potential impacts of agricultural activities on watershed health include:

- Leaching and runoff of contaminants (fertilizers, pesticides, herbicides, sediment) from agricultural lands can influence water quality in receiving environments
- Drainage of wetlands and loss of wetland ecosystem services
- Loss and compaction of riparian areas due to cropping or livestock grazing/trampling
- Overgrazing impacting vegetation and soil health and consequently watershed health
- Non-native and weed species invasion

Agricultural activities can contribute excess nutrients, bacteria and pesticides to receiving water bodies. A province-wide study (CAESA) conducted from 1993 to 1998 evaluated the impacts of agricultural land use activity on water quality. The study found that streams draining watersheds with higher agricultural intensity (defined using fertilizer expenses, chemical expenses and animal unit density) had higher total and dissolved nutrients and higher bacterial counts than streams that drained watersheds with lower agricultural intensity (Anderson et al. 1998). However, it also found that total nitrogen export from some high intensity watersheds was lower than from some watersheds with moderate agricultural intensity. This indicates that other factors in addition to agricultural intensity, such as climate, runoff potential, land cover and instream processes contribute to the observed range of both phosphorus (P) and nitrogen (N) export. A recent literature review found that export coefficients for TP from agricultural land uses range from as low as 0 to as high as 38 kg/ha/year, while export of nitrogen ranges from 0.085 to 54 kg/ha/year (Riemersma et al., 2006).

More recent agricultural research has focused on better estimating contaminant runoff (particularly phosphorus) from agricultural land and measuring the effectiveness of related BMPs. Overall, research is finding that there are critical source areas, areas where high runoff potential coincides with elevated soil test phosphorus (STP), that are responsible for the majority of nutrient losses through runoff from agricultural land. A reduction in STP concentrations and control of runoff from high-risk areas (i.e., run-on and run-off management practices) is thought to be the most effective way to reduce contaminant loading (particularly P) into surface waters from agricultural activities (Jedrych & Martin, 2006).

### 5.2.4 *Forestry*

Forestry occurs on both private and public lands in the watershed, primarily in the headwaters. Although forestry activities are highly regulated in Alberta, they can have impacts on water quality and aquatic ecosystem health, particularly at a local scale (Feller 2005). The impacts of forest harvesting in a watershed on stream water chemistry is highly variable depending on a wide range of biotic, abiotic, and forest management variables (Feller 2005). However, increased downstream delivery of suspended sediment typically is a primary concern, as well as nutrients, changes to chemical cycling, and higher stream temperatures resulting from reduced forest cover for shade (Waters, 1995; Forman, et al., 2003). Some of the key potential concerns related to forestry are summarized in greater detail below.

***Forestry and Riparian Areas:*** Well-vegetated forested riparian areas provide highly effective binding root masses that protect stream banks from erosion (Pollen, Simon, & Collison, 2004). Riparian areas also play a critical role in keeping water cool, and the removal of riparian vegetation tends to result in increased water temperatures (Waters, 1995; Forman et al., 2003; Moore and Richardson, 2012) . Although forestry practices have evolved and many riparian areas are now retained, loss of riparian vegetation due to forest harvesting still remains a local concern in some areas.

Fires burn through riparian areas, creating a natural range of variability in seral stages within riparian areas. There have been recent discussions in the forestry industry regarding whether mimicking natural disturbances and allowing some harvesting in riparian areas should be conducted as a tool to enhance forest complexity and mimic natural disturbances (Sibley et al., 2012). However, at present, implementing this tool is contrained by considerable uncertainty (Sibley et al., 2012; Moore and Richarson, 2012). There are concerns that there is not enough knowledge and understanding on how riparian harvesting should be done, how much forest removal can take place in riparian areas, and whether riparian areas with some harvesting would function as well as those left to develop naturally.

***Clear-cutting:*** Multiple studies show that the greater the percentage of trees cut in a watershed, the greater will be the impacts on stream water chemistry in a watershed (Feller et al. 2005; Stephan 2012). Therefore, the impacts of clear-cutting are scale dependent. Current cutting cycles and proportions of clearcuts in the Red Deer watershed and its sub-watersheds appear to have minor impacts as shown by water quality monitoring in the main stem. Therefore, there is no need for alarm over clear-cutting in the watershed as it is currently practised.

Logging Roads: Logging roads tend to produce the most sediment of all forestry activities (Waters, 1995; Forman, et al., 2003). In addition, debris flows, landslides, and other mass soil movements associated with logging roads can occur long after logging activities themselves have ceased (Waters, 1995). Logging roads also provide access for recreational uses.

***Silvicultural Practices:*** In areas undergoing reforestation, herbicides are sometimes used, although amounts used by the forestry industry tend to be very small.

***Slash Burning:*** Forestry practices in the watershed including piling and burning slash to reduce the risk of large forest fires and to speed up seedling regeneration within cutblocks. The effects of this type of slash burning are highly variable depending on site characteristics. However, fire can change the forest floor, expose mineral soils to erosion, and change nutrient dynamics, leading to increased delivery of sediment and nutrients downstream (Beese, Blackwell, Green, & Hawkes, 2005). The effects of slash burning in Alberta are typically small and localized. There are also requirements to locate slash burn piles away from riparian areas and ephemeral streams. Consequently, effects of this type of slash burning are likely very localized and insignificant at broader scales.

***Log yards:*** Log sorting, bark stripping, and chipping occurs at these locations. Studies of log sort yards in Alberta, including one study site at Sunpine Forest Products Ltd. just north of the study area, have shown that runoff from log yards contain high concentrations of organics and phenols, high Total Suspended Solids, high biochemical oxygen demand, and high chemical oxygen demand (AENV 2002). Log yards with clay soils, defined runoff paths and pine or aspen logs at the site had higher organic levels in their runoff compared to a site with spruce logs and a muskeg/clay surface (AENV 2002). A range of structural best practices have been recommended to mitigate pollution from these sites, and these should be implemented and inspected on a regular and ongoing basis (AENV 2002).

***Equipment operations:*** Spills of oils and greases from machinery used in forestry can be a concern.

### 5.2.5 ***Recreation and Tourism***

Recreation activities can pose varying risks to water quality and aquatic ecosystem health. Concentrations of random camping and motorized activities have been noted as a major concern in the upper watershed, particularly on long weekends. Horse and equestrian activities, as well as dispersed, low-intensity hiking , swimming, and a wide range of other activities occur throughout the watershed.

Motorized vehicles can cause erosion and increased sedimentation in streams, lakes, rivers and wetlands. In addition, spills of fuel, oil, hydraulic suspension fluids, and other toxic substances are hazards to local water quality and aquatic ecosystem health

Local increased erosion due to vegetation loss, soil compaction, and erosion from trail use and expansion is a concern, particularly when motorized activities are involved. Bacteria, viruses, and cysts from fecal matter can be introduced to the watershed, especially in areas where outhouse facilities are not used or are improperly sited or maintained. Littering of solid waste is another concern. As with many activities, concerns are higher when recreational activities occur in high-risk areas close to watercourses, and have steep slopes and unstable soil texture.

Shoreline development along lakes, reservoirs, and rivers removes riparian buffer vegetation and can result in erosion and entry of other potential contaminants into the lake. Construction of cottages or other recreational facilities directly on the shoreline, as well as clearing and landscape maintenance practices between buildings and the shore are particular concerns. Treated wood used for dock construction can also potentially leach small quantities of creosote or chromated copper arsenate.

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### 5.2.6 *Industry*

Industrial activities have been separated into three categories for discussion purposes: oil and gas, aggregate mining (sand/gravel), and other types of industrial activities.

#### *5.2.6.1 Oil and Gas*

Industry is highly regulated and must conform to all approvals, licenses, permits, etc. intended to control and reduce risks to the environment. Regardless, some residual risks to the environment remain whether unanticipated or accidental, including (CAPP, 2010; Marsh, 2010):

- Spills / leaks of hydrocarbons (BTEX, PAHs, free hydrocarbons, etc.) and other chemicals (e.g., drilling fluids, glycols, etc.) from pipelines, well sites, and other facilities
- Wells that are not properly drilled, maintained, or sealed provide pathways for contaminant movement to shallow aquifers or surface runoff
- Watercourse crossings from pipelines and access roads pose risks of impacts on watershed due to erosion and sediment mobilization, loss of riparian vegetation, culvert erosion over time, etc.
- Produced (saline) water management and disposal, including potential impacts associated with flooding of storage sites during extreme weather events
- Water use from surface and groundwater sources for industrial production or hydrostatic testing
- Impacts on wetlands due to well site footprints and/or industrial runoff into wetlands
- Hydraulic fracturing (oil and shale gas formations) including use of additives in fracturing fluid and possible interrelationships between groundwater and surface water
- Air emissions from flaring, gas processing, plastics manufacturing + deposition in the watershed
- Contribution to cumulative effects on water quality, aquatic ecosystem health, wetlands, air quality (including deposition of contaminants in the watershed), aesthetics, noise, traffic and rural community character

#### *5.2.6.2 Aggregate Mining*

Aggregate mining operations primarily pose risks of sedimentation and higher TSS downstream. Although these operations are regulated by the province and municipalities, they do pose residual risks to water quality, aquatic ecosystem health, and other watershed values (e.g., river valley aesthetics), particularly since they are often concentrated in close proximity to streams and rivers where sand and gravel tends to be most common.

Large volumes of water used for aggregate washing operations are typically high in sediment and contain many fine particles. In addition, sand and gravel mines can alter river/stream channel morphology, leading to increased velocity, headcutting eroding action, and streambed modification, all of which can increase the amount of suspended sediment (TSS) in surface waters (Waters, 1995; Kanehl & Lyons, 1992). Possible other risks from aggregate mining include reduced filtration of sediments when they are located in a groundwater discharge area, spills of hydraulic fluids from machinery, and gradual wear and tear from machinery and buildings on the site releasing very small amounts of metals and hydrocarbons.

Due to the inherently high permeability of gravel and sand pits, water on the site often moves rapidly downwards into the groundwater profile. Depending on the hydrogeology of the area, some of this water may then migrate directly into surface waters.

#### *5.2.6.3 Other Industry*

Other types of industry apart from oil and gas represent a variety of risks to watersheds as listed in Table 14. Runoff from facilities, potential spills, and leaching of contaminants from waste storage and transport facilities are all potential sources of contamination to surface waters.

**Table 14. Other Industries in the Watershed**

| Industry Type | Key Risks to Water Quality and Ecosystem Health |
| --- | --- |
| Coal Mining and Coal-Fired Power Plants | Deposition / precipitation of acidifying air emissions and nutrients<br>Contribution to Climate Change through high GHG emissions<br>Local hydrological changes |
| Fertilizer Plants | Nutrients and eutrophication |
| Food Processing / Bottling / Meat Packing Plants | Nutrients in effluent, BOD, pathogens |
| Industrial Parks | TSS, nutrients, wide variety of contaminants, increased peak flows / hydrology changes |

### 5.2.7 ***Linear Developments***

Linear developments include oil and gas pipelines and access roads, seismic lines, as well as transportation corridors, public roads and highways (gravel and paved), railways, power lines and other utility rights of ways. The cumulative effects of linear developments have been shown to negatively impact water quality, fish and wildlife populations in Alberta (Scrimgeour et al., 2008; Stevens et al., 2006).

**Impacts of Linear Transportation Corridors on Water Quality and Aquatic Ecosystems**

Some of the key impacts of linear transportation corridors on watersheds include (Forman et al., 2003):

- Erosion of unpaved road surfaces and areas surrounding culverts and crossing structures can be a source of sediment to receiving water bodies
- The impervious nature of roads increases runoff and erosion risks
- Many chemicals including oil, grease, and heavy metals are found on and adjacent to roads, and originate primarily from gradual wear of the road deck, and vehicle leaks, and emissions
- Asphalt contains condensed polycyclic aromatic hydrocarbons, sulfur and many heavy metals including nickel, vanadium, lead, chromium, mercury, arsenic, and selenium. Other materials are often incorporated into road recycling / resurfacing projects including coal fly ash, reclaimed concrete, boiler ash, demolition waste, and tires. These chemicals can leach slowly over time due to stress, deformation, and cracks in the road surface.
- Road maintenance activities such as salting, de-icing, and dust suppression
- Traffic accidents and spills may contaminate surface water, groundwater and soils

- Roads are an organizing element for nearly all human activities and provide access to remote areas of the watershed for people engaged in a wide range of activities and pursuits, such as off-highway vehicle (OHV) use
- Railway corridors may be sources of many of the above contaminants as well; for example, creosote has been used on many railway ties throughout Alberta.

Powerline corridors in the watershed may pose risks to water quality due to the lack of vegetative cover, which creates local areas of erosion, as well as application of herbicides in the right-of-way. Preservatives used on wooden power poles such as arsenic and copper may slowly leach.

Linear footprints impact landscapes through fragmentation and increasing the edge density of landscapes. This results in a variety of impacts to watershed and ecological processes, including providing sources and conduits for pollution, and colonization by invasive species. Linear footprints in a watershed have been shown to impact fish communities in Central Alberta through increased erosion and sedimentation (Stevens & Council, 2008). Increased sedimentation can impact fish through reduction in food (insects), infilling of gravel spawning areas, reduced feeding due to decreased visibility, and increased stress and gill abrasion from increased sediment loads.

### 5.2.8 *Other Land Use Activities*

Other land use activities and associated risks in the watershed include:

- **Solid Waste Management / Landfills.** Potential leachate containing a wide range of contaminants seeping into groundwater and through runoff to surface water
- **Illegal Dumping.** Illegal dumping of household waste, construction waste, or toxic industrial waste outside of formal landfills may be a larger concern than landfills themselves
- **Golf Courses.** High nutrient and pesticide inputs, sometimes in close proximity to riparian environments, and high water use from irrigation leading to high possibility of leaching
- **Peat Harvesting.** Localized impacts on wetlands and hydrology

### 5.2.9 *Cumulative Effects*

Cumulative effects are a result of all of the above land use activities, as well as other factors such as climate change, forest fires, floods, wildlife, natural stream erosion and other natural factors. Multiple stressors, combined with natural disturbances such as forest fires and floods, pose a risk of deteriorating water quality and aquatic ecosystem health. It is difficult to predict exactly how much risk is too much and when and how much ecosystem change would be observed due to the complexity of the system and difficulties in modelling and predicting future states. A prudent strategy for dealing with this complexity is to ensure ongoing vigilance in identifying and mitigating risks to water quality and aquatic ecosystem health.

***DOGRIB FIRE***

The Dogrib fire that occurred in the headwaters near Bearberry in 2001 was a major widespread fire that impacted water quality and ecosystem dynamics. The Foothills Research Institute has studied the effects of this fire.

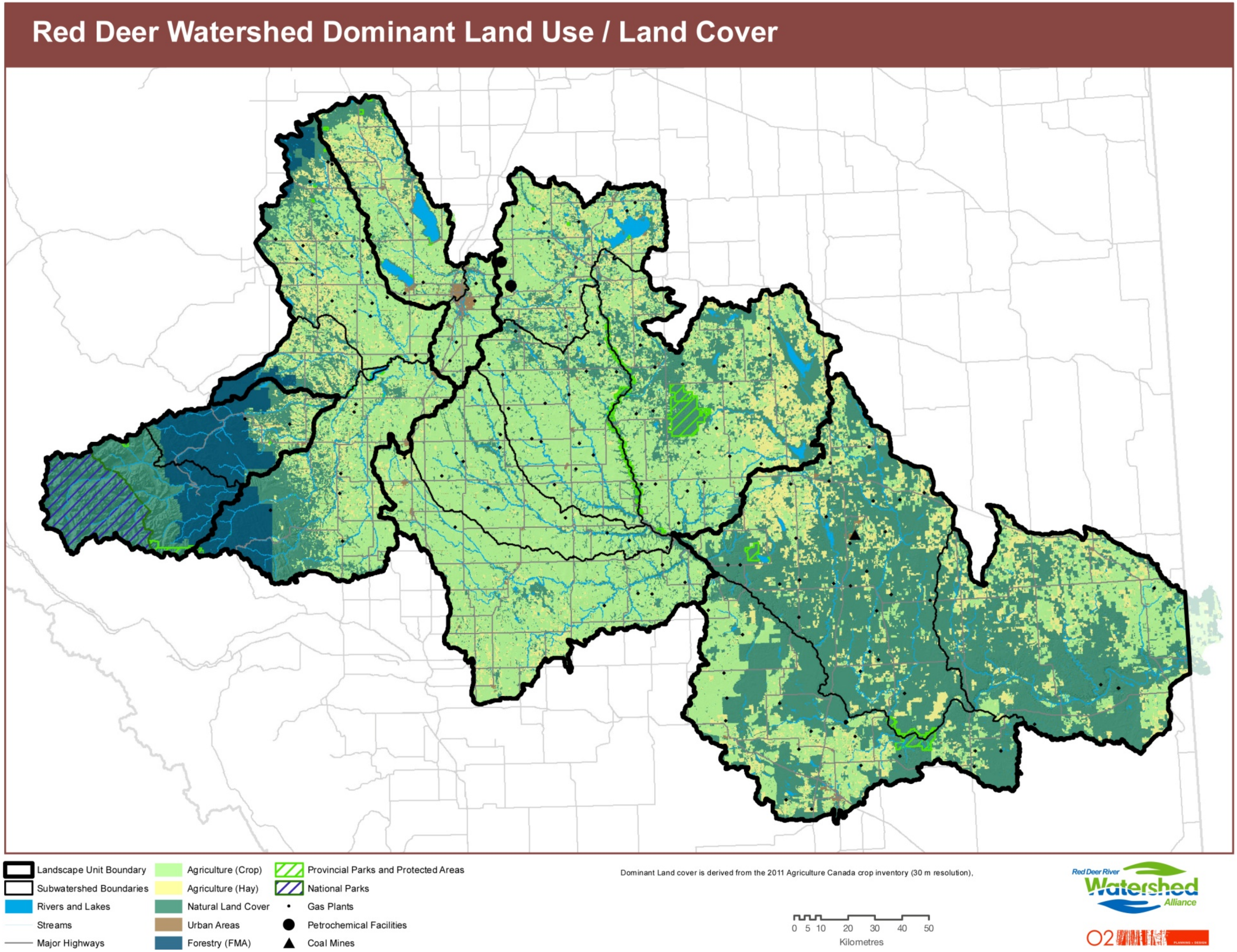


**Figure 21. Map of Dominant Land Use / Land Cover in the Red Deer River Watershed**

## 5.3 Baseline Land Use Data and Mapping

Multiple land uses occur in many parts of the watershed, including forestry, agriculture, oil and gas, petrochemical industries, coal mining, aggregate mining, utility corridors, urban development, country residential development, recreation and tourism. Major dominant land use types are shown in Figure 21, while Appendix B summarizes land use statistics for each sub-watershed and landscape unit. Key statistics and locations for each land use are summarized below.

### 5.3.1 *Urban Development*

Cities and towns in the watershed include a mixture of residential, commercial, and industrial land uses. These are concentrated along the Highway 2 central corridor, particularly in the City of Red Deer. Other urban areas along the Highway 2 corridor include the Towns of Sylvan Lake, Blackfalds, Innisfail, Olds, Didsbury, Carstairs, and Crossfield (Table 15).

Runoff from many urban land uses in the Calgary Metropolitan Region also drain into the Red Deer watershed (see box). Further east, local concentrations of urban land use and population include Brooks, Drumheller, Three Hills, and Hanna (Table 15).Sundre and Rimbey are the largest towns on the west side of the watershed.

Developed and urban lands occupy about 1.0 % of the watershed. Although this is a relatively small surface area of the Red Deer River watershed, some small streams have urbanized watersheds and are regarded as “hot spots” of imperviousness. These streams are affected by increased peak flow, volumes, erosion, and pollution.

#### URBAN LAND USE IN THE CALGARY REGION: EFFECTS ON THE RED DEER RIVER

The existing RDRWA watershed boundary does not account for stormwater and irrigation infrastructure. The WID Western Headworks (WH) Canal bisects SE Calgary, conveying water from the Bow River to Lake Chestermere, where it is divided into canals, many of which drain north into the Rosebud River and Red Deer River system.

Urban stormwater enters Lake Chestermere from the Town of Chestermere, a portion of the Town of Strathmore, some industrial land uses in Rocky View County, and from outfalls to the WH Canal from Calgary. In the past, the majority of NE Calgary drained into the canal. However, this has been mostly remediated with the $85 million Shepard Stormwater Diversion Project, completed in 2010.

A large part of SE Calgary and a portion of NE Calgary still drain into the Western Headworks Canal and Lake Chestermere. However, during major runoff events, a check structure and wasteway on the WH Canal near 80th Street E. diverts stormwater runoff to the Shepard Constructed Wetland. Outside the irrigation season (October 1 to April 30), the check structure is closed and all runoff including snow melt is diverted to the Shepard Constructed Wetland. The existing moratorium on diverting new stormwater outfalls into the WH Canal ensures that stormwater from future City of Calgary developments east of 84th Street E. will not affect the Red Deer River.

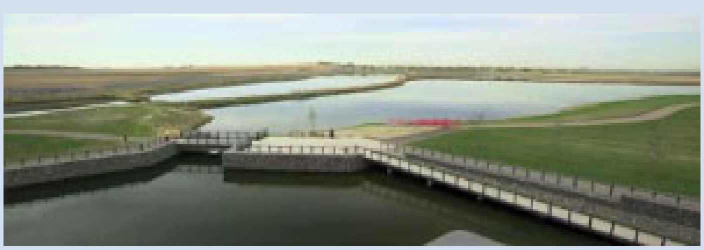

**Figure 22. Shepard Constructed Wetland, SE Calgary**

**Table 15. Largest Urban Areas Affecting the Red Deer River Watershed***

| City / Town | 2011 population | Change in population (2006-2011) (%) | 2011 Land Area (km$^2$) | Density** (people/ km$^2$) |
|---|---|---|---|---|
| Red Deer | 90,207 | +9% | 61.04 | 1,478 |
| Calgary†Ω | ~57,100 | N/A | ~37† | ~1,100 |
| ChestermereΩ | 14,363 | +50% | 8.91 | 1,612 |
| Brooks | 13,676 | +9% | 18.23 | 758 |
| Sylvan Lake | 12,762 | +19% | 16.84 | 758 |
| StrathmoreΩ | 12,216 | +20% | 10.57 | 1,156 |
| Olds | 8,235 | +14% | 14.87 | 554 |
| Innisfail | 7,876 | +7% | 19.53 | 403 |
| Drumheller | 6,723 | +3% | 11.08 | 607 |
| Blackfalds | 6,300 | +36% | 16.36 | 385 |
| Didsbury | 4,876 | +14% | 5.47 | 892 |
| Carstairs | 3,442 | +28% | 11.53 | 298 |
| Three Hills | 3,198 | +1% | 5.80 | 551 |
| Crossfield | 2,853 | +7% | 11.87 | 240 |
| Hanna | 2,673 | -6% | 8.56 | 312 |
| Sundre | 2,610 | +3% | 11.23 | 232 |
| Rimbey | 2,378 | +6% | 11.34 | 210 |

†Calgary values adjusted to account for city population estimates in communities draining to the WH Canal-values from 2006 and 2011 are so different due to the completion of the Shepard Stormwater Diversion Project by the City of Calgary
ΩA proportion of urban drainage from these municipalities enters the Red Deer River watershed through the WID canals
*Reported statistics are by "Population Centre" (Statistics Canada, 2012) to exclude undeveloped annexed lands
**For comparison, the City of Vancouver, BC, has a density of 5,249 people/km$^2$, while Kingston, ON = 1,260 people/km$^2$

Comprehensive assessment of wastewater from urban areas is beyond the scope of this study. However, highlights include:

- The City of Red Deer improved wastewater treatment during 1989 to 2010, with major upgrades to the treatment plant implemented in 1999/2000 and 2010
- The Central Alberta Wastewater Strategy aims to regionalize wastewater treatment by routing wastewater to the City of Red Deer for advanced treatment, including:
    - 80 km "South Leg" serving Olds, Bowden, Innisfail, and Penhold (under construction)
    - 34 km "West Leg" serving Sylvan Lake and small summer villages (under construction)
    - Planned future 22 km "North Leg" serving the towns of Blackfalds and Lacombe
- The Town of Blackfalds' existing wastewater treatment system may require an interim upgrade The Town of Chestermere pumps its wastewater back to the City of Calgary for treatment and discharge into the Bow River and is therefore not a concern for the RDRWA
- The Town of Strathmore discharges all its treated wastewater into the Bow River

#### *5.3.1.1 Population Growth and Future Outlook*

Moderately strong population growth throughout much of the watershed was observed over the last 5 years (Table 9). However, population increases were lower than the 2001-2006 period, when the City of Red Deer grew by over 22% (4.4% per annum) compared to the 9% observed from 2006-2011 (1.8% per annum). Remarkably, the population of the City of Red Deer has more than tripled in size since 1975, when the population was just over 30,000 people.

In 2008, a 40% increase in population in the watershed was forecasted by 2031, with the City of Red Deer forecasted to grow at a rate of 4.1% per annum (Associated Engineering, 2008). However, these projections were likely somewhat high due to the slow economic growth from 2008-2011. Observed population growth in the City of Red Deer from 2006-2011 was 1.8% per annum (Table 15).

### 5.3.2 ***Rural Development***

There are many business and industrial parks that now occur in rural municipalities. Red Deer County has extensive commercial and industrial lands surrounding the City of Red Deer in the "Gasoline Alley" area. Lacombe County and Mountain View County have also recently developed industrial parks alongside Highway 2, although many of these are still lying vacant. Major industrial petrochemical developments also occur near Joffre (also discussed in Section 5.2.6).

The population within the 18 rural municipalities in the watershed was estimated at 83,112 in 2006 (Aquality 2009). This is not expected to have changed considerably since then, although some small decreases in population are expected in the more remote rural counties.

Low density country residential developments occur in several parts of the watershed, particularly surrounding the City of Red Deer (Figure 23). Some expansion of this land use type is likely occurring. However, comprehensive information on the extent and location of these development types is not readily available and would likely need to be compiled from local municipalities individually.


**Figure 23. Country Residential Developments West of the City of Red Deer**

### 5.3.3 *Agriculture*

Crop and livestock agriculture dominate central portions of the watershed, as well as areas surrounding Brooks. Information on agricultural land use activities was compiled from the 2005 Census data and the Agriculture Canada 2011 Crop Inventory (AESB-AAFC 2010). It was supplemented by information on intensive livestock operations obtained from Agriculture Canada.


**Figure 24. Intensive Agriculture, Central Watershed, Near Trochu**

#### *5.3.3.1 Cropland*

Agriculture Canada's 2011 Crop Inventory indicates that 42% of the watershed is used for *annual* crops, with wheat (17%), barley (12%), and canola (11%) being the dominant crops (Table 16). Peas, oats, lentils, flax, corn, mustard seed, vegetables, beans, rye, and sunflowers also occur in small amounts (all <1% of the watershed). Fallow land in 2011 was estimated at 1% of the watershed. An additional 12% of the watershed is used for perennial hay crops and tame pasture[22]. Sub-watersheds with the most cropland are all located in the Central Agricultural landscape unit, with the highest amount of cropland located in the Kneehills, Rosebud, and Threehills sub-watersheds.

Irrigated crops occur in southern and eastern parts of the watershed. Irrigation is focused on lands serviced by the Western Irrigation District (WID) in Rocky View County and Wheatland County, as well as lands serviced by the Eastern Irrigation District (EID) in the County of Newell. Both the WID and EID obtain their water from the Bow River. Irrigation return flows from the WID enter the Rosebud River at several locations and subsequently the Red Deer River. Substantial irrigation return flows also enter the Red Deer River from the EID lands north of Brooks. There is also smaller private irrigation along much of the Red Deer River downstream from Content.

The 2006 federal Census data includes a large amount of information on farming activities. Appendix B summarizes selected variables from this database, including information on[23]:

- Number of farms reporting the use of buffer zones around water bodies
- Area over which chemical fertilizer is applied (ha)

[22]An additional estimated 25% of the watershed consists of native grassland/rangeland

[23]As estimated from the available 2006 Statistics Canada Ag Census data, based on soil landscape polygons, resampled to RDRWA watershed polygons and assuming an equal distribution of each variable across each soil landscape polygon

- Area over which manure is applied (ha)
- Total expenses of herbicides, insecticides, and fungicides ($)
- Total expenses of fertilizer and lime ($)
- Annual kg of phosphorus in manure from all livestock (kg P / year + converted to kg P/ha/year)

**Table 16. Dominant Crop Types in the Watershed**

| CROPLAND DESCRIPTION | TOTAL AREA ($KM^2$) | % of watershed |
|---|---|---|
| Wheat | 8721.17 | 17.3% |
| Hay/Pasture* - Perennial Crops / Tame Pasture | 6246.53 | 12.4% |
| Barley | 6118.91 | 12.1% |
| Oilseeds – Canola/Rapeseed | 5297.50 | 10.5% |
| Fallow | 521.99 | 1.0% |
| Pulses – Peas | 275.22 | 0.5% |
| Oats | 56.78 | 0.1% |
| Lentils | 47.00 | 0.1% |
| Flaxseed | 42.92 | 0.1% |
| Corn | 41.46 | 0.1% |
| Oilseeds – Mustard | 32.46 | 0.1% |
| *TOTAL – ALL ANNUAL CROPS* | 21,192 | 42% |
| *TOTAL-ALL CROPS INCLUDING HAY* | 27,438 | 54% |

*crop types <0.05% were not included in the above summary

*5.3.3.2 Livestock*

Estimates of livestock populations in the RDRB State of the Watershed report (Aquality 2009) include:

- >2.2 million cows (including calves)
- >700,000 pigs
- >3 million chickens
- >130,000 turkeys

Figure 26 shows the distribution of large intensive livestock operations throughout the watershed, as well as total annual phosphorus in manure from all livestock in kg P/ha/year[24]. Appendix B summarizes the amount (kg) of P in manure for each landscape unit and sub-watershed.

The main livestock of concern to watershed values are typically cattle and swine operations (AEC 2009). Areas with particularly high cattle densities surround Brooks in the Matzwhin sub-watershed, Acme and Linden in the Kneehills sub-watershed, as well as north of Strathmore in the Rosebud sub-watershed, and around Rimbey in the Blindman sub-watershed (Figure 26). Dairy cattle operations >100 animals are shown in Figure 26. These are concentrated around Linden in the Kneehills sub-watershed, as well as

[24]As estimated from the available 2006 Statistics Canada Ag Census data, based on soil landscape polygons

the Blindman sub-watershed just east of Gull Lake, and lower portions of the Medicine River sub-watershed. Dairy operations tend to be smaller in size (e.g., <700 animals) compared to beef cows. However, due to washing requirements, dairy cows produce an average of 139 pounds of manure per cow per day, over 17 times higher than beef cattle (Trevor Wallace, personal communication).

Swine operations are also concentrated near Linden and Acme, as well as over 13 locations with >3,000 pigs located just east of the City of Red Deer (Figure 26). Pigs produce an average of over 86 lbs of manure per day (Trevor Wallace, personal communication).

The largest "hotspot" for total manure production from livestock occurs near Brooks, with other major hotpots in the central portions of the Rosebud and Kneehills sub-watersheds, and the central part of the Medicine River sub-watershed (Figure 26). On a per hectare basis, the Blindman, Waskasoo, Kneehills, and Rosebud sub-watersheds contain the highest intensity of manure production (Appendix B). However, the highest total mass (kg) of P from manure is produced in the Rosebud, Matzhiwin, and Little Red sub-watersheds (Appendix B).

### *Feedlots*

Feedlots are considered to be potentially significant contaminant sources due to considerable manure production and related management and storage requirements. Locations of large feedlots were provided by Agriculture Canada and presented in Figure 26. The largest feedlot near Brooks has an animal capacity of 55,000. There are over 11 cattle feedlots with 10,000-50,000 capacity in the watershed and many more with 1,000-10,000 capacity (Figure 26).


**Figure 25. Large Feedlot, 9 km W of Carbon, Alberta, Rosebud River Sub-Watershed**

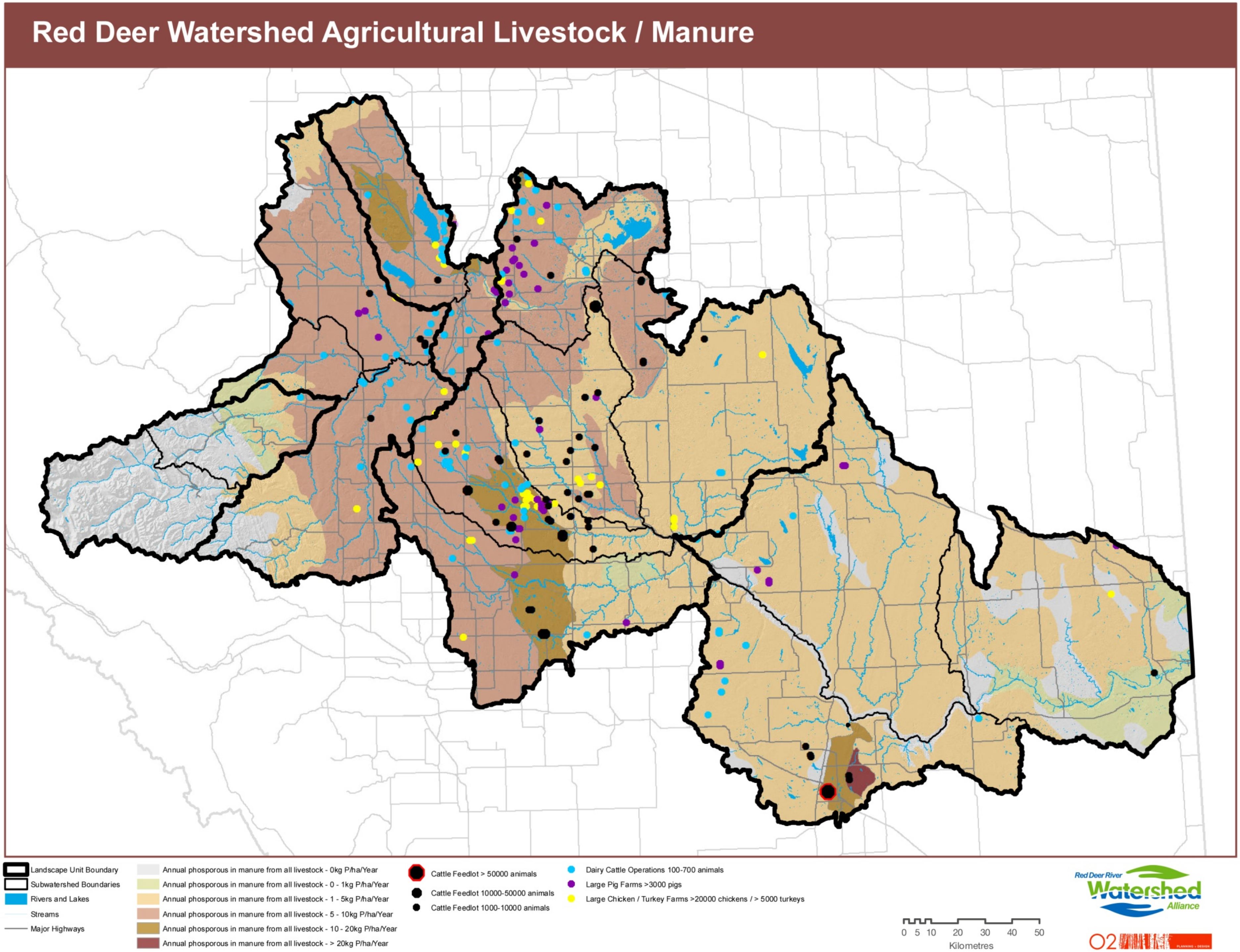


**Figure 26.** **Map of Agricultural Livestock Intensity in the Red Deer Watershed**

### 5.3.4 *Forestry*

Forestry dominates land use in the James sub-watershed, and several other parts of the headwaters (Figure 21). The two major areas of forestry activity include Forest Management Agreement (FMA) area R10 and FMA B9. The operator in FMA R10 is Sundre Forest Products, while the operator in FMA B9 is Spray Lakes Sawmills.

Data from the Alberta Biodiversity Monitoring Institute (ABMI) was obtained and used to summarize information on cutblock locations in the watershed (ABMI 2010). These estimates indicate approximately 598 $km^2$ of cutblocks in the Red Deer watershed overall, constituting about 1.2 % of the entire land base. Cutblocks are concentrated in the Upper Headwaters, where over 8% of the landscape consists of cutblocks. The sub-watershed with the highest proportion of cutblocks is the James sub-watershed in the Upper Headwater (14% cutblocks). The Lower Headwaters also contain over 263 $km^2$ of cutblocks, constituting about 3.5% of the entire land base in this landscape unit.


**Figure 27. Cutblocks near Burnstick Lake, Upper Headwaters**
(note extensive oil and gas activities as well)

### 5.3.5 *Recreation and Tourism*

Recreation and tourism activities occur in many parts of the watershed, including in provincial parks and recreation areas, public forested lands and private lands. Recreation and tourism features have not been systematically inventoried in the watershed. However, some of the well known activities in the Upper Watershed include backcountry skiing at Skoki Lodge in Banff National Park, camping, horseback riding in the Ya-Ha-Tinda Valley, backcountry hiking, scrambling, fishing, hunting, and off-road vehicle use. Considerable off-road vehicle use, random camping, and increased angling pressure have also been identified as concerns in the headwaters (Fitzsimmons, 2012). Recreation and tourism in other parts of the watershed are focused in particular areas including Gleniffer Lake, Sylvan Lake, Pigeon Lake, Pine Lake, Buffalo Lake, the Red Deer River Valley (including Waskasoo Park), Drumheller, and Dinosaur Provincial Park.

### 5.3.6 *Industry*

Information on industrial activities was obtained from provincial databases (IHS, 2012)[25]. Oil and gas wells, pipelines, and gas plants occur extensively throughout the watershed, but are concentrated in certain areas. Figure 28 indicates the density of oil and gas wells in the watershed. Details of oil and gas related activities in the study area are presented in Table 17. Figure 21 indicates the locations of gas plants in the watershed, which are concentrated in areas of gas extraction. Appendix B includes information on oil and gas facilities split by sub-watershed and landscape units. Well site density is highest in the Dry Grasslands landscape unit, with particularly high gas well densities in a large proportion of the Matzhiwin sub-watershed.

**Table 17. Oil and Gas Facilities and Wells in the Watershed**

| Facility / Well Type | Total # |
|---|---|
| **Oil and Gas Facilities (IHS 2012)** | |
| Battery | 15,544 |
| Compressor Stations | 1,440 |
| Gas Plants-Operating | 162 |
| Other | 3,487 |
| Total-Facilities | 20,633 |
| **Oil and Gas Wells (IHS 2012)** | |
| Abandoned | 26,146 |
| Conventional Gas (flowing + pumping) | 39,053 |
| Coalbed Methane Gas (Flowing + Commingled CBM + Other) | 16,140 |
| Oil wells (flowing + pumping) | 6,797 |
| Other/ Miscellaneous (includes "Commingled, Standing, etc.) | 41,905 |

There are over 130,000 oil and gas wells, of which 103,895 (80%) are active (IHS 2012). Conventional gas is the dominant industrial activity in the watershed, followed by coal bed methane, and conventional oil. There are over 200 separate industrial entities operating oil and gas facilities in the watershed. The primary industrial operators in the watershed are listed in Table 18.Major facilities and spatial patterns of the oil and gas industry in the watershed include:

- *Joffre Petrochemicals Site:* The Nova Chemicals plant site at Joffre is one of the largest ethylene and polyethylene manufacturing complexes in the world. This industrial complex, located 16 km east of the City of Red Deer, occupies almost 2 $km^2$ of land. The Union Carbide plant site 8 km NW of Joffre occupies an additional 1 $km^2$ of land.
- *Conventional Gas:* Conventional gas extraction dominates industrial activity in the watershed. Although the activity occurs throughout the watershed, it is concentrated in particular north and northeast of Brooks, as well as in the County of Stettler, and Clearwater County west of the Town of Eckville. Some sour gas (containing $H_2S$) is also located in some areas, including the Rosebud River sub-watershed, as well as near Sundre and just east of the City of Red Deer.

[25] Including the IHS_OilGas Wellsites, the IHS_Facility_Point, and the IHS_Pipelines layers

- *Coalbed Methane:* Unconventional coalbed methane gas extraction has occurred almost exclusively in the "Central Agricultural" landscape unit of the watershed. This is a relatively new industrial activity in the watershed.
- *Crude oil:* Oil production is concentrated in the Lower Headwaters of the watershed. Two recent pipeline leaks have occurred in this part of the watershed (see box). Localized oil fields and associated production occur in other parts of the watershed as well.

**Table 18. Major Oil and Gas Companies Operating in the Watershed (IHS 2012)**

| >400 wells | 250-400 wells | 200-250 wells | 100-200 wells |
|---|---|---|---|
| Encana Corporation | Husky Oil Ltd. | Pengrowth Corporation | 981384 Alberta Ltd. |
| Cenovus Energy Inc. | Canadian Natural Resources Ltd. | Direct Energy Marketing Ltd. | Quicksilver Resources Canada Inc. |
| EOG Resources Canada Inc. | Taqa North Ltd. | ConocoPhillips Canada Corp. | Nuvista Energy Inc. |
| Apache Canada Ltd. | Penn West Petroleum Ltd. | Anderson Energy Ltd. | Arc Resources Ltd. |
| | Bonavista Petroluem Ltd. | NAL Resources Ltd. | Harvest Operations Corp. |
| | | | Enermark Inc. |

**RECENT OIL PIPELINE LEAKS IN THE WATERSHED**

Two separate oil pipeline spills in the headwaters have occurred in recent years:

***June 2008 Pembina Pipeline Corp. Spill*:** High flows in the Red Deer River caused erosion that freely exposed a section of Pembina Pipeline Corporation's Cremona crude oil pipeline. About 75 to 125 barrels of crude oil were released, leaving an oily sheen on Gleniffer Reservoir and 6,800 kilograms (15,000 lbs) of oil-soaked debris. The remediation was not completed until 2011.

***June 2012 Plains Midstream Spill:*** Heavy rains in early June 2012 caused a similar but larger break on a 46-year-old pipeline owned by Plains Midstream Canada. The spill leaked approximately 1,000-3.000 barrels (160,000 – 475,000 litres) of light sour crude oil into the Red Deer River.

### *5.3.6.1 Aggregate Mining*

Available provincial GIS data indicates that there are over 220 gravel / sand pits throughout the watershed, covering a total area of over 14 km$^2$ (although portions of this area are likely to have been reclaimed). Due to the nature of these alluvial sand and gravel deposits, the majority of these mines occur close to streams and rivers. For example, two large mines occur along the Red Deer River just upstream from The City of Red Deer.

Recently, AESRD reported that, under the *Code of Practice for Pits*, the Red Deer regional office has 253 pit registrations on file (more than any other regional office in the province), but only 19 reclamation certification applications (AESRD 2013 Pit Education Sessions).

It may be desirable to probe and prioritize the risks posed by individual aggregate mines with a supplementary study.

#### *5.3.6.2 Linear Developments*

Surface linear footprints such as roads and railways were kept separate from subsurface linear footprints (i.e., pipelines), due to the differing nature of impacts and risks associated with these two types of linear footprint. Information on both linear footprint types is summarized in Appendix B.

A query and statistical GIS summaries of the IHS (2012) data show that oil and gas pipelines in the watershed cover a total length of there are 78,000 km. Pipeline density ranges from a low of 0.12km/km$^2$ in the Panther sub-watershed to a high of 2.48 km/km$^2$ in the Matzhiwin sub-watershed.

A query of all publicly available GIS data indicates that roads and railways in the watershed cover a total length of about 35,000 km. Surface linear density ranges from a low of 0.07 km/km$^2$ in the Panther sub-watershed to a high of 1.26 km/km$^2$ in the Central Urbanizing sub-watershed.

#### *5.3.6.3 Other Industrial Activity*

Readily available information on other industrial activities is provided in Table 19.

**Table 19. Other Industries in the Watershed**

| **Industry Type** | **Major Facilities and Locations** |
|---|---|
| Coal Mining and Coal-Fired Power Plants | South of Hanna, AB along Hwy. 36 |
| Fertilizer Plants | Benalto, Beiseker, Olds, Drumheller<br>(likely incomplete list) |
| Food Processing / Bottling / Meat Packing Plants | XL Foods meat packing plant, Brooks<br>Olymel pork / poultry meat plant, City of Red Deer<br>Armstrong Cheese Co., City of Red Deer<br>etc. |
| Industrial Parks | Edgar Industrial Area, Red Deer<br>Riverside Heavy Industrial Park, Red Deer<br>In Red Deer, 183 ha of industrial land was absorbed and developed since 1995<br>Insulation Factory, Innisfail<br>etc. |
| Peatland Harvesting | West of Olds, AB |

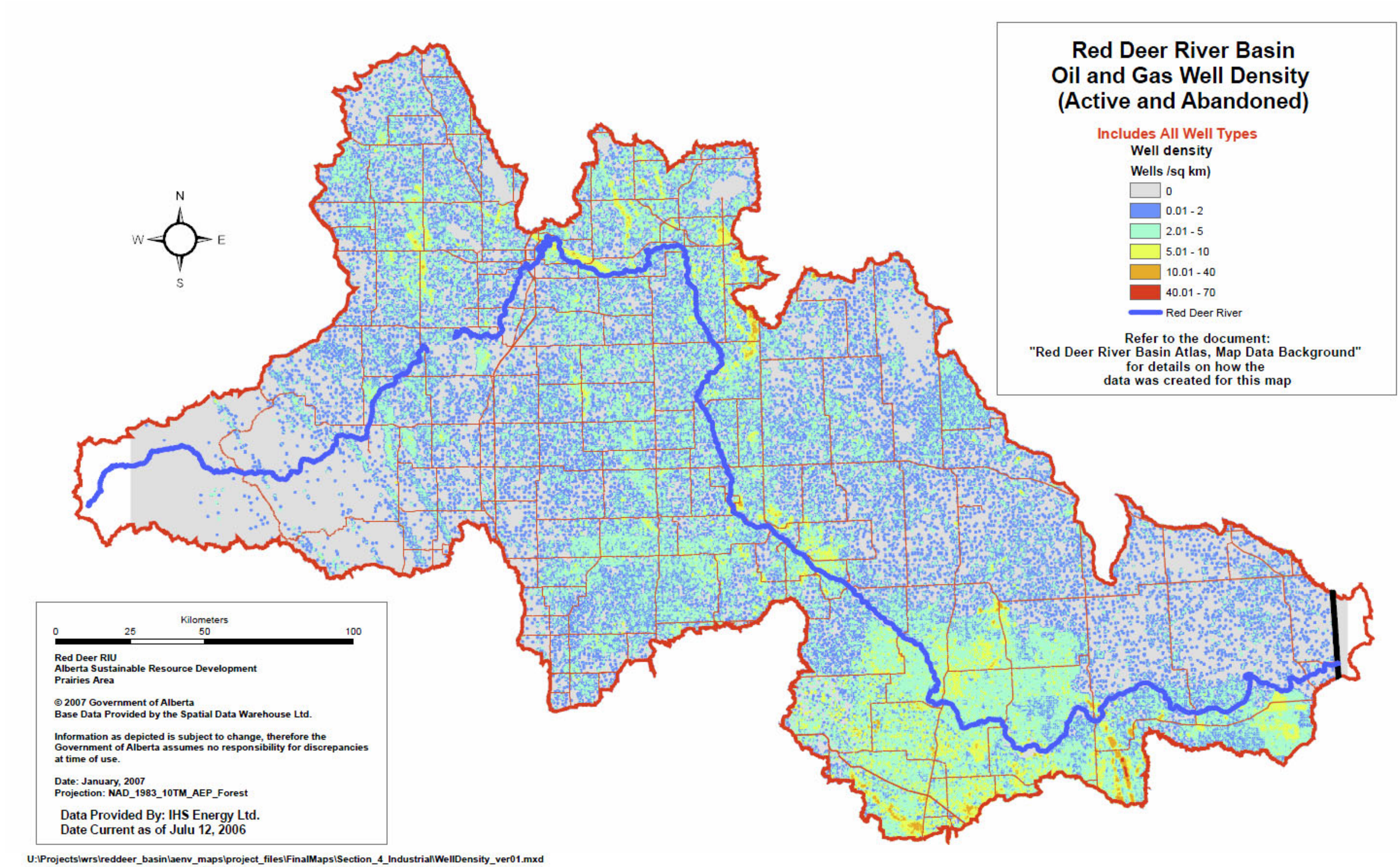


**Figure 28.** **Map of Oil and Gas Well Density (Active and Abandoned)** *(RDRWA, 2007)*

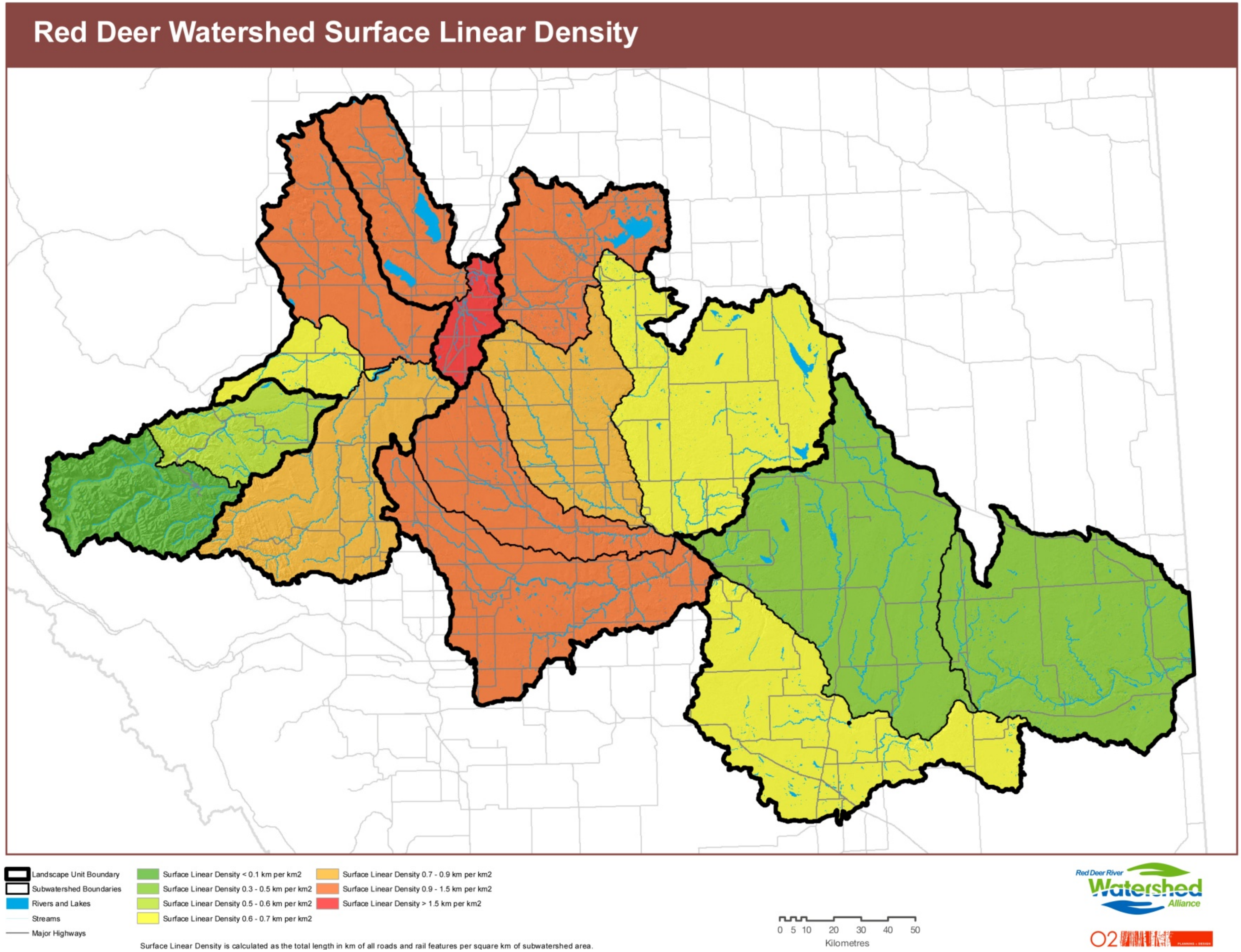


**Figure 29.** **Map of Surface Linear Density in Sub-Watersheds of the Red Deer River Watershed**

### 5.3.7 *Parks / Protected Areas*

Parks and protected areas in the watershed are mapped on Figure 21. Approximately 3.1 % of the watershed consists of parks and protected areas. Banff National Park covers over 1,027 $km^2$ in the Upper Headwaters. There are 57 provincial parks and protected areas in the watershed, including 10 Provincial Parks, 1 Wildland Provincial Park, 26 Natural Areas, 17 Public Recreation Areas, 2 Ecological Reserves, and 1 Wilderness Area. A portion of the lower Red Deer River valley including Dinosaur Provincial Park and some limited surrounding areas are designated a UNESCO World Heritage Site. Table 20 and Table 21 summarize information on parks and protected areas in the watershed.

The largest provincial park is the Rumsey Natural Area and adjacent Rumsey Ecological Reserve (~185 $km^2$ combined) near Big Valley[26]. Other notable parks in the watershed include Dinosaur Provincial Park, the north edge of the Don Getty Wildland Provincial Park, the Tolman Badlands Heritage Rangeland Natural Area, the Hand Hills Ecological Reserve, and Dry Island Buffalo Jump Provincial Park.

The Waskasoo Park system in Red Deer includes an additional 994 ha (9.9 $km^2$) of municipal parkland. Other municipal parks in the watershed are not included in this summary, but tend to be relatively small (<10 ha each).

**PRESCRIBED BURNS IN PROTECTED AREAS**

A prescribed fire is an intentional fire planned and managed by fire specialists. Parks Canada conducts prescribed burns in the uppermost portions of the watershed to restore ecological integrity and natural processes in Banff National Park. The province has been known to conduct prescribed burns as well. Although these activities are planned and conducted carefully, it is possible that they may generate risks to watershed values downstream.

Forest fires impact water quality due to sediment input of the ash and soot, loss of organic matter on the forest floor, and chemical changes to surface and groundwater. This has recently been extensively studied in the “Lost Creek” wildfire studies in southwestern Alberta (Emelko et al. 2011; Bladon et al. 2008). Far more contaminants of concern were exported downstream from burned watersheds than unburned watersheds, while burned watersheds subsequently salvage logged had the highest rates of contaminant export. Highlights included:

- Turbidity measured in streams ($95^{th}$ percentile) was 3x higher in burned watersheds
- Over 6.5x as much nitrate ($NO3^-$) exported downstream from burned watersheds in the first year
- Over 4.1x as much dissolved organic nitrogen (DON) exported downstream in the first year
- Observed increases in contaminants such as nutrients, heavy metals, and chlorophyll-a
- Increases were particularly elevated during snowmelt freshet as well as during storm flows
- A rapid decline in mean concentrations of many nutrients three years after the fire, although high contaminant loads were still exported during major snowmelt or precipitation events

For small fires, major water quality impacts are generally insignificant at broader scales. However, large-scale fires that burn a large proportion of a watershed’s area can increase Total Suspended Solids (TSS), nitrogen and phosphorus export downstream (Emelko et al. 2011; Bladon et al. 2008).

[26] Note that some drilling for gas has been allowed in this park

**Table 20. Parks and Protected Areas in the Watershed**

| Park / Protected Area | Notes (Location, Landmarks, etc.) | Area Within Watershed (ha) | % of Entire Watershed |
|---|---|---|---|
| Banff National Park | Upper Headwaters, upstream of Ya Ha Tinda Valley | 102,665 | 2.1% |
| Rumsey Natural Area | Central Agricultural, near Big Valley | 15,133 | 0.3% |
| Dinosaur Provincial Park | Dry Grasslands, Red Deer Valley NE of Brooks<br>UNESCO World Heritage Site | 8,076 | 0.2% |
| Don Getty Wildland Provincial Park | Upper Headwaters south edge, and small portion of Lower Headwaters | 5,981 | 0.1% |
| Tolman Badlands Heritage Rangeland | Central Agricultural, Red Deer Valley upstream of Drumheller | 5,756 | 0.1% |
| Rumsey Ecological Reserve | Central Agricultural, near Big Valley | 3,434 | 0.1% |
| Hand Hills Ecological Reserve | Dry Grasslands,<br>East of Drumheller | 2,312 | <0.1% |
| Dry Island Buffalo Jump Provincial Park | Central Agricultural, Red Deer Valley East Of Trochu | 1,588 | <0.1% |
| Waskasoo Park* (City of Red Deer) | Centrepiece of City of Red Deer park system | 994 | <0.1% |
| Midland Provincial Park | Central Agricultural, Red Deer Valley near Drumheller (adjacent to Royal Tyrell Museum) | 616 | <0.1% |
| Scalp Creek | Near Banff National Park | 394 | <0.001% |
| Other | Mean size of all remaining parks is 64 ha<br>Most are located in the upper and lower headwaters | 3,051 ha | 0.06% |
| *TOTAL* | - | 149,006 ha | 3.1% |

*This table does not include any smaller municipal parks and protected areas
**Source: ATPR (2012)

**Table 21. Protected Areas as a Proportion of Each Landscape Unit**

| Landscape Unit | Total # Of Protected Areas | Total Area of Protected Areas (km2) | % of Landscape Unit |
|---|---|---|---|
| Upper Headwaters | 17 | 1084.9 $km^2$ | 28.7% |
| Lower Headwaters | 20 | 19.0 $km^2$ | 0.3% |
| Central Urbanizing | 9 | 11.6 $km^2$ | 0.8% |
| Central Agricultural | 14 | 269.1 $km^2$ | 1.5% |
| Dry Grasslands | 4 | 105.4 $km^2$ | 0.6% |
| ***ENTIRE RED DEER WATERSHED*** | *58* | *1490.1 $km^2$* | *3.1%* |

## 5.4 Red Deer Watershed Land Use Goals and Outcomes

Table 22 outlines draft management goals and outcomes for land use in the Red Deer Watershed.

**Table 22. Draft Management Goals and Outcomes for Land Use**

| DRAFT MANAGEMENT GOALS | DRAFT OUTCOMES FOR LAND USE |
|---|---|
| LG1. Land uses are located and managed in ways that do not result in unacceptable impacts to water quality, water quantity and aquatic ecosystem health | LO1. Public and private lands are managed with source water protection as a high priority |
| | LO2. Ecological infrastructure (including wetlands, riparian areas, alluvial aquifers, native vegetation, steep slopes) is conserved and integrated when planning and managing land uses |
| | LO3. Particular attention is paid to the headwaters and other highly sensitive areas when planning and managing land uses |
| LG2. Planning, approval and management of land use and human activities in the watershed are aligned to achieve watershed management objectives | LO4. The RDRWA collaborates with provincial and municipal government agencies and other groups to facilitate efficient resourcing and delivery of watershed protection programs and services |
| | LO5. Cumulative effects management, risk mitigation, and integrated land management principles are applied to land management decisions |
| | LO6. Partnerships between individuals, community groups, businesses and government agencies are cultivated to achieve plan goals and objectives |
| LG3. Educational opportunities are provided to identify ways to contribute to a healthy watershed | LO7. Watershed functions and ecological services are better understood by residents, governing agencies, First Nations and stakeholders |
| | LO8. Appropriate actions to maintain a healthy watershed environment are taken by individuals, municipalities, developers, industry, farms, etc. |
| | LO9. People recognize that a healthy economy depends on a healthy watershed |
| LG4. Knowledge of land uses and watershed functions increase over time | LO10. Knowledge of how land uses impact the watershed is enhanced, as well as Beneficial Management Practices to mitigate impacts |

## 5.5 Proposed Indicators and Targets for Land Use

This section discusses and proposes indicators and targets for land use in the Red Deer River watershed. The targets are intended to provide a baseline to reference to future watershed management decisions. Draft targets have been specified in tables. Justifications for proposed indicators and targets are also provided. Additional indicators for consideration are also discussed in Appendix A.

### 5.5.1 *Natural Land Cover*

Natural terrestrial land cover types have hydrologic benefits. Forests encourage infiltration, prevent erosion, stabilize slopes, and reduce watershed pollutant loadings. These functions often have substantial economic benefits as well. An analysis of communities in the United States found that watersheds covered by at least 60% forest typically require less than half the water treatment costs than watersheds with 30% forest cover, and only one-third the cost of watersheds with only 10% forest cover (Postel & Thompson, 2005). Native grasslands and shrublands help conserve pre-development hydrology and watershed health due to deep root systems that encourage infiltration during rainfall, high surface litter that influences evapo-transpiration and traps wind-blown snow, and soil organic matter that provides a high water-holding capacity (Naeth et al., 1991; Self-Davis & Moore, 2003).

In addition, riparian conservation and best practices are necessary but likely insufficient for high watershed health. Studies on Midwestern streams in the US found that “local riparian vegetation was a weak secondary predictor of stream integrity,” whereas land use in the catchment was more important and even “able to overwhelm the ability of local site vegetation to support high-quality habitat and biotic communities” (Roth et al., 1996).

Natural land cover targets (Table 23) were based on existing baseline conditions. It has been assumed that no further net loss of natural areas is highly desirable for both watershed health and biodiversity considerations. However, the implementation of BMPs that increase the amount of natural riparian areas (see Chapter 4) is also considered a priority particularly for the Lower Headwaters.

**Table 23. Draft Targets / Baseline Conditions for Natural Land Cover**

| Watershed-Based Landscape Unit | Natural Land Cover Targets (%) |
|---|---|
| Entire Watershed | >44% |
| Upper Headwaters | >87% |
| Lower Headwaters | >37% |
| Central Urbanizing | >24% |
| Central Agricultural | >23% |
| Dry Grasslands | >63% |

*Baseline cover is the % value listed, and the target is to increase from the baseline number over time
**More detailed tables for each of the 15 sub-watersheds as well as wetland type can be found in Appendix B

### 5.5.2 *Impervious Areas*

Several studies suggest that watershed imperviousness >10% represents a threshold where conditions of water quality, stream channel stability, and stream biodiversity deteriorate rapidly; a second threshold at >25% has been identified, where channels become highly unstable and water quality typically very poor (Leitao & Ahern, 2002; CWP, 2001). However, impacts at lower levels are also present. One recent study found stream stability and biodiversity decreased rapidly in watersheds with > 5% impervious area (Fitzgerald et al., 2012). Reducing stormwater runoff can be accomplished with Low Impact Development (LID) green infrastructure that captures and retains stormwater close to the source, including the use of rain gardens, bio-swales, green roofs, street trees, stormwater reuse, constructed wetlands and stormwater ponds, pervious pavement, etc.

All municipalities should aim to minimize permanent loss of agricultural or natural lands due to future development of residential, industrial, commercial, and other developments, as well as to increase density. However, since extensive urban areas are absent from most of the watershed, targets for imperviousness are only recommended for areas with extensive urban development (Table 24).

**Table 24. Draft Imperviousness Targets**

| Area | Baseline Estimate* | Targets (%) |
|---|---|---|
| Central Urbanizing Watersheds | 2-3% | <5% |
| Waskasoo | 4-5% | <10% |
| Blindman | 1.5-2.5% | <5% |

*Approximate conditions using available 2011 satellite data products, based on an assumption of 50% imperviousness in urban areas which is typical for Alberta (O2, 2009b)

### 5.5.3 *Livestock Intensity*

The indicator selected for livestock intensity is the average kg P / ha / year in manure from all livestock (Table 25). This variable is compiled by Statistics Canada/Agriculture Canada and updates should be available every 5 years, although GIS processing is required for reporting purposes by sub-watershed. The variable represents manure intensity in the watershed as well as potential loadings of nutrients and pathogens found in manure. However, this indicator must be interpreted with care. It is not necessarily livestock intensity per se that is an issue, but rather the amount of phosphorus or pathogens mobilized into surface waters, which depends on landscape factors and BMPs. Therefore, this indicator should be interpreted in tandem with the susceptibility of the landscape to contaminant mobilization[27] as well as the degree and effectiveness of BMPs implemented by producers.

BMP adoption by feedlot and cow-calf producers should continue to be a key focus of the RDRWA, perhaps focused in areas of higher risk to surface water quality. This may be especially important in areas such as the Lower Headwaters, which have high livestock intensities and are upstream from a major municipal water supply for the City of Red Deer.

[27] See Chapter 6 for a more detailed analysis of landscape factors leading to surface water quality risk

**Table 25. Baseline Conditions and Draft Targets for Livestock Intensity**

| Watershed-Based Landscape Unit | Livestock Intensity (average kg P / ha / year) | |
|---|---|---|
| | Baseline Conditions* | Draft Targets |
| Entire Watershed | 4.4 | - Maintain baseline conditions if feasible<br>- Implement BMPs for all livestock operations<br>- As feasible, restrict livestock from areas with the highest risk of contaminant mobilization in manure to surface waters and/or implement more aggressive and widespread BMPs in sensitive high risk areas (see Chapter 6) |
| Upper Headwaters | 0.7 | |
| Lower Headwaters | 6.0 | |
| Central Urbanizing | 8.4 | |
| Central Agricultural | 3.8 | |
| Dry Grasslands | 2.4 | |

*These estimates represent baseline (2006) conditions. They represent area-weighted calculations of available 2006 agricultural census polygons; and assume an equal distribution across each federal soil landscape polygon; further details for each sub-watershed are in Appendix B.

### 5.5.4 *Linear Development*

Targets for linear development density for the watershed management plan should be based on the potential impacts of roads on water quality and watershed dynamics, aquatic habitats and organisms, and terrestrial biodiversity as well. Although biodiversity issues will be examined in greater detail in Phase 4 of the IWMP, it is worth noting several available studies relevant to the Alberta context on linear road density targets and thresholds. Regression analysis in the Battle River watershed in central Alberta indicates that road densities at a sub-watershed scale of about 0.7 $km/km^2$ impaired the integrity of fish communities (Stevens & Council, 2008). Healthy bull trout populations (a sensitive species) in the Upper and Lower Headwaters of the watershed may require a more stringent target of about 0.28 to 0.87 $km/km^2$ (Fitzsimmons, 2012; JCWP, 2012). Smith-Fargey (2004) noted that in grassland areas, a road density of <0.5 $km/km^2$ is considered to be in “good” condition. High road densities also impact grizzly bear, which will be examined in greater detail in Background Technical Report Number 4 of the IWMP, which is intended to address biodiversity.

The 2012 Jumping Pound Creek IWMP specified that road density should not increase substantially above the "current density" of 0.40 $km/km^2$. A similar approach was taken here, where existing road densities in each landscape unit were specified as current density targets to maintain into the future. However, it is acknowledged that if urban development occurs, it may be difficult to retain existing linear development densities and some changes may be inevitable.

**Table 26. Draft Targets / Baseline Conditions for Surface Linear Density***

| Watershed-Based Landscape Unit | Surface Road + Rail Density (km/km$^2$) |
|---|---|
| Entire Watershed | 0.40 |
| Upper Headwaters | 0.25 |
| Lower Headwaters | 0.82 |
| Central Urbanizing | 1.26 |
| Central Agricultural | 0.83 |
| Dry Grasslands | 0.51 |

*If necessary, "open route density", a separate indicator that also includes seismic lines, could also be considered

### 5.5.5 *Social and Programmatic Indicators*

**Table 27. Proposed Social and Programmatic Indicators for Land Use[28]**

| Grouping | Indicator | Target |
|---|---|---|
| Municipal | Percentage of municipalities in the watershed that have adopted a policy, guideline, or bylaw for watershed conservation, addressing avoidance of ecological infrastructure, landscape connectivity, and relevant BMPs (e.g., stormwater management including discharge rates and annual volume targets for urban areas, agricultural practices in rural municipalities, etc.) | 100% of municipalities |
| | Percentage of municipalities in the watershed that have taken steps to minimize consumption of land for permanent urban or industrial land uses within their Municipal Development Plan (MDP) or through other means | 100% of municipalities |
| | Percentage of municipalities that require Erosion and Sediment Control (ESC) Plans be planned, designed, and implemented for new developments, including random inspections by qualified staff | 100% of municipalities |
| | Percentage of municipalities in the watershed that have adopted a performance management system (e.g., inventories, indicators, targets) to evaluate progress towards watershed management goals and potential "stop work" orders for non-compliance | 100% of municipalities |
| | Number of Low Impact Development (LID) stormwater projects installed | e.g., Increase over time (potentially partner with the ALIDP to measure and report on quantities) |
| | Percentage of Inter-Municipal Development Plans that address watershed management and landscape connectivity principles | 100% of Inter-Municipal Development Plans in the watershed |
| | Percentage of municipalities with water conservation management plans | 100% of municipalities |
| Provincial Regulatory Bodies | Percentage of decisions made by provincial regulatory bodies that include steps to address, as applicable: (i) watershed cumulative effects, (ii) erosion and sediment control plans, (iii) Low Impact Development, and (iv) Integrated Land Management principles | 100% of all land use decisions made by provincial regulatory bodies incorporate these considerations |

[28] Some of the ideas and wording were adapted from BRBC (2012)

| Grouping | Indicator | Target |
|---|---|---|
| Watershed Stewardship Groups | Amount of support to local WSGs including programs, funding, in-kind and technical support, policy development, etc. | Increase amount of financial support provided to WSGs |
| | Number of restoration and conservation pilot projects undertaken by WSGs | Increase the number of restoration and conservation pilot projects undertaken by WSGs |
| | Number of workshops undertaken by WSGs and attendance | e.g., 3 workshops per year with attendance of >30 people at each workshop |
| Agriculture | % of farms using grassed buffers as a BMP<br>(see Riparian Chapter) | >50% of farms reporting use of grassed buffers by 2016 |
| Gravel / Sand Extraction Industry | Ratio of pit registrations to reclamation certification applications for pits under the *Code of Practice for Pits*<br>*(# reclamation applications : # of pit registrations)* | Improve from baseline (1:13)<br>Draft target is 1:10 in short term and 1:5 in long term |
| | Support the implementation of the new provincial aggregate policies | 100% support and implementation of the new policies |
| Oil and Gas Industry | Number of operators certified and actively using the ISO 14001 Environmental Management System or similar standards | 100% of oil and gas operators |
| | Number of operators conducting annual reviews of standard operating procedures for possible changes due to new legislation and policies, BMPs, or recommendations from new applied research | 100% of oil and gas operators |
| | Number of pipeline operators implementing proactive, aggressive monitoring systems to detect structural issues in a manner that will considerably reduce the risk of future spills and/or blowouts | 100% of pipeline operators |
| Forestry | Number of major forestry operators certified to CSA –Z809 Forest Certification Standard or ISO 14001 | 100% of all forestry certified |
| | Annual review of Operating Ground Rules for possible changes supported by new legislation and policies, BMPs, or recommendations from new applied research | 100% |
| All sectors | Awareness among landowners of riparian issues increases | e.g., 30% increase over 10 years |

## 5.6 Management Implications and Recommendations

The following recommendations relate specifically to land use in the Red Deer River watershed. Recommendations are listed under three main categories: monitoring and data acquisition, research needs, and recommendations related to key Beneficial Management Practices (BMPs).

### 5.6.1 *Monitoring and Data Acquisition*

As previously noted in this document, a key recommendation is to ***Establish an Integrated Monitoring and Reporting Framework.*** A single integrated monitoring and reporting framework is required to track and report progress against established indicators and targets, including those related to land use. Regular reporting on indicators should be in a consistent format and databases should be maintained over time. Clear, meaningful, and measurable milestones for the plan and its implementation are required (Davenport, 2003). This database will be key for performance monitoring over time and adaptive management. Developing, implementing, and maintaining this framework will be a key component of the IWMP that requires close and on-going cooperation among agencies, stakeholders and partners and a clear definition of roles and responsibilities (Anderson, 2012). It is recommended that this framework take the form of a Watershed Cumulative Effects Management System (WCEMS) (Patrick & Noble, 2012).

Other, more specific monitoring and data acquisition actions recommended include:

- ***Point Sources from Urban and Industrial Outfalls:*** Industries and municipalities have been required to document the quality and quantity of their effluent. It is recommended that this information be obtained through the comprehensive water quality monitoring project currently being initiated by AESRD .
- ***ABMI human footprint layers*:** These are freely available GIS data products. Currently, layers have been completed for half the watershed, and additional releases are expected shortly.
- ***Seismic lines:*** Compile additional information on seismic lines
- ***Water Quality-Land Use Linkages in Research and Policy:*** Evaluate water quality results in relation to upstream point and non-point sources. Expand monitoring to areas with water quality concerns. Develop action plans to reduce loading from these sources.
- ***Updated Agricultural Census Data (2013):*** Data from the 2011 census will be available from Agriculture Canada in geospatial formats in spring 2013 (Bahram Daneshfar, personal communications).
- ***Country Residential Developments:*** Assemble information on all country residential developments and/or major country residential nodes from individual municipalities in the watershed

### 5.6.2 *Research Needs*

The following outlines key research needs for land use under several categories.

- ***Broad Scale vs. Fine Scale Modelling.*** Continue to conduct fine-scale detailed watershed modelling exercises for high-risk areas, and broad-scale modelling for strategic basin and watershed management and planning.
- ***Establish Total Loading Limits.*** The assimilative capacity of the Red Deer River for Phosphorus, TSS, and potentially other variables should be examined and used to establish total loading limits. The established WQOs provide a good basis for establishing loading limits.

However, apportioning acceptable loadings among point and non-point sources, and appropriately considering natural fluctuations are difficult tasks fraught with uncertainties.

- ***Land Use, BMPs, and Water Quality.*** Link land use and GIS-based indicators to both water quality monitoring and modelling results in an integrated framework. Evaluate monitoring data against water quality model predictions for point and non point source loadings. Further refine models and monitoring where data gaps occur to better refine land use targets and BMP education prioritization for all sectors.
- ***Compile Integrated Point and Non-Point Loading Data:*** Compile municipal and industrial point sources and associated loadings to the Red Deer River and tributaries and tie to water quality objectives
- ***Integrated Hydrologic Models****.* Refine / develop hydrologic models to incorporate future climate change scenarios and water use predictions related to all sectors (e.g., industry fracking, municipal growth, irrigation, etc)
- ***Forestry in the Headwaters.*** Research / refine impacts of forestry activities in the headwaters including riparian management strategies and both short-term and long-term considerations regarding water quality and aquatic health.
- ***Integrated Research on Economics and Optimization.*** There is also a real need for incorporating costs and economics into integrated watershed modelling in order to optimize competing objectives. For example, the INFFER (Investment Framework for Environmental Resources) is being examined by AESRD in the context of the Bow River Phosphorus Management Plan under development. INFFER is used to evaluate and compare projects on the basis of environmental benefits per dollar spent (www.inffer.org) (Roberts et al., 2012).
- ***Coordinate with AESRD Initiatives.*** These activities could potentially be integrated within the ongoing work by AESRD on developing a state of the art modelling tool for the Red Deer River watershed, which is proceeding (Chris Teichreb, personal communication).

**Municipalities**

- ***Review and Harmonize Municipal Policies and Plans.*** Municipal land use bylaws, municipal development plans, and inter-municipal development plans should be reviewed and compiled and compared to best practices for watershed management.
- ***Municipal Environmentally Significant Areas Inventories.*** All cities, towns, and counties should conduct an ESA assessment as per Red Deer County. This should be informed by and coordinated with the provincial-scale ESA inventory.
- ***Impervious Areas and Stormwater Management.*** Better estimate total imperviousness of sub-watersheds and imperviousness areas in high-risk areas (e.g., close proximity to receiving watercourses).
- ***Low Impact Development (LID) in Cold Climates*****.** Continue technical and policy research into the design and performance of LID infrastructure in cold climates.
- ***Septic Sludge.*** Further research is required on the impacts from land spreading of septic waste sludge (BRBC 2012).

**Industry**

- ***Research Impacts of Hydraulic Fracturing.*** Research into the possible effects of hydraulic fracturing on surface and groundwater quantity and quality is required (Anderson 2012). This is currently a major focus of industry.
- ***Research/Evolve BMPs.*** Continue to develop and enhance BMPs and Integrated Land Management approaches for industry through research and practical applications.
- ***Creative Approaches to Subdivision Planning and Design.*** Refer to the document "*Protecting Riparian Areas: Creative Approaches to Subdivision Development in the Bow River Basin: A Guide for Municipalities, Developers, and Landowners.*" (BRBC 2002).

**Agriculture**

- Identify the major source(s) of agricultural contaminant sources in the watershed
- Continue research on agricultural BMP effectiveness for non-point source pollution

**Recreation and Tourism**

- **Recreation and Tourism Features Inventory for the Red Deer.** The province has recently completed several inventories of recreation and tourism information, including a provincial Recreation and Tourism Features Inventory (RTFI)[29]. The RTFI includes spatial information on high density off-road vehicles and random camping areas, which may be useful. The RTFI is currently underway for the Red Deer region and can be used to help prioritize areas for management.

### 5.6.3 *Beneficial Management Practices*

The RDRWA (2009) has conducted detailed reviews and international case studies of BMPs for land use issues. This included sections on crop production, livestock grazing, manure management, forestry, urban stormwater, linear development, oil and gas development, recreation and "new or different approaches." Some key BMPs synthesized / highlighted for this report are summarized below under several general categories.

#### *5.6.3.1 General (All Land Uses)*

***Compliance and Enforcement:*** Effective compliance and enforcement of existing / future regulations and policies is critical.

***Avoid Developing Areas of Ecological Infrastructure:*** Avoid land uses on areas with wetlands, riparian areas, alluvial aquifers, steep slopes, floodplains, native vegetation, Environmentally Significant Areas (ESAs), etc.

[29] O2 completed this work on behalf of ATPR, including the RTFI, the Recreation Opportunity Spectrum (ROS), scenic resource assessments, and the development of a Significant Tourism and Recreation Areas (STREAM) model.

***Apply Integrated Land Management (ILM) Principles.*** ILM is a way of thinking that reduces the footprint of human land use and associated natural resources. It encompasses sharing footprints across industries, reclaiming or re-using footprints, and coordinating developments to minimize new footprints[30]. Although focused on public lands the approach can also be used on private lands.

***Erosion and Sediment Control Practices.*** ESC practices for all land use types include minimizing exposed soils, phasing construction, stabilizing exposed surfaces with a range of measures, filtering sediment-laden flow, and impounding water to allow settling. There is currently a professional designation in Alberta entitled "Certified Professional in Erosion and Sediment Control" (CPESC).

#### *5.6.3.2 Urban and Rural Intensive*

***Low Impact Development and Incentives:*** LID is key to reduce the impacts of intensive commercial, industrial, and residential land uses. LID includes decentralized networks of source control stormwater management facilities such as rain gardens, bioswales, permeable pavement, green roofs, etc. All urban municipalities should adopt LID design standards, construction and maintenance procedures. However, incentives are required for widespread application, including "polluter pays" stormwater utility charges, indirect or direct incentives for green roof construction, or fast-tracking of approvals for LID (O2, 2009b). The Alberta Low Impact Development Partnership should be consulted on LID best practices, knowledge, and experience appropriate for Alberta.

**RED DEER RIVER VALLEYS AND TRIBUTARIES PARK CONCEPT PLAN**

The River Valley & Tributaries Park Concept Plan (RVTPC Plan), completed in 2010, used a series of GIS-based technical analyses combined with a stakeholder design workshop to conceptualize an expanded park system within and immediately adjacent to the City of Red Deer. The Plan includes 3,655 hectares of land (2,889 hectares of Proposed Parkland plus 766 hectares of Special Study Area), 358 km of trails, and 14 park nodes. Included in the plan are lands adjacent to the Red Deer River, Blindman River, Sylvan Creek, Waskasoo Creek, Piper Creek, Hazlett Lake, Cameo Lake, unnamed tributaries, wetlands, sloughs and floodplains (O2, 2010).

***Reduce Sprawl.*** Allocate urban and non-agricultural land uses in appropriate locations at appropriate densities to reduce the consumption of agricultural and natural lands. Use urban growth boundaries on a regional scale to prevent urban and rural sprawl and low density 'leapfrog' development. Within urban and semi-urban municipalities, specify minimum densities for greenfield development, and identify priority areas for redevelopment and rezoning. However, it is not just about density; increased density should be combined with more open space located strategically as well (O2, 2009b; O2, 2007).

***Use statutory plans to adopt watershed management plan principles*.** Imbed watershed management plans and policies within statutory land use planning documents at multiple scales (i.e., Municipal Development Plan, Area Structure Plans, Area Redevelopment Plans, Tentative Plans, etc.).

***Integrate Open Space Planning with Watershed Management.*** Additional open space beyond currently required Municipal Reserve and Environmental Reserve would improve watershed protection. For example, the 6 m ER setback in the *Municipal Government Act* is often interpreted as a fixed width when in fact it is a minimum width and typically municipalities must protect much more than 6 m to "prevent pollution" or provide "public access."

***Conserve Urban Topsoil.*** Require more aggressive plans to conserve urban topsoil during urban development permitting processes (e.g., minimum 300 mm of topsoil for all landscaped areas).

***Revise Land Use Bylaws to reflect water management plan principles*.** Revisions to municipal Land Use Bylaws are one of the most promising avenues for integrating watershed management with land use

[30] http://www.srd.alberta.ca/LandsForests/IntegratedLandManagement/ILMToolbox.aspx

planning. Key leverage points include greater restrictions on floodplain development, district overlay zones to protect special hydrologic zones, changes to parking stall dimensions or parking ratios, and landscaping requirements that emphasize xeriscaping, stormwater reuse, topsoil retention, and maximizing pervious cover in subdivisions and urban and rural industrial parks.

#### *5.6.3.3 Country Residential*

***Encourage Use of Transfer of Development Credits (TDC).*** Further explore TDC programs that allow development potential to be transferred from areas where a community would like more conservation to areas where they would like more development. A TDC program for Red Deer County has been previously investigated (Miistakis Institute, 2006).

***Encourage Land Stewardship and Green Acreages.*** Distribute and encourage green practices on acreages with the "Green Acreages" guide.

***Septic Management and Sludge Management.*** An ongoing education and outreach program is required to ensure country residential property owners are aware of issues with sewage disposal in the watershed and proper maintenance practices. Face to face meetings as well as mail-outs are recommended if resources are available. A template for an information brochure is available from the Regional District of Nanaimo (http://www.rdn.bc.ca/cms/wpattachments/wpID1866atID2664.pdf) but should be adapted to address the unique characteristics of the watershed.

***Other Tools:*** Develop and apply additional tools such as conservation easements, tax benefits, market-based instruments under the *Land Stewardship Act,* etc to promote conservation of key areas of watershed ecological infrastructure

#### *5.6.3.4 Agriculture*

***Conservation tillage.*** No Till and Reduced Till practices conserve land and water resources, soil organic matter and moisture. The result is not only watershed benefits and less erosion, but in some cases (depending on climate and soil type) it may also provide improved yields and better nutrient management. Retention of nitrogen and phosphorus, the two most relevant nutrients as regards water quality, are promoted by conservation tillage, via incorporation in humus and adsorption onto soil mineral particles (Shotyk 2012).

***Agricultural riparian buffers.*** Conserve as large a riparian area as possible, and convert crops to perennial hay cover or agroforestry operations within riparian areas as appropriate.

***Manage Livestock Access to Riparian Areas*** (see previous chapters)

***Conserve / Restore wetlands*** (see previous chapters)

***Integrated Pest Management*** to reduce reliance on pesticides

***Beneficial Management Practices for all Producers:*** Inform and educate stakeholders about BMPs to reduce agricultural runoff and associated contaminants, with particular focus in priority areas. Refer to provincial "Beneficial Management Practices" reports, including:

- *Environmental Manual for Dairy Producers in Alberta* (AM + AARD, 2003)
- *Environmental Manual for Feedlot Producers in Alberta* (ACFA + AARD, 2002)

***Environmental Farm Plans***

***Investigate Payments for Ecosystem Services Programs in Key Areas*** (e.g., upstream of Red Deer). Some existing programs of Alberta Agriculture and Rural Development (AARD) as well as Red Deer

County offer grant programs to help with funding for fencing animals out of riparian areas. Red Deer County's "Off the Creek" Program is a good example.

#### *5.6.3.5 Oil and Gas*

- Implement adequate erosion and sediment control measures
- Ensure sufficient emergency response training and equipment available for mobilization (e.g., through Western Canada Spill Services)
- Conduct integrated study of older pipeline river crossings and highlight areas at high risk requiring upgrades
- Reclaim disturbances as soon as possible (minimize amount of time with open trench during pipelining operations, rapid reseeding of disturbed land around drilling, well and pipeline construction sites, etc.)
- Apply Integrated Land Management (ILM) principles (parallel existing footprints and corridors, avoid all sensitive areas, coordinate footprints with forestry cut blocks, consider recreational access issues and controls, etc.)
- Minimize stream crossings
- Cross streams with Horizontal Directional Drills to minimize riparian and in-stream disturbance
- Restore riparian areas
- Locate block valves strategically to minimize potential spill volumes into water bodies
- Comprehensive detection and correction of oil spill leaks
- Conserve wetland hydrology
- Adequate management of water intake and discharge locations for hydrostatic testing
- Minimize water use
- Safely manage production of saline produced water
- Continue to evolve approaches to adopt "cutting edge" research, technologies, and methods
- Review and implement all Beneficial Management Practices as described in documents produced by the Canadian Association of Petroleum Producers (CAPP)

#### *5.6.3.6 Forestry*

- Minimize impacts to riparian areas, steep slopes, and other sensitive areas when planning and conducting forestry activities
- Continue to follow all provincial regulations and rules when planning / conducting forestry
- Follow sustainable forestry certification standards or similar such as CSA–Z809 Forest Certification Standards and/or ISO 14001 when planning and conducting forestry
- Where appropriate and feasible, conduct forest harvesting using alternative methods, including selective cutting and patch cutting, as these are preferable to clear-cutting to preserve watershed values

*5.6.3.7 Recreation*

- Control recreational access to sensitive areas in the watershed using direct strategies (e.g., access control with water bars, trenches, gates, felled timber, trail design criteria, etc.) and indirect strategies (e.g., signage, education, bottom up stewardship initiatives, etc.)
- Designate and promote formal alternative areas for recreational activities to divert users from more sensitive areas of the watershed to more areas that pose lower risks due to usage
- Restore areas damaged by recreational usage (e.g., ATVs, horse trails, etc.)
- Install and/or upgrade bridges and other water crossing structures on recreational trails to minimize bank erosion and riparian damage

*5.6.3.8 Education*

- Ongoing targeted education of public officials, civil servants, the development community, and the public is required to ensure proper understanding, support, and technical knowledge.
- Resources are rarely adequate to deliver education and technical assistance to "everyone." Therefore, defining target audiences who most need to adopt BMPs is an approach to make the best use of these limited resources. For example, targeting outreach and aggressive BMP promotion is recommended where high risk activities occur on areas with high sensitivity to surface water contamination (see Chapter 6)

*5.6.3.9 Leadership*

To ensure watershed protection is better integrated with land use planning at multiple scales, leadership is required not only from the Red Deer River Watershed Alliance, but also from the provincial government, municipalities, and other stakeholders.

# 6. WATERSHED SURFACE WATER SENSITIVITY ANALYSIS

## 6.1 Introduction / Purpose

This section presents the findings of a GIS-based sensitivity analysis conducted to help link land use, wetlands and riparian features in the Red Deer River basin to surface water quality objectives. The analysis used a raster-based GIS overlay technique at 30 m resolution based on existing available data inputs. The focus of the analysis was to map the watershed in terms of low to high sensitivity to the risk of non-point source contamination sources that may be present in specific areas. Point sources need to be addressed separately.

**DEFINITIONS**

**Risk:** The chance or possibility of a hazard causing harm to the functioning of a drinking water system, human health, or the environment

**Source (contaminant):** A substance that is located in, on, or under the land and has the potential to cause harm to human health, water resources, or the wider environment

**Pathway:** The means or route by which a source of contamination can migrate; an identified receptor can be exposed to, or be affected by an identified source

**Receptor:** Something that could come to harm, including human health, water resources, surface water courses or the wider environment

*Source: CCME (2002), DEFRA (2000)*

## 6.2 Definitions and Approach

The concept of risk with respect to surface water quality centers on the concept of a source of contamination, a water body or watercourse receptor, and a pathway to that surface water receptor. Fundamental to the concept of environmental risk is that all three components must be present for a risk to exist. The absence of one of these components results in the potential for risk being eliminated. Figure 30 provides a conceptual view of environmental risk based on these three components.

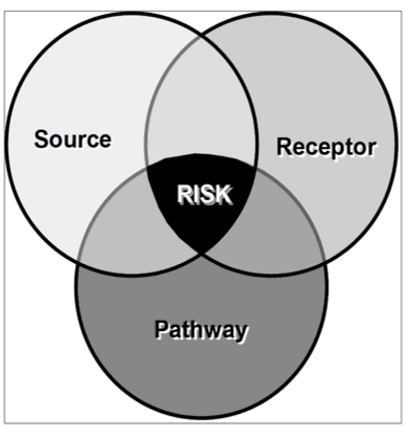


**Figure 30.** The Three Essential Elements of Risk (*Source: International Network for Acid Prevention)*

In the context of this project, the "receptor" was defined as including all surface water bodies in the watershed. Sources were considered as land use activities that may introduce nutrients, sediment and bacteria into the watershed, which were discussed in the preceding chapters[31]. For this phase of the IWMP, the main pathways of surface water contamination were assumed to be through runoff and

[31] Note that, in some cases, mitigation measures implemented by industry may be sufficient to reduce the "source" component of risk to acceptable levels.

erosion causing mobilization of potential contaminants. Contributions from groundwater were not considered.

Water flowing over land can pick up parasites, nutrients, organic matter, fecal bacteria and other water quality contaminants. This runoff gathers in lakes and streams and can eventually reach the Red Deer River. Sometimes parasites and metals are attached to soil particles or organic matter, or they may be picked up directly by water and carried along. Pathways through which contaminants can reach the Red Deer River vary depending on a variety of factors such as slope, overland runoff, erosion, and proximity to water bodies.

The mapping exercise assessed the pathway and receptor portions of the risk model. In other words, it assesses how easily contaminants, if mobilized, can move from the source area to surface waters. Potential surface water contaminant pathways and data sources used to create the water quality sensitivity map are described below in more detail.

**Slope.** Slope is one of the most important predictors of both runoff potential and terrain stability, and can be used to predict the likelihood that a source of contaminants can be mobilized (Schwab, 2008). A provincial-scale DEM at 30m resolution is available and was used to determine slope categories. Percent slopes were calculated using the DEM and partitioned into three intervals Table 28. In addition, steep slopes (>15%) directly adjacent to variable width riparian areas were ranked as a potentially more important pathway for contamination than steep slopes not spatially adjacent to riparian areas.

**Runoff / Annual Water Yield.** During runoff, including spring snowmelt and heavy rainfall events, concentrations of many substances (including parasites) in the river increase. Rainfall and snowmelt distribution and intensity vary across the watershed in response to climatic gradients. Annual average water yield from the landscape can be expressed interchangeably as either $m^3/km^2/yr$, or as mm/year. In the Red Deer River watershed, water yield ranges from a low of about 0 mm/year to a high of over 350 mm/year in the headwaters. The data source used for this variable was the water yield polygons for Alberta (Kienzle & Mueller, 2010) that are derived from the naturalized flow records of stream and river gauging stations across the province. Runoff potential is one of the most important factors influencing water quantity and quality, and accordingly this variable was weighted higher than others (Table 28).

**Erosion Risk Potential.** A Water Erosion Prediction Model (WEPP) has been developed for the province, and considers climate, soil, landscape and land management (e.g., tillage) in an interactive, highly detailed model that includes inputs of daily climate data and AGRASID soil polygons (Jedrych & Martin, 2006). The WEPP model outputs were considered very important as well as highly detailed, and accordingly were assigned a relatively high weight in the model (Table 16)[32]. The model results provide erosion predictions based on infiltration theory, hydrology, soil physics, plant science, hydraulics, and erosion mechanics (Flanagan & Livingston, 1995). The model uses site-specific information on soil, hill slope, climate, and land use conditions. Despite the need for some field verification (Jedrych pers. comm. 2012), the predictions help identify potential critical source areas. Specific field scale management can then be directed to provide the greatest environmental benefit.

**Non-contributing areas.** These areas, mapped by the Prairie Farm Rehabilitation Administration (PFRA), consist of endorheic basins with no surface outlet to the Red Deer River drainage network. They are low lying depressions that typically, under normal circumstances (1:2 year events) will contribute no surface flow downstream. Therefore, activities in these areas may pose water quality risks to wetlands, but pose a much lower water quality risk to streams and rivers that are often used more for drinking water and other uses. Therefore, non-contributing areas were provided a lower score than areas that do contribute flow to the stream network.

[32] Unfortunately, the WEPP model was based only on the “White” Area of the province. Rather than having “missing data” for the Green Area of public lands in the headwaters, these areas were conservatively ranked as “high” for application purposes but ideally should be properly calculated for any future detailed quantitative watershed assessment purposes.

**Riparian areas and condition.** Land use activities in and adjacent to riparian areas have a much higher chance of impacting water quality, particularly during high flow events. Land use activities such as cultivation, livestock grazing, urban development or ATV use can impact water quality through erosion and direct contamination of surface water resources. Buffer width areas were delineated using the provincial variable width riparian model (ASRD 2010). Since healthy riparian areas have the ability to minimize runoff of contaminants and therefore protect water bodies, information on the intactness of the riparian area (see Chapter 4) was also used to determine the rank score assigned to the riparian area (Table 28).

**Table 28. Watershed Surface Water Sensitivity Analysis Methods**

| Variable Name and Source | Range / Class | Rank | Comments |
|---|---|---|---|
| Slope from DEM<br>(Use best resolution DEM distributed for project) | 0-7% | 1 | Similar to approach taken by BRBC (2011) |
| | 7-15% | 2 | |
| | >15% | 3 | |
| | >15% and immediately adjacent to a riparian area | 4 | |
| Annual Water Yield<br><br>(Kienzle, University of Lethbridge)<br><br>(Yield_U2 Field in "new_annual-water-yield_Clip" | <5 mm /year | 1 | Reassign polygon #45 (Red Deer River near Sundre) (-999 error value) to >200 mm /year class<br><br>Reassign polygon #1 (Red Deer River at the Mouth) (-999 error value) to 0-5 mm class |
| | 5-10 mm/year | 2 | |
| | 10-20 mm/year | 3 | |
| | 20-30 mm / year | 4 | |
| | 30-50 mm / year | 5 | |
| | 50-75 mm / year | 6 | |
| | 75-100 mm / year | 7 | |
| | 100-200 mm / year | 8 | |
| | >200 mm / year | 9 | |
| Erosion Risk Potential<br>(Jedrych and Martin 2006)<br><br>(RDR_erosion_potential)<br>"NewErosion" field | "Negligible" | 1 | Based on Water Erosion Prediction Model (WEPP), considers climate, soil, landscape and land management (e.g., tillage) in an interactive, highly detailed model.<br><br>Not complete for "Green Area" in headwaters-these were defaulted to "High"="5" |
| | "Very Low" | 2 | |
| | "Low" | 3 | |
| | "Moderate" | 4 | |
| | "High" | 5 | |
| | "Very High" | 6 | |
| | "Extreme" | 7 | |
| Non-Contributing Areas (PFRA) | Area is "non-contributing" to mainstem flow ("non.shp") | 0.5 | |
| | Area contributes flow to mainstem (everything not within the "non.shp" file above) | 1 | |
| Riparian Areas<br><br>(Casyls / ASRD 2010)<br><br>(Land Cover from Ag. Canada 2011 Crop Inventory) | Riparian area is not present | 1 | Healthy riparian areas (layer is already developed from riparian section) |
| | Riparian area is present and is natural | 2 | |
| | Riparian area is present and is hay / tame pasture | 3 | |
| | Riparian area is present and degraded (agricultural crop, urban) | 4 | |
| Floodplain in urban areas (AESRD 2012) | No floodplain identified | 1 | Updated 2012 provincial floodplain completed-note this is only completed for very limited areas close to or within urban developments |
| | Floodplain identified | 2 | |

**Provincial Floodplain.** Finally, the provincial floodplain maps, updated by AESRD in 2012, were also used as a layer. Although this floodplain layer is only mapped in certain areas and overlaps considerably with the variable width riparian model, it was considered reasonable to include this layer to increase the value of mapped floodplains further, since it is primarily mapped within and adjacent to urban areas, which have the potential to introduce a wide range of contaminants to rivers and streams if floodplains are developed.

The above layers were overlaid on top of one another in GIS using raster pixels (30 m resolution) for each layer. Values were all multiplied to obtain a final surface water sensitivity map.

## 6.3 Results

Figure 31 summarizes the GIS analysis, which identifies critical areas for source water protection. Potential surface water contamination pathway values are summarized from low to high or yellow to red. Red areas indicate locations with high sensitivity or vulnerability to potential surface water contamination. The headwaters stand out as having a particularly high sensitivity, due primarily to high annual runoff and many steep slopes.

A large amount of variation is evident in the Central Agricultural and Central Urbanizing landscape units, reflecting the influence of soil type, topography, and riparian area location and condition on potential contaminant pathways. The Threehills sub-watershed appears to have a higher overall sensitivity than other sub-watersheds in the Central Agricultural landscape unit. In the Dry Grasslands, sensitive areas are concentrated in the Red Deer River Valley and directly along tributaries.

### CAVEATS FOR INTERPRETING THE RESULTS

This mapping exercise represents the inherent sensitivity of different parts of the watershed. It does *not* indicate the relative risk of individual activities or industries. In other words, the map indicates where a given activity with a potential contaminant source (e.g., oil spill, feedlot, urban development) would have the highest risk of impacting surface waters. Areas mapped as having a high inherent sensitivity may not necessarily pose risks to water resources, as contaminant sources must also be present to generate risk. In addition, some sources of potential contaminants (e.g., toxic waste dump, intensive feedlot) pose a much higher risk than others (e.g., small private woodlot), and this is not represented on the map.

In combination with other baseline information, the sensitivity map suggests that land use activities in the Lower Headwaters landscape unit are a priority for management and BMP implementation. For example, in the Medicine River sub-watershed, crops occupy over 50% of the landscape, livestock densities are relatively high, oil and gas activity is high, and there is high sensitivity in this sub-watershed. Although the Upper Headwaters are identified as having the highest overall sensitivity, there are fewer potential land use activities causing source concerns. Nonetheless, any activity, including oil and gas, recreation and forestry, can pose local water quality risks. There are other local hotspots of sensitivity in the Central Agricultural, Central Urbanizing, and Dry Grasslands landscape units (Figure 31), which should also be targeted as priorities to ensure widespread application of BMPs for all land use activities. Ongoing vigilance, monitoring, regulation, and adaptive management for all industries and activities is recommended to minimize potential water quality risks.

It is important to note, that the underlying data include a wider range of values than those displayed on the map. The data can be used for finer-scale analyses and maps for specific program objectives (e.g., industry-specific themes, municipal applications, etc.).

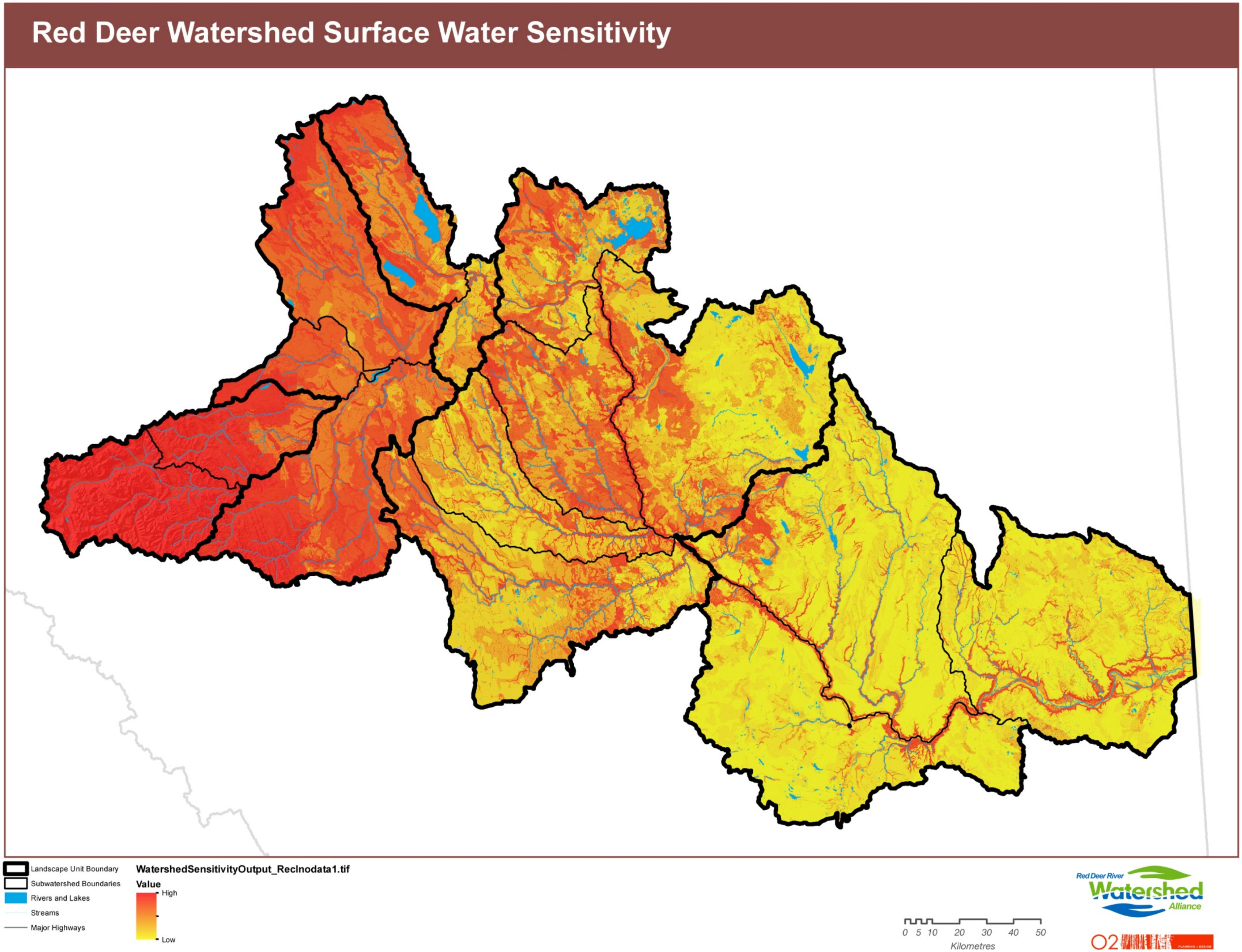


**Figure 31. Map of Red Deer Watershed Surface Water Sensitivity**

# 7. CONCLUSIONS

A watershed plan needs a system of outcomes, indicators, and targets to synthesize information on watersheds and to help craft monitoring and management programs. Indicators and targets are critical to measure an organization's progress towards meeting their vision and specified outcomes. This can allow for a performance management system gauging success through time.

This document has compiled research on wetlands, riparian areas, and land use within the watershed, to recommend a system of environmental, programmatic, and social indicators which can be monitored over time within an integrated monitoring and reporting framework. BMPs for different sectors have also been specified as well as areas requiring further research.

A GIS overlay procedure has also integrated information on the sensitivity of different areas to potential surface water contamination. This mapping information is a useful screening tool to identify priorities for management for the WPAC, WSGs, the provincial government, municipalities, and other groups. The underlying output data can also be used to provide finer scale maps showing more detail and variation for sub-watersheds, municipalities, or industry-specific applications.

All targets are to be interpreted and applied with care, as they are based on existing baseline data inventories, and gaps may be present. In addition, targets represent averages over broad scales. Finer-scale targets could be specified using other boundaries, including sub-sub-watersheds, soil parent material types, townships, or even quarter sections.

Throughout the watershed planning and implementation process, indicators and targets should be refined, and modified to reflect changing conditions and priorities in an adaptive management process.

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## GLOSSARY

**Alluvial aquifer** – The water-bearing alluvial sediments adjacent to rivers and streams and hydraulically connected aquifers

**Bioswale** – A landform, typically in urban contexts, designed and built to remove silt and pollution from surface runoff, consisting of a drainage course with gently sloped sides filled with vegetation, compost, and/or riprap

**Brownfield** – An industrial or commercial site that is idle or underused because of real or perceived environmental pollution

**Cumulative effects** – The combined effects of past, present and foreseeable human activities, over time, on the environment, economy, and society in a particular place.

**Greenfield** – An undeveloped or agricultural tract of land that is a potential site for future industrial or urban development

**Impervious surface** – Areas where the infiltration and percolation of water into the soil is prevented due to human infrastructure such as roads, parking lots, and buildings

**Indicator** – Measurable surrogates for environmental end points of value to the public

**Lacustrine** – Of or relating to lakes

**Lentic** – Of or relating to still waters (e.g., lakes, ponds)

**Lotic** – Of or relating to flowing waters

**Natural land cover** – includes all wetlands, grassland/rangeland, shrubland, barren rock, and intact forest classes (for the purposes of this report)

**Non-contributing areas** – Topographically disconnected basins isolated from the regional drainage network that do not contribute surface flow to creeks and streams in a watershed

**Perennial vegetation land cover** – Includes all natural land cover as well as all hay / tame pasture land cover (for the purposes of this report)

**Perennial stream** – A stream or river channel that has continuous flow in parts of its stream bed all year round during years of normal rainfall

**Perennial vegetation** – A plant that lives for more than two years

**Root wad** – The root mass of a tree

**Xeriscaping** – A low-maintenance landscaping technique applicable to prairie regions that conserves soil and water, encompassing a range of techniques including the use of native and drought-tolerant plants, reducing the area of lawn, grouping plants with similar watering needs together, grading towards planting beds and landscaped ponds, mulching, and soil management

# APPENDIX A: ADDITIONAL INDICATORS FOR CONSIDERATION

## A.1 Additional Indicators for Wetlands

This section discusses some additional factors related to wetlands in the landscape for consideration related to setting indicators and targets in the IWMP. These consist of additional site-specific criteria to consider within the process of wetland compensation (A1.1 to A1.6), as well as potentially new programmatic measures related to tracking wetlands avoidance both within and outside of the regulatory process (A1.7 and A1.8).

### *A.1.1 Wetland Density*

Using a guideline based on wetland density (i.e., number per unit area) rather than percentage surface area may help address the variety of very small, spatially discontinuous prairie potholes or riparian wetlands. Prairie pothole wetlands, which are typically found on glacial moraines, often have an average density of 20 wetlands/km$^2$ or more. Old glacial lake beds, on the other hand, typically contain wetlands connected to surficial drainage systems at an average density of 5 wetlands/km$^2$ (Huel, 2000).

By considering wetland density in addition to wetland cover targets, situations where many small wetlands are lost and consolidated into single large compensation wetlands would theoretically be avoided to ensure the wetland density targets are met.

Baseline wetland density in the watershed based on GIS queries ranges from a low of 1.2 wetlands/km$^2$ in the Panther sub-watershed, to a high of 9.2 wetlands/km$^2$ in the Rosebud sub-watershed. By landscape unit, it ranges from a low of 2.2 wetlands/km$^2$ in the Central Urbanizing area, to a high of 6.0 wetlands/km$^2$ in the Central Agricultural area. Local variations are also highly evident across the landscape (Figure 13).

It is worth pointing out the major differences between wetland cover as a % of the landscape, and wetland density:

- Watersheds with many small prairie pothole wetlands, such as the Rosebud sub-watershed, have very high wetland densities (9.2 / km$^2$) despite having low overall wetland cover of only 4.9%
- Conversely, watersheds characterized by more large contiguous wetlands such as the Blindman River sub-watershed have very low wetland densities (2.4 wetlands/km$^2$), but high wetland cover (>10%)

At this time, it is felt that specifying wetland density targets requires further expert discussion on the utility of the indicator and the appropriate reporting scale(s) prior to specifying quantitative targets. Although the intent may be to monitor changes in the distribution of wetland types over long time periods, changes over short time periods at the sub-watershed scale would be unlikely to register due to the sheer number of wetlands. In addition, this indicator, perhaps more than any, may depend on the definitions and experience of the staff who completed the wetland inventories in different areas within the merged provincial wetlands inventory.

### *A.1.2 Wetland Size and Shape*

A diversity of wetland types, sizes, shapes, and seasonal hydrological regimes across the landscape are desirable to maximize ecosystem services. In prairie landscapes, ephemeral, seasonal, semi-permanent, and permanent wetlands all have different roles to play in a variety of hydrologic and biodiversity habitat functions.

Larger, natural wetlands tend to provide higher biodiversity due to microhabitat diversity and large patches support higher biodiversity by providing microhabitat diversity, higher population sizes, and a buffer against extinctions (MacArthur & Wilson, 2001; Forman, 1995). Where feasible and appropriate, wetlands should be a minimum of 0.2 ha in size. In addition, if a wetland restoration project is larger than 2.0 ha, small islands and complex shorelines should be included, where feasible, to promote maximum use by wildlife (O2, 2007; TetrES Consultants Inc., 2006).

However, specifying minimum size targets for wetlands is problematic as each wetland is unique and contributes unique values and services. For example, waterfowl often use a variety of ephemeral and permanent wetland types during different seasons. Small Class I and II wetlands often play a key role in flood control functions on a cumulative basis, particularly for wetlands at higher landscape positions (O2, 2011a).

Wetlands with wider wet meadow zones tend to support more wetland-dependent songbirds (Bayley et al., 2010).

Therefore, an appropriate target may be to maintain the current distribution of wetland sizes and shapes, or to restore wetlands to what was originally typical for the area. This should be linked to compensation / wetland creation criteria on a site specific basis.

### *A.1.3 Wetland Location*

Wetland position in the watershed is an important consideration for maintaining wetland values and functions. The following locations of wetlands make them critically important and a higher priority overall for conservation (O2, 2007; Cedfeldt et al., 2000):

- Wetlands located in the headwaters of a watershed (critically important for flood control and water supply functions)
- Wetlands located in the floodplain (important for flood attenuation)
- Wetlands providing habitat for rare or threatened species and/or providing higher overall biodiversity values
- Where wetlands occur together in a complex[33], as these can provide greater overall value than if wetlands are dispersed and located further apart from one another

Wetland restoration projects must also ensure that site hydrology and soil conditions are appropriate for wetland reestablishment.

### *A.1.4 Wetland Riparian Buffer Widths*

Wetlands should be surrounded by riparian buffers to filter runoff and protect habitat. A summary of literature on prairie potholes in agricultural fields found riparian buffer widths of 10-60 m trapped most sediment in runoff (Melcher & Skagen, 2005). Naturally vegetated riparian areas surrounding wetlands strongly increase wetland biodiversity. Most waterfowl nests occur within 300 m of a prairie pothole wetland; 95% of salamander populations are found within 165 m of a wetland; and small predators such as striped skunk and red fox tend to hunt within 50 m of a wetland (Semlitsch, 1998; Horn et al., 2005).

Appropriate riparian buffers vary depending on site-specific characteristics. New provincial guidelines for wetland riparian buffers include 10 m for Class I and II wetlands, and 20-50 m for Class III-VII wetlands, as well as additional slope-dependent setback modifiers (AEW, 2012). However, where biodiversity is a major concern, a 100 m minimum buffer around wetlands is recommended, whereas a buffer of up to 200-300 m may be necessary to fully protect breeding waterbirds and species at risk (O2, 2007; TetrES Consultants Inc., 2006). A 500 m setback from wetlands containing trumpeter swan breeding habitat may be necessary (JCWP, 2012). Additional information on appropriate wetland riparian widths can be found on page 4-105 in: RDRWA (2009).

*Wetland buffers should be as wide as possible and should be applied to all wetlands, although the appropriate setback is highly context-specific. It is suggested here that the provincial guidelines should be applied, unless the wetland is important for biodiversity in which case a 100m minimum buffer is recommended.*

### *A.1.5 Ratio of Wetlands: Adjacent Natural Uplands*

Wetlands often support far more biodiversity when surrounded by natural uplands. For example, northern pintail ducks require wetlands with open water and adjacent grassland habitat for nesting. One expert panel convened by Environment Canada defined a ratio of natural upland cover to wetlands as “very good” if exceeded a ratio of 5:1 (Smith-Fargey, 2004). In Michigan, an area of permanent grassland three to six times

[33] In BC, it has been suggested that wetland complexes can be identified and mapped where two or more wetlands occur within 200 m of one another and where the total wetland surface area is greater than 5 ha (BCMOFR, 1995), although in prairie pothole landscapes this often results in very large numbers of wetlands being grouped together as a complex.

larger than the wetland itself has been recommended to reduce predation on nesting waterfowl species (Sargent & Carter, 1999). A 3:1 ratio of upland permanent cover to wetland area is recommended to protect wildlife habitat around wetlands in Saskatchewan (Huel, 2000).

Considering the above, in parts of the watershed where biodiversity support is one of the key functions of wetlands, adjacent upland habitats and integrity of the habitat complex should be considered, with a recommended target ratio of 5 parts natural upland to 1 part wetland. For example, the Mikwan-Goosequill-Hummock Lakes in Red Deer County is an Environmentally Significant Area (ESA) of national significance; habitat complexes in this area include nesting habitat for piping plover (an “At Risk” species), as well as habitat for a variety of sensitive or rare species including ferruginous hawk, short-eared owl, Sprague’s pipit, Virginia rail, Canadian toad, and widgeon grass (Fiera, 2009). It also provides habitat for moose, deer, and a wide range of other wildlife.

Vegetation diversity in wetland riparian areas and surrounding upland habitats should reflect the species composition characteristic of the natural sub-region in which the wetland is located.

### *A.1.6 Wetland Functions and Ecosystem Services*

Estimating the ecosystem services of individual wetlands is an evolving interdisciplinary field of study. In Alberta, AESRD has investigated the potential of adapting the Wetland Ecosystem Services Protocol for the United States (WESPUS) (Adamus, 2011) as a rapid assessment technique to measure wetland functions and services. WESPUS models over 16 ecosystem functions, including water storage and delay, sediment retention, P removal, N removal, carbon sequestration, and habitat functions for different species guilds (e.g., invertebrates, waterbirds, amphibians, native plants). WESPUS requires field visits, combined with desktop assessments to rate 140 criteria in an Excel spreadsheet. Another tool under development in Alberta is the Index of Biotic and Hydrologic Integrity (IBHI) (Bayley et al., 2010).

A potential target for both of these tools would be that restored or built compensation wetlands should measure similar values as the undisturbed wetland(s) in the *Water Act* wetlands approvals process for the settled (White) area of the province. However, effectively achieving this will likely require more formal direction and involvement from AESRD at a provincial level, including a formal wetland policy and guidance documents for a "WESPAB" (Wetland Ecosystem Services Protocol for Alberta") applicable for each natural sub-region.

### *A.1.7 Wetland Avoidance Within the Regulatory Process*

The wetlands regulatory process under the *Water Act* (see box; Figure 17) in the Red Deer watershed could be tracked using indicators such as the number of avoided wetlands occurring within the regulatory process. This would consist of the number of instances where a proposed wetland disturbance is rejected by the regulator and the applicant is required to come up with an alternative development plan. Recent research shows that this rarely occurs (Clare & Krogman, 2012).

### *A.1.8 Wetland Avoidance Outside the Regulatory Process*

Industry environmental practitioners often communicate that wetland avoidance does occur through the planning and siting of spatial development footprints (i.e., gas wells and facilities) to avoid wetlands. However, as no regulatory application is initiated if a project footprint is located to avoid wetlands, avoidance outside the regulatory process remains largely untracked. Addressing this may require a research program to track wetland avoidance outside the regulatory process, likely led by industry. The potential benefits to industry from formally documenting and demonstrating environmental stewardship may be great. Although the logistics and standards of this type of tracking system requires further analysis, the industry representative on the TAC steering committee was supportive of this initiative and the TAC team feels this is consistent with the direction that the provincial wetland policy will be taking once finalized.

## Alberta's Wetlands Regulatory Process in the Settled ("White") Area

The Alberta *Water Act* and the provincial *Wetland Restoration / Compensation Guide* (AENV, 2007) provide regulatory and policy guidance for wetlands in the settled agricultural and urban areas of Alberta ("White Area"). The stated priority is to promote avoidance of impacts on wetlands whenever possible. Implementation of the policy has focused on mitigating degradation or loss of "unavoidable impact" as close to the site as possible, and enhancing, restoring, or creating wetlands in areas where they have been depleted or degraded through compensation wetlands (AENV, 2007; Clare et al., 2011) (Figure 32).

Guidelines are specified for wetland replacement compensation ratios, distances between disturbed and restored sites, prescribed compensation fee payments, and wetland restoration agencies (primarily Ducks Unlimited at present) who undertake physical restoration works (AENV, 2007).

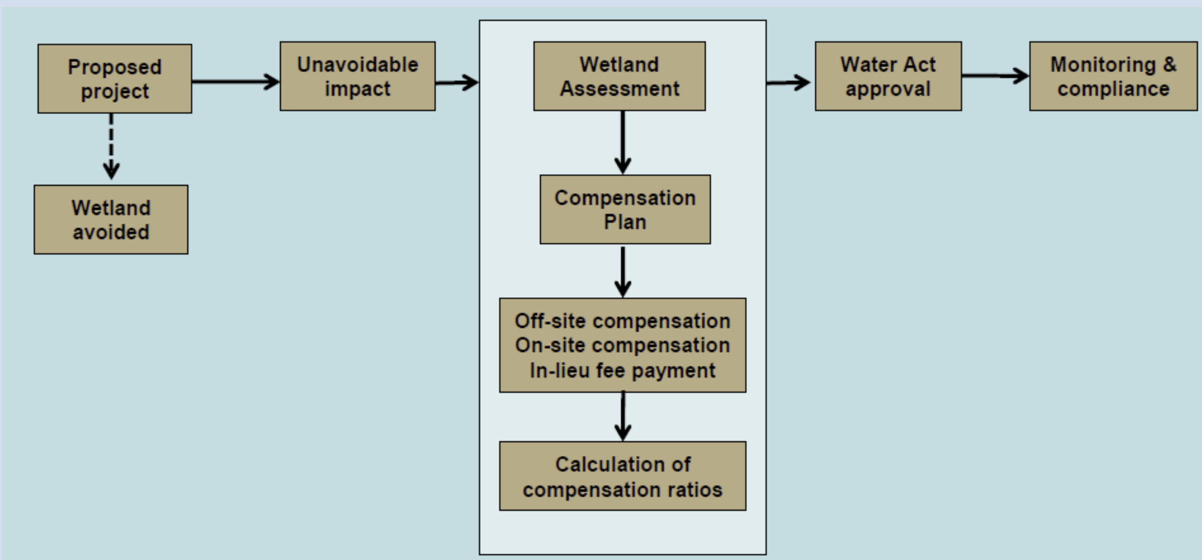



**Figure 32. Regulatory Approval Process for Wetland Disturbance ("White" area of Alberta)**
*Source: (Bavlev et al.. 2010)*

## Alberta's Evolving Wetland Policy

The government is planning to introduce a new wetland policy sometime in the near future, which may have very different regulatory requirements from the current situation. Although the report authors and most of the TAC team members believe that the information in this report is generally consistent with the direction the province is taking, careful thought will need to be given as to whether these are the most effective and appropriate measures to track.

## A.2 Additional Indicators for Riparian Areas

This section provides additional indicators for riparian areas for consideration.

### *A.2.1 Riparian Indicator: Lower Order Riparian Areas with Permanent Vegetation*

Lower order streams (first and second order) are the source of most water and mobilized sediment entering a river system (Dunne and Leopold 1978; Forman 1995). Any erosion and sediment mobilization in these areas moves downstream into larger streams and watercourses, creating a disproportionate impact on overall water quality (EC, 2004; Dunne & Leopold, 1978; WDNR, 2006).

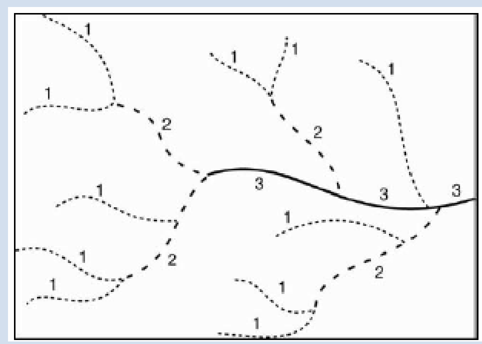
It is important to maintain buffers for ephemeral, intermittent, and perennial streams to protect water quality in the prairies (Dodds & Oakes, 2006). In Kansas, land use in lower order headwater riparian areas explained a large proportion of observed nitrogen and phosphorus concentrations downstream, and it has been concluded that protecting riparian zones for only higher order streams is insufficient to protect water quality (Dodds & Oakes, 2008).

Yet many lower order streams are often perceived to have low ecological value, particularly for fish and wildlife. As a result, these streams are often the most neglected in many contexts (urban, forest, agricultural, industry).

Environment Canada (2004) has recommended that at least 75% of first and second order streams in agricultural areas should be in permanent vegetation cover. Targets for these streams in the headwaters are recommended to be higher as they are important for source protection. Based on these recommendations, proposed targets for lower order streams in the Red Deer River are listed below. Existing land cover estimates for lower order streams specifically are also recommended to be calculated using baseline information.

#### Definition of Stream Order

Stream order is a basic method of classifying streams, where the smallest headwater streams are called first-order streams. Where two first-order streams meet, a second-order stream is created. Where two second order streams meet, a third-order stream is created, and so on. The province has a database where these “Strahler” stream orders have been defined for the entire province.




*Source: (Ward & Trimble, 2004)*

**Table 29. Potential Additional Targets for Perennial Land Cover for 1st and 2nd Order Streams**

| Watershed-Based Landscape Unit | % of All Lower Order Riparian Areas with Permanent Vegetation (Natural + Hay or Pasture) |
|---|---|
| Entire Watershed | >75% |
| Upper Headwaters | >95% |
| Lower Headwaters | >85% |
| Central Urbanizing | >75% |
| Central Agricultural | >75% |
| Dry Grasslands | >90% |

### *A.2.2 Riparian Health Inventories (Site Specific)*

Riparian health as measured by the Cows and Fish RHI method is considered a useful indicator particularly at the site-specific scale. However, applying this indicator to report on and summarize trends at the watershed scale may require additional effort and new sets of data that are either randomized or consist of revisiting the same sites at a future date. RHI field sampling is not fully randomized as the Cows and Fish program is based primarily on landowner, community or municipality initiative. Sampling protocols often vary between sampling locations dependent on landowner, community or municipal interests or overall goals of the RHI project. Therefore, variability and change in this indicator over time may reflect statistical randomness and sampling artifacts as opposed to actual changes over time.

However, examining changes at particular sites over time would enable determination of improvements over time, but would require concerted efforts to set in place such monitoring. Despite these limitations, it is still felt that the RHI is a useful and recognized indicator that can be reported on over time, particularly since it integrates well with existing Cows and Fish programming underway and anticipated for the future.

Ideally the target for measured average RHI scores should be set as high as possible. The Jumpingpound Creek IWMP specified a target for average RHI scores of >80% for middle and lower reaches, and >90% for the headwaters where forest cover dominates (JCWP, 2012). However, in the Bow River Basin, a watershed with a similar size and comparable land use patterns to the Red Deer River, the BRBC (2012) specified gradual improvements over time from baseline conditions.

It is proposed that the best use of the RHI method is to set potential targets at the site scale. An aspirational target at the site-scale would be for "healthy" conditions (score >80%). However, it is acknowledged that this may not be realistic for all sites. Meeting aggressive targets would require the voluntary participation of many landowners (including incentives from local and provincial governments), and continued, cooperative efforts by municipalities, agencies, organizations and programs such as Cows and Fish, Watershed Stewardship Groups (WSGs), Alberta Agriculture (e.g., Growing Forward program), etc.

The RHI method could also be used as a very rough measure for monitoring trends over time at the watershed scale, as has been recommended in riparian indicator #2 in the main body of this report. However, caution is required if this is to be done; unless the exact same sites are sampled during each time period it remains unclear what the reported trends at a watershed scale actually represent. More refined targets for the Upper Headwater and Lower Headwaters could also be pursued, but would require further data compilation to be conducted by Cows and Fish.

### *A.2.3 Width of Riparian Setbacks*

A variable width approach as presented in Section 4.4.1 is useful. However, many upland areas adjacent to the physical riparian vegetation are also important for water filtration and wildlife movement. Therefore, in some cases, an additional buffer zone surrounding the physical riparian area is desirable. This is particularly the case where steep slopes occur, which are vulnerable to erosion, and should be protected within riparian setbacks to protect watershed health.

Kennedy et al. (2003) found that recommended optimal riparian buffer widths in the literature range from one meter to 1600 meters, with 75 % of values extending up to 100 meters. Their recommendation was that, in general, to protect both water quality and conserve wildlife, buffers should have a *minimum* width of 100 m on each side of a river or stream.

Bentrup (2008) recommended the following riparian corridor widths for different species requirements:

- 30-60m: invertebrates and fish
- 30-110m: plants and avian edge species
- 30-200m: reptiles and amphibians
- 60-100m: small mammals
- 60-1600m: interior forest bird species
- 110m-5km: large mammals including large predators

Along river valley corridors, for visual diversity and landscape aesthetics for recreation, tourism, and cultural values, very large corridors may be required. This is consistent with the 2000 Integrated Resource Plan for the

Red Deer River corridor, where the planning area was defined by the valley break of slope plus an additional 150 m setback, to a maximum distance of 3 km from the river (AENV, 2000).

In conclusion, targets for riparian setback widths are not always straightforward to establish. To address this more completely may require further investigations; however, preliminary targets are suggested as:

- Provincial guidelines for water quality buffers should be applied (AEW 2010) (Table 7) as appropriate
- Minimum riparian setback of 100 m for water quality and some wildlife values should be considered where appropriate; larger areas may be required where the variable width riparian area is larger than this (see 4.4.1 above)
- If the above is considered too onerous or costly, the *Field Manual on Buffer Design for the Canadian Prairies* should be used in agricultural areas
- Municipalities should consider developing and applying variable width riparian setback policies based on a variety of criteria (e.g., Lakeland County, City of Calgary)
- Even larger buffer widths are recommended along major regional river valley corridors such as the Red Deer River and major tributaries, as appropriate and feasible

### *A.2.4 Connectivity of Riparian Areas*

Connectivity in riparian habitats is particularly important and should be maximized to the highest extent feasible to prevent perforations that can degrade riparian services by providing conduits for runoff and water pollution as well as habitat changes (Dramstad et al., 1996). Identification of small breaks in the connectivity of otherwise intact riparian area corridors could be used to target restoration efforts (e.g., small zones of poor health in between areas with good health on the Red Deer River mainstem - see Figure 19).

| Indicator | Target |
|---|---|
| **Riparian Area Connectivity** | • Maximize riparian connectivity to the greatest extent feasible<br>• Restore small areas of disconnected riparian areas occurring in otherwise healthy riparian areas corridors |

### *A.2.5 Vegetation Diversity*

Different types of riparian vegetation play different functions and a diversity of vegetation types across a region and at the site level is important.

One particular area of importance in the Red Deer Watershed is the distinct area of plains cottonwood that is a unique community in the river valley in all areas downstream of Bleriot Ferry. The transition from balsam poplar (*Populus balsamifera*) dominated areas to plains cottonwood (*Populus deltoides)* riparian communities occurs between Tolman Bridge and Bleriot Ferry (AENV, 2000).

A potential indicator and guideline for vegetation diversity is provided below. However, vegetation diversity is captured by the riparian health inventory methods (both aerial and field-based) and therefore there would be a degree of redundancy by including it as a separate indicator.

| Indicator | Target |
|---|---|
| **Riparian Vegetation Diversity** | • Vegetation in riparian habitats should contain a diverse mixture of native plant types including trees and shrubs (where site conditions are appropriate), grasses, and forbs |

### A.3 Additional Considerations for Land Use Indicators

Other indicators that should be discussed or researched further with respect to land use include:

- *Forestry:* total cutblock as % of sub-watersheds, # of cutblocks in sensitive areas, etc.
- *Parks and Protected Areas*: number and coverage of parks in the watershed in strategic areas (e.g., Table 21-for example, coverage of parks in Lower Headwaters should be increased
- *Sand and Gravel Extraction:* total amount of sand and gravel pits in sensitive areas, reclamation certificates for sand and gravel pits, etc.
- *Oil and Gas Well Density:* identifies risks to groundwater and surface water from hydrocarbons or salinity - higher risk in higher drilling density areas. Performance measures- Maintain density by balancing new wells with fully reclaimed well sites. Monitor and increase number of reclaimed wells. Current oil and gas well densities in the watershed are summarized in Appendix B.
- *Pipeline Linear Density:* Current pipeline linear densities in the watershed are summarized in Appendix B. Re-use of common corridors using Integrated Land Management to minimize landscape fragmentation is highly recommended.
- *Range Health Scores* and *Forage and Litter Biomass* in rangelands
  e.g., Jumpingpound Creek IWMP specified targets and thresholds in lbs/acre
- *Soil Erosion Target:* Maximum soil erosion target / soil loss tolerance per year (requires additional research) (BRBC 2012 specified targets for erosion and sediment control plans)
- *Point Sources from Urban and Industrial Outfalls:* Industries and municipalities have been required to document the quality and quantity of their effluent. It is recommended that this information be obtained through the comprehensive water quality monitoring project currently being initiated by AESRD.

# APPENDIX B: DATA TABLES

# Wetland Statistics for Subwatersheds and Watershed Landscape Units in the Red Deer River Watershed

*Based on Provincial CWCSS merged provincial wetlands inventory

**Landscape Unit: DRY GRASSLANDS**

| SUBWATERSHED | Area (km2) | Wetland Class | Wetland Area (km2) | Wetland Cover (%) |
|---|---|---|---|---|
| Berry | 6830.9 | Bog | 0.0 | 0.0% |
| | 6830.9 | Fen | 0.0 | 0.0% |
| | 6830.9 | Marsh | 257.2 | 3.8% |
| | 6830.9 | Open Water | 46.1 | 0.7% |
| | 6830.9 | Swamp | 0.0 | 0.0% |
| | 6830.9 | *Total* | 303.3 | **4.4%** |
| Matzhwin | 4954.1 | Bog | 0.0 | 0.0% |
| | 4954.1 | Fen | 0.0 | 0.0% |
| | 4954.1 | Marsh | 243.1 | 4.9% |
| | 4954.1 | Open Water | 88.0 | 1.8% |
| | 4954.1 | Swamp | 0.0 | 0.0% |
| | 4954.1 | *Total* | 331.1 | **6.7%** |
| Alkali | 6016.9 | Bog | 0.0 | 0.0% |
| | 6016.9 | Fen | 0.0 | 0.0% |
| | 6016.9 | Marsh | 369.1 | 6.1% |
| | 6016.9 | Open Water | 14.2 | 0.2% |
| | 6016.9 | Swamp | 0.0 | 0.0% |
| | 6016.9 | *Total* | 383.3 | **6.4%** |

| WATERSHED LANDSCAPE UNIT | Area (km2) | Wetland Class | Wetland Area (km2) | Wetland Cover (%) |
|---|---|---|---|---|
| DRY GRASSLANDS | 17801.9 | Bog | 0.0 | 0.0% |
| | 17801.9 | Fen | 0.0 | 0.0% |
| | 17801.9 | Marsh | 869.4 | 4.9% |
| | 17801.9 | Open Water | 148.2 | 0.8% |
| | 17801.9 | Swamp | 0.0 | 0.0% |
| | | *Total* | 1017.6 | **5.7%** |

**Landscape Unit: CENTRAL AGRICULTURAL**

| SUBWATERSHED | Area (km2) | Wetland Class | Wetland Area (km2) | Wetland Cover (%) |
|---|---|---|---|---|
| Michichi | 5835.7 | Bog | 0.0 | 0.0% |
| | 5835.7 | Fen | 0.0 | 0.0% |
| | 5835.7 | Marsh | 622.2 | 10.7% |
| | 5835.7 | Open Water | 177.1 | 3.0% |
| | 5835.7 | Swamp | 0.0 | 0.0% |
| | 5835.7 | *Total* | 799.3 | **13.7%** |
| Rosebud | 4391.3 | Bog | 0.0 | 0.0% |
| | 4391.3 | Fen | 0.0 | 0.0% |
| | 4391.3 | Marsh | 172.5 | 3.9% |
| | 4391.3 | Open Water | 37.3 | 0.8% |
| | 4391.3 | Swamp | 0.0 | 0.0% |
| | 4391.3 | *Total* | 209.8 | **4.8%** |
| Kneehills | 2496.4 | Bog | 0.0 | 0.0% |
| | 2496.4 | Fen | 0.0 | 0.0% |
| | 2496.4 | Marsh | 117.0 | 4.7% |
| | 2496.4 | Open Water | 11.6 | 0.5% |
| | 2496.4 | Swamp | 0.0 | 0.0% |
| | 2496.4 | *Total* | 128.6 | **5.2%** |
| Threehills | 3010.9 | Bog | 0.0 | 0.0% |
| | 3010.9 | Fen | 0.0 | 0.0% |
| | 3010.9 | Marsh | 105.9 | 3.5% |
| | 3010.9 | Open Water | 25.2 | 0.8% |
| | 3010.9 | Swamp | 0.0 | 0.0% |
| | 3010.9 | *Total* | 131.1 | **4.4%** |
| Buffalo | 2565.8 | Bog | 0.0 | 0.0% |
| | 2565.8 | Fen | 0.6 | 0.0% |
| | 2565.8 | Marsh | 195.0 | 7.6% |
| | 2565.8 | Open Water | 80.8 | 3.1% |
| | 2565.8 | Swamp | 0.0 | 0.0% |
| | 2565.8 | *Total* | 276.3 | **10.8%** |

| WATERSHED LANDSCAPE UNIT | Area (km2) | Wetland Class | Wetland Area (km2) | Wetland Cover (%) |
|---|---|---|---|---|
| CENTRAL AGRICULTURAL | 18300.0 | Bog | 0.0 | 0.0% |
| | 18300.0 | Fen | 0.0 | 0.0% |
| | 18300.0 | Marsh | 911.7 | 5.0% |
| | 18300.0 | Open Water | 226.0 | 1.2% |
| | 18300.0 | Swamp | 0.0 | 0.0% |
| | 18300.0 | *Total* | 1137.7 | **6.2%** |

**Landscape Unit: CENTRAL URBANIZING**

| SUBWATERSHED | Area (km2) | Wetland Class | Wetland Area (km2) | Wetland Cover (%) |
|---|---|---|---|---|
| Waskasoo | 723.5 | Bog | 0.0 | 0.0% |
| | 723.5 | Fen | 0.0 | 0.0% |
| | 723.5 | Marsh | 20.8 | 2.9% |
| | 723.5 | Open Water | 5.5 | 0.8% |
| | 723.5 | Swamp | 0.0 | 0.0% |
| | 723.5 | *Total* | 26.3 | **3.6%** |
| Blindman | 2105.9 | Bog | 3.1 | 0.1% |
| | 2105.9 | Fen | 18.8 | 0.9% |
| | 2105.9 | Marsh | 56.2 | 2.7% |
| | 2105.9 | Open Water | 138.6 | 6.6% |
| | 2105.9 | Swamp | 9.2 | 0.4% |
| | 2105.9 | *Total* | 225.9 | **10.7%** |

| WATERSHED LANDSCAPE UNIT | Area (km2) | Wetland Class | Wetland Area (km2) | Wetland Cover (%) |
|---|---|---|---|---|
| CENTRAL URBANIZING | 2829.4 | Bog | 3.1 | 0.1% |
| | 2829.4 | Fen | 18.8 | 0.7% |
| | 2829.4 | Marsh | 77.0 | 2.7% |
| | 2829.4 | Open Water | 144.1 | 5.1% |
| | 2829.4 | Swamp | 9.2 | 0.3% |
| | 2829.4 | *Total* | 252.3 | **8.9%** |

**Landscape Unit: LOWER HEADWATERS**

| SUBWATERSHED | Area (km2) | Wetland Class | Wetland Area (km2) | Wetland Cover (%) |
|---|---|---|---|---|
| Little Red | 3702.7 | Bog | 0.0 | 0.0% |
| | 3702.7 | Fen | 8.8 | 0.2% |
| | 3702.7 | Marsh | 105.9 | 2.9% |
| | 3702.7 | Open Water | 14.2 | 0.4% |
| | 3702.7 | Swamp | 3.3 | 0.1% |
| | 3702.7 | *Total* | 132.2 | **3.6%** |
| Raven | 935.7 | Bog | 22.2 | 2.4% |
| | 935.7 | Fen | 35.4 | 3.8% |
| | 935.7 | Marsh | 25.2 | 2.7% |
| | 935.7 | Open Water | 6.8 | 0.7% |
| | 935.7 | Swamp | 16.3 | 1.7% |
| | 935.7 | *Total* | 105.9 | **11.3%** |
| Medicine | 2864.2 | Bog | 7.7 | 0.3% |
| | 2864.2 | Fen | 172.2 | 6.0% |
| | 2864.2 | Marsh | 77.2 | 2.7% |
| | 2864.2 | Open Water | 25.9 | 0.9% |
| | 2864.2 | Swamp | 106.4 | 3.7% |
| | 2864.2 | *Total* | 389.3 | **13.6%** |

| WATERSHED LANDSCAPE UNIT | Area (km2) | Wetland Class | Wetland Area (km2) | Wetland Cover (%) |
|---|---|---|---|---|
| LOWER HEADWATERS | 7502.6 | Bog | 29.9 | 0.4% |
| | 7502.6 | Fen | 216.4 | 2.9% |
| | 7502.6 | Marsh | 208.3 | 2.8% |
| | 7502.6 | Open Water | 46.9 | 0.6% |
| | 7502.6 | Swamp | 126.0 | 1.7% |
| | 7502.6 | *Total* | 627.5 | **8.4%** |

**Landscape Unit: UPPER HEADWATERS**

| SUBWATERSHED | Area (km2) | Wetland Class | Wetland Area (km2) | Wetland Cover (%) |
|---|---|---|---|---|
| James | 1531.4 | Bog | 0.8 | 0.1% |
| | 1531.4 | Fen | 113.7 | 7.4% |
| | 1531.4 | Marsh | 6.4 | 0.4% |
| | 1531.4 | Open Water | 8.6 | 0.6% |
| | 1531.4 | Swamp | 37.7 | 2.5% |
| | 1531.4 | *Total* | 167.1 | **10.9%** |
| Panther | 1216.2 | Bog | 0.0 | 0.0% |
| | 1216.2 | Fen | 51.8 | 4.3% |
| | 1216.2 | Marsh | 0.2 | 0.0% |
| | 1216.2 | Open Water | 7.0 | 0.6% |
| | 1216.2 | Swamp | 6.3 | 0.5% |
| | 1216.2 | *Total* | 65.3 | **5.4%** |

| WATERSHED LANDSCAPE UNIT | Area (km2) | Wetland Class | Wetland Area (km2) | Wetland Cover (%) |
|---|---|---|---|---|
| UPPER HEADWATERS | 2747.6 | Bog | 0.8 | 0.0% |
| | 2747.6 | Fen | 165.5 | 6.0% |
| | 2747.6 | Marsh | 6.6 | 0.2% |
| | 2747.6 | Open Water | 15.6 | 0.6% |
| | 2747.6 | Swamp | 44.0 | 1.6% |
| | | *Total* | 232.4 | **8.5%** |

Area within Banff National Park excluded from statistical summaries due to missing data in the CWCSS database

**ENTIRE RED DEER RIVER WATERSHED**

| Area (km2) | Wetland Class | Wetland Area (km2) | Wetland Cover (%) |
|---|---|---|---|
| 49181.5 | Bog | 33.8 | **0.1%** |
| 49181.5 | Fen | 401.3 | **0.8%** |
| 49181.5 | Marsh | 2373.8 | **4.8%** |
| 49181.5 | Open Water | 686.8 | **1.4%** |
| 49181.5 | Swamp | 179.2 | **0.4%** |
| 49181.5 | *Total* | 3674.8 | **7.5%** |

Area within Banff National Park excluded from statistical summaries due to missing data in the CWCSS database

## Wetland Density Statistics for Subwatersheds and Watershed Landscape Units in the Red Deer River Watershed

*Based on the Provincial CWCSS merged provincial wetlands inventory

| Landscape Unit | SubWatershed Name | Area (km2) | Wetland Count | Wetland Density (# of wetlands per km2) | Wetland Cover for comparison | Ratio (Cover/Density) |
|---|---|---|---|---|---|---|
| Central Agricultural | Michichi | 5835.7 | 33289.0 | 5.7 | 13.70% | 41.63787116 |
| Central Agricultural | Buffalo | 2565.8 | 13837.0 | 5.4 | 10.80% | 49.93412218 |
| Central Agricultural | Kneehills | 2496.4 | 7869.0 | 3.2 | 5.20% | 60.61903197 |
| Central Agricultural | Rosebud | 4391.3 | 40235.0 | 9.2 | 4.80% | 190.8846365 |
| Central Agricultural | Threehills | 3010.9 | 13789.0 | 4.6 | 4.40% | 104.0853332 |
| Central Urbanizing | Waskasoo | 723.5 | 1128.0 | 1.6 | 3.60% | 43.30937046 |
| Central Urbanizing | Blindman | 2105.9 | 5116.0 | 2.4 | 10.70% | 22.70393161 |
| Dry Grasslands | Berry | 6830.9 | 20035.0 | 2.9 | 4.40% | 66.65929646 |
| Dry Grasslands | Alkali | 6016.9 | 29680.0 | 4.9 | 6.40% | 77.07481109 |
| Dry Grasslands | Matzhwin | 4954.1 | 15609.0 | 3.2 | 6.70% | 47.02533799 |
| Lower Headwaters | Little Red | 3702.7 | 7717.0 | 2.1 | 3.60% | 57.89271558 |
| Lower Headwaters | Medicine | 2864.2 | 11524.0 | 4.0 | 13.60% | 29.58444746 |
| Lower Headwaters | Raven | 935.7 | 3558.0 | 3.8 | 11.30% | 33.64974686 |
| Upper Headwaters | James | 1531.4 | 6078.0 | 4.0 | 10.90% | 36.41152375 |
| Upper Headwaters | Panther | 1216.2 | 1500.0 | 1.2 | 5.40% | 22.84074972 |

*Panther statistics are for that portion outside of Banff National Park boundary

| Landscape Unit | | | | |
|---|---|---|---|---|
| Central Agricultural | | 18300.0 | 109019.0 | 6.0 |
| Central Urbanizing | | 2829.4 | 6244.0 | 2.2 |
| Dry Grasslands | | 17801.9 | 65324.0 | 3.7 |
| Lower Headwaters | | 7502.6 | 22799.0 | 3.0 |
| Upper Headwaters | | 2747.6 | 7578.0 | 2.8 |
| | | | | |
| Entire Watershed | | 49181.5 | 210964.0 | 4.3 |

# Riparian Statistics for Subwatersheds and Watershed Landscape Units in the Red Deer River Watershed

| SubWatershed Name | Area km2 | Total Riparian Area (km2) | *Total Lotic Riparian Area as % of SubW area* | Developed / Urban (km2) | Developed / Urban (% of all riparian) | Crops (km2) | Crops (% of all riparian) | Hay/ Tame Pasture km2 | Hay / Tame Pasture (% of all riparian) | Natural (Intact) (km2) | Natural (% of all riparian areas with natural land cover in the subwatershed) | Cutblocks (km2) | Cutblocks (% of all riparian) | Perennial Land Cover (Natural + Hay / Tame Pasture) (km2) | Perennial Land Cover (% of all riparian) (km2) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Landscape Unit: DRY GRASSLANDS | 17801.9 | 2001.7 | *11.2%* | 8.1 | 0.4% | 336.6 | 16.8% | 258.5 | 12.9% | 1398.4 | 69.9% | 0 | 0.0% | 1656.9 | 82.8% |
| Berry | 6830.9 | 838.4 | *12.3%* | 2.1 | 0.2% | 51.3 | 6.1% | 117.9 | 14.1% | 667.1 | 79.6% | 0 | 0.0% | 785.0 | 93.6% |
| Matzhwin | 4954.1 | 443.3 | *8.9%* | 4.3 | 1.0% | 101.4 | 22.9% | 53.8 | 12.1% | 283.7 | 64.0% | 0 | 0.0% | 337.5 | 76.1% |
| Alkali | 6016.9 | 720.0 | *12.0%* | 1.7 | 0.2% | 183.9 | 25.5% | 86.8 | 12.1% | 447.5 | 62.2% | 0 | 0.0% | 534.3 | 74.2% |
| Landscape Unit: CENTRAL AGRICULTURAL | 18300.0 | 1461.9 | *8.0%* | 6.9 | 0.5% | 716.2 | 49.0% | 134.2 | 9.2% | 604.7 | 41.4% | 0 | | 738.8 | 50.5% |
| Michichi | 5835.7 | 558.9 | *9.6%* | 0.0 | 0.0% | 155.3 | 27.8% | 81.8 | 14.6% | 321.8 | 57.6% | 0 | 0.0% | 403.6 | 72.2% |
| Rosebud | 4391.3 | 332.7 | *7.6%* | 2.7 | 0.8% | 214.8 | 64.6% | 24.0 | 7.2% | 91.2 | 27.4% | 0 | 0.0% | 115.2 | 34.6% |
| Kneehills | 2496.4 | 217.5 | *8.7%* | 1.8 | 0.8% | 156.7 | 72.1% | 5.7 | 2.6% | 53.2 | 24.5% | 0 | 0.0% | 58.9 | 27.1% |
| Threehills | 3010.9 | 211.9 | *7.0%* | 1.0 | 0.5% | 131.3 | 62.0% | 4.1 | 1.9% | 75.5 | 35.6% | 0 | 0.0% | 79.5 | 37.5% |
| Buffalo | 2565.8 | 141.0 | *5.5%* | 1.4 | 1.0% | 58.1 | 41.2% | 18.6 | 13.2% | 62.9 | 44.6% | 0 | 0.0% | 81.5 | 57.8% |
| Landscape Unit: CENTRAL URBANIZING | 2829.4 | 234.2 | *8.3%* | 5.1 | 2.2% | 99.4 | 42.4% | 43.7 | 18.6% | 86.1 | 36.8% | 0 | 0.0% | 129.8 | 55.4% |
| Waskasoo | 723.5 | 58.8 | *8.1%* | 1.8 | 3.1% | 42.6 | 72.5% | 1.6 | 2.6% | 12.8 | 21.8% | 0 | 0.0% | 14.4 | 24.4% |
| Blindman | 2105.9 | 175.4 | *8.3%* | 3.2 | 1.8% | 56.8 | 32.4% | 42.1 | 24.0% | 73.3 | 41.8% | 0 | 0.0% | 115.4 | 65.8% |
| Landscape Unit: LOWER HEADWATERS | 7502.6 | 833.6 | *11.1%* | 5.0 | 0.6% | 257.7 | 30.9% | 86.3 | 10.4% | 476.4 | 57.2% | 8.1 | 1.0% | 562.7 | 67.5% |
| Little Red | 3702.7 | 388.6 | *10.5%* | 3.7 | 1.0% | 127.4 | 32.8% | 25.1 | 6.5% | 227.0 | 58.4% | 5.4 | 1.4% | 252.1 | 64.9% |
| Medicine | 2864.2 | 317.5 | *11.1%* | 1.0 | 0.3% | 111.2 | 35.0% | 42.9 | 13.5% | 162.4 | 51.2% | 0.0 | 0.0% | 205.4 | 64.7% |
| Raven | 935.7 | 127.5 | *13.6%* | 0.3 | 0.3% | 19.2 | 15.1% | 18.2 | 14.3% | 87.1 | 68.3% | 2.7 | 2.1% | 105.3 | 82.6% |
| Landscape Unit: UPPER HEADWATERS | 2747.6 | 409.2 | *14.9%* | 5.1 | 1.3% | 24.6 | 6.0% | 19.0 | 4.6% | 342.7 | 83.8% | 17.7 | 4.3% | 361.7 | 88.4% |
| James | 1531.4 | 275.6 | *18.0%* | 4.8 | 1.7% | 24.6 | 8.9% | 19.0 | 6.9% | 214.0 | 77.7% | 13.2 | 4.8% | 233.0 | 84.5% |
| Panther (Outside Banff NP) | 1216.2 | 133.6 | *11.0%* | 0.4 | 0.3% | 0.0 | 0.0% | 0.0 | 0.0% | 128.7 | 96.4% | 4.5 | 3.4% | 128.7 | 96.4% |
| **TOTALS** | 75065.9 | 7061.2 | *9.4%* | 42.2 | **0.6%** | 2483.2 | **35.2%** | 786.8 | **11.1%** | 3732.8 | 52.9% | 16.3 | 0.2% | 4519.6 | 64.0% |

Based on satellite-derived land cover (2011 Crop Inventory from Agriculture Canada-30 m resolution), intersected with the provincial variable width lotic riparian polygons (DEM derived)

The land cover classes were binned into the following classes for the purpose of reporting:

'Developed / Urban' = 34 (Urban)

'Crops' includes: 120= Agricultural Crop Classes, 130= Too wet to be seeded, 131= Fallow, 133-197 inclusive = Agricultural Crop Classes

'Hay / Tame Pasture' is based on class 122 = Hay/Pasture

'Natural' is based on 20 = Water, 50=Shrubland, 80=Wetland, 110=Grassland/Rangeland, 210 / 220 / 230 = Forest Classes

For the purposes of reporting, the 'Natural' and 'Hay/Tame Pasture' classes were also grouped together and termed 'Perennial Land Cover'

| |
|---|
| >80% |
| 60-80% |
| 40-60% |
| <40% |

# LAND USES IN SUBWATERSHEDS AND LANDSCAPE UNITS

| **SubWatershed Name** | **Area (km2)** | *Developed / Urban (km2)* | *Developed / Urban (% of subwatershed)* | *Crops (km2)* | *Crops (% of subwatershed)* | *Hay / Tame Pasture km2* | *Hay / Tame Pasture (% of subwatershed)* | *Natural (km2)* | *Natural (% of subwatershed)* | *Cutblocks (km2)* | *Cutblocks (% of subwatershed)* | *Perennial Cover (Natural + Hay / Tame Pasture) (km2)* | *Perennial Cover (% of subwatershed) (km2)* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Landscape Unit: DRY GRASSLANDS | 17801.9 | 100.3 | 0.6% | 4083.2 | 22.9% | 2487.2 | 14.0% | 11128.0 | 62.5% | 0.0 | 0.0% | 13615.2 | 76.5% |
| Berry | 6830.9 | 36.1 | 0.5% | 741.3 | 10.9% | 1170.4 | 17.1% | 4882.6 | 71.5% | 0.0 | 0.0% | 6053.0 | 88.6% |
| Matzhwin | 4954.1 | 42.1 | 0.8% | 1696.3 | 34.2% | 500.2 | 10.1% | 2714.0 | 54.8% | 0.0 | 0.0% | 3214.2 | 64.9% |
| Alkali | 6016.9 | 22.1 | 0.4% | 1645.5 | 27.3% | 816.6 | 13.6% | 3531.4 | 58.7% | 0.0 | 0.0% | 4348.0 | 72.3% |
| | | | | | | | | | | | | | |
| Landscape Unit: CENTRAL AGRICULTURAL | 18300.0 | 158.5 | 0.9% | 11891.0 | 65.0% | 2096.7 | 11.5% | 4150.7 | 22.7% | 0.2 | 0.0% | 6247.5 | 34.1% |
| Michichi | 5835.7 | 27.2 | 0.5% | 2555.6 | 43.8% | 1082.9 | 18.6% | 2169.0 | 37.2% | 0.0 | 0.0% | 3251.9 | 55.7% |
| Rosebud | 4391.3 | 58.1 | 1.3% | 3565.4 | 81.2% | 313.3 | 7.1% | 453.5 | 10.3% | 0.0 | 0.0% | 766.8 | 17.5% |
| Kneehills | 2496.4 | 25.4 | 1.0% | 2122.9 | 85.0% | 70.3 | 2.8% | 277.8 | 11.1% | 0.0 | 0.0% | 348.1 | 13.9% |
| Threehills | 3010.9 | 21.4 | 0.7% | 2254.4 | 74.9% | 126.4 | 4.2% | 608.7 | 20.2% | 0.0 | 0.0% | 735.1 | 24.4% |
| Buffalo | 2565.8 | 26.4 | 1.0% | 1392.6 | 54.3% | 503.8 | 19.6% | 641.8 | 25.0% | 0.2 | 0.0% | 1145.6 | 44.7% |
| | | | | | | | | | | | | | |
| Landscape Unit: CENTRAL URBANIZING | 2829.4 | 117.6 | 10.6% | 1526.1 | 53.9% | 493.4 | 17.4% | 685.3 | 24.2% | 6.6 | 0.2% | 1178.8 | 41.7% |
| Waskasoo | 723.5 | 55.4 | 7.7% | 549.5 | 75.9% | 20.9 | 2.9% | 97.6 | 13.5% | 0.0 | 0.0% | 118.5 | 16.4% |
| Blindman | 2105.9 | 62.2 | 3.0% | 976.6 | 46.4% | 472.5 | 22.4% | 587.8 | 27.9% | 6.6 | 0.3% | 1060.3 | 50.3% |
| | | | | | | | | | | | | | |
| Landscape Unit: LOWER HEADWATERS | 7502.6 | 71.0 | 0.9% | 3454.2 | 46.0% | 1031.0 | 13.7% | 2705.5 | 36.1% | 263.5 | 3.5% | 3736.6 | 49.8% |
| Little Red | 3702.7 | 48.6 | 1.3% | 1710.0 | 46.2% | 302.3 | 8.2% | 1438.7 | 38.9% | 226.0 | 6.1% | 1741.0 | 47.0% |
| Medicine | 2864.2 | 17.7 | 0.6% | 1499.0 | 52.3% | 512.8 | 17.9% | 829.4 | 29.0% | 5.1 | 0.2% | 1342.2 | 46.9% |
| Raven | 935.7 | 4.8 | 0.5% | 245.2 | 26.2% | 216.0 | 23.1% | 437.4 | 46.7% | 32.4 | 3.5% | 653.4 | 69.8% |
| | | | | | | | | | | | | | |
| Landscape Unit: UPPER HEADWATERS | 3774.0 | 18.1 | 0.5% | 120.1 | 3.2% | 119.1 | 3.2% | 3190.1 | 84.5% | 328.6 | 8.7% | 3309.2 | 87.7% |
| James | 1531.4 | 15.8 | 1.0% | 120.1 | 7.8% | 119.1 | 7.8% | 1064.5 | 69.5% | 213.7 | 14.0% | 1183.6 | 77.3% |
| Panther | 2242.6 | 2.3 | 0.1% | 0.0 | 0.0% | 0.0 | 0.0% | 2125.6 | 94.8% | 114.9 | 5.1% | 2125.6 | 94.8% |
| **TOTALS** | 50207.9 | 465.6 | **0.9%** | 21074.6 | **42.0%** | 6227.5 | **12.4%** | 21859.7 | 43.5% | 598.8 | 1.2% | 28087.2 | 55.9% |

*Based on 2011 Crop Inventory (Agriculture Canada), combined with Alberta Biodiversity Monitoring Institute (ABMI) data on forestry cutblocks (ABMI 2010)

**Natural includes Water, Shrubland, Wetland, Grassland/Rangeland, and Forest Classes, but not recent cutblocks as documented by ABMI which are reported separately

| |
|---|
| >80% |
| 60-80% |
| 40-60% |
| <40% |

# CENSUS AGRICULTURAL DATA 2006: SELECTED VARIABLES BY SUBWATERSHED AND LANDSCAPE UNIT

| Sub Watershed / Landscape Unit | Sub Watershed Area Km2 | SUM_WSBUFF | SUM_WSFERT | | SUM_WSMANURE | | SUM_WSLVKG | | SUM_WSCHEM | SUM_WSFE_1 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | (# farms using buffer zones around water bodies) Number of farms | (Area over which fertilizer chemical applied) in ha | (Area over which fertilizer chemical applied) converted to km2 | (Area over which manure applied) in ha | (Area over which fertilizer chemical applied) converted to km2 | (annual KG phosphorus in manure from all livestock) in kg | (annual KG phosphorus in manure from all livestock) in kg/ha | expenses of herbicides, insecticides, fungicides in $ | expenses of fertilizer and lime purchases in $ |
| Landscape Unit: DRY GRASSLANDS | 17802 | 149 | 175466 | 1755 | 21712 | 217 | 4328937 | 2.4 | $11,929,509 | $13,068,336 |
| Alkali | 6017 | 18 | 32771 | 328 | 3281 | 33 | 586483 | 1.0 | $3,151,815 | $2,094,772 |
| Berry | 6831 | 59 | 58536 | 585 | 8626 | 86 | 1573240 | 2.3 | $3,364,977 | $3,519,293 |
| Matzhwin | 4954 | 72 | 84159 | 842 | 9806 | 98 | 2169215 | 4.4 | $5,412,716 | $7,454,272 |
| | | | | | | | | | | |
| Landscape Unit: CENTRAL AGRICULTURAL | 18300 | 451 | 588338 | 5883 | 49713 | 497 | 6992848 | 3.8 | $32,406,749 | $49,973,653 |
| Michichi | 5836 | 139 | 184446 | 1844 | 13926 | 139 | 1772541 | 3.0 | $10,027,366 | $13,489,249 |
| Rosebud | 4391 | 185 | 249778 | 2498 | 20578 | 206 | 3242934 | 7.4 | $13,979,548 | $21,839,052 |
| Kneehills | 2496 | 127 | 154114 | 1541 | 15210 | 152 | 1977373 | 7.9 | $8,399,836 | $14,645,352 |
| Threehills | 3011 | 118 | 167575 | 1676 | 11341 | 113 | 1619199 | 5.4 | $10,183,769 | $16,187,195 |
| Buffalo | 2566 | 168 | 103945 | 1039 | 17392 | 174 | 1844591 | 7.2 | $5,441,042 | $10,614,207 |
| | | | | | | | | | | |
| Landscape Unit: CENTRAL URBANIZING | 2829 | 259 | 101272 | 1013 | 21152 | 212 | 2388338 | 8.4 | $5,203,843 | $11,014,427 |
| Waskasoo | 723 | 63 | 34648 | 346 | 5255 | 53 | 606083 | 8.4 | $2,034,298 | $3,838,890 |
| Blindman | 2106 | 196 | 66624 | 666 | 15897 | 159 | 1782255 | 8.5 | $3,169,545 | $7,175,537 |
| | | | | | | | | | | |
| Landscape Unit: LOWER HEADWATERS | 7502 | 610 | 187222 | 1872 | 34840 | 348 | 4524338 | 6.0 | $7,439,793 | $18,155,572 |
| Little Red | 3702 | 279 | 97680 | 977 | 16776 | 168 | 2045547 | 5.5 | $4,025,383 | $9,367,158 |
| Medicine | 2864 | 247 | 74176 | 742 | 14458 | 145 | 1925147 | 6.7 | $3,024,223 | $7,512,464 |
| Raven | 936 | 84 | 15365 | 154 | 3606 | 36 | 553643 | 5.9 | $390,186 | $1,275,951 |
| | | | | | | | | | | |
| Landscape Unit: UPPER HEADWATERS | 3775 | 45 | 6149 | 61 | 1796 | 18 | 273464 | 0.7 | $154,996 | $469,485 |
| James | 1531 | 44 | 6091 | 61 | 1768 | 18 | 269942 | 1.8 | $153,897 | $465,302 |
| Panther | 2244 | 0 | 59 | 1 | 28 | 0 | 3522 | 0.0 | $1,099 | $4,183 |
| | | | | | | | | | | |
| TOTAL (ENTIRE WATERSHED) | 50208 | 1800 | 1329967 | 13300 | 157947 | 1579 | 21971715 | 4.4 | $72,759,700 | $119,482,875 |

*Results are rough estimates as the highest resolution Census data is reported by soil landscape polygons-average values for each Census polygon were calculated and then used to assign values to the proportion of each Census polygon in each subwatershed
Essentially this assumes that an equal distribution of farms exist over each soil landscape polygon which may not capture local variations

# OIL AND GAS WELL SITE DENSITY

Based on IHS (2012) Data

| Landscape Unit | SubWatershed | Total IHS (2012) Wellsite Count | SubWS Area Km2 | Wellsite Density (sites per km2) |
|---|---|---|---|---|
| Central Agricultural | Buffalo | 7746 | 2565.787978 | 3.019 |
| Central Agricultural | Kneehills | 6177 | 2496.359941 | 2.474 |
| Central Agricultural | Michichi | 11496 | 5835.682639 | 1.970 |
| Central Agricultural | Rosebud | 14208 | 4391.286707 | 3.235 |
| Central Agricultural | Threehills | 8112 | 3010.859974 | 2.694 |
| Central Urbanizing | Blindman | 4610 | 2105.938519 | 2.189 |
| Central Urbanizing | Waskasoo | 1340 | 723.4769982 | 1.852 |
| Dry Grasslands | Alkali | 7820 | 6016.881436 | 1.300 |
| Dry Grasslands | Berry | 14232 | 6830.86881 | 2.083 |
| Dry Grasslands | Matzhwin | 25566 | 4954.140879 | 5.161 |
| Lower Headwaters | Little Red | 2842 | 3701.652408 | 0.768 |
| Lower Headwaters | Medicine | 7237 | 2864.183765 | 2.527 |
| Lower Headwaters | Raven | 1378 | 935.7195404 | 1.473 |
| Upper Headwaters | James | 1087 | 1531.42363 | 0.710 |
| Upper Headwaters | Panther | 119 | 2243.719737 | 0.053 |
| | | 113970 | | |
| | | | | |
| | | **Total IHS Wellsite Count** | **LUnit Area Km2** | **Wellsite Density (sites per km2)** |
| | | | | |
| Central Agricultural | | 47739 | 18299.97724 | 2.609 |
| Central Urbanizing | | 5950 | 17840.12778 | 0.334 |
| Dry Grasslands | | 47618 | 16067.24484 | 2.964 |
| Lower Headwaters | | 11457 | 16248.44363 | 0.705 |
| Upper Headwaters | | 1206 | 18688.02574 | 0.065 |

# PIPELINE LINEAR DENSITY

Based on IHS (2012) DATA

| Landscape Unit | SubWatershed | Total IHS Pipeline segment length Km | SubWS Area Km2 | Pipeline Linear Density (km per km2) |
|---|---|---|---|---|
| Central Agricultural | Buffalo | 4741.8 | 2565.8 | 1.85 |
| Central Agricultural | Kneehills | 4238.5 | 2496.4 | 1.70 |
| Central Agricultural | Michichi | 8747.0 | 5835.7 | 1.50 |
| Central Agricultural | Rosebud | 8431.3 | 4391.3 | 1.92 |
| Central Agricultural | Threehills | 6315.2 | 3010.9 | 2.10 |
| Central Urbanizing | Blindman | 2917.9 | 2105.9 | 1.39 |
| Central Urbanizing | Waskasoo | 895.9 | 723.5 | 1.24 |
| Dry Grasslands | Alkali | 4697.7 | 6016.9 | 0.78 |
| Dry Grasslands | Berry | 9848.3 | 6830.9 | 1.44 |
| Dry Grasslands | Matzhwin | 12279.8 | 4954.1 | 2.48 |
| Lower Headwaters | Little Red | 4237.3 | 3701.7 | 1.14 |
| Lower Headwaters | Medicine | 7008.2 | 2864.2 | 2.45 |
| Lower Headwaters | Raven | 1789.0 | 935.7 | 1.91 |
| Upper Headwaters | James | 1577.6 | 1531.4 | 1.03 |
| Upper Headwaters | Panther | 274.6 | 2243.7 | 0.12 |
| | | | | |
| | | | | |
| | **Landscape Unit** | **Total IHS Pipeline segment length Km** | **LUnit Area Km2** | **Pipeline Linear Density (km per km2)** |
| | | | | |
| Central Agricultural | | 32473.8 | 18300.0 | 1.77 |
| Central Urbanizing | | 3813.8 | 2829.4 | 1.35 |
| Dry Grasslands | | 26825.8 | 17801.9 | 1.51 |
| Lower Headwaters | | 13034.5 | 7501.6 | 1.74 |
| Upper Headwaters | | 1852.2 | 3775.1 | 0.49 |
| | | | | |
| TOTAL | | 78000.1 | 50208.0 | 1.55 |

# SURFACE LINEAR DENSITY

Based on all readily available road and rail layers

| Landscape Unit | SubWatershed | Total Road/Rail segment length Km | SubWS Area Km2 | Linear Density (km per km2) |
|---|---|---|---|---|
| Central Agricultural | Buffalo | 2349.5 | 2565.8 | 0.92 |
| Central Agricultural | Kneehills | 2261.2 | 2496.4 | 0.91 |
| Central Agricultural | Michichi | 3927.8 | 5835.7 | 0.67 |
| Central Agricultural | Rosebud | 4056.0 | 4391.3 | 0.92 |
| Central Agricultural | Threehills | 2660.3 | 3010.9 | 0.88 |
| Central Urbanizing | Blindman | 2323.3 | 2105.9 | 1.10 |
| Central Urbanizing | Waskasoo | 1235.5 | 723.5 | 1.71 |
| Dry Grasslands | Alkali | 2425.8 | 6016.9 | 0.40 |
| Dry Grasslands | Berry | 3401.1 | 6830.9 | 0.50 |
| Dry Grasslands | Matzhwin | 3206.2 | 4954.1 | 0.65 |
| Lower Headwaters | Little Red | 2856.5 | 3701.7 | 0.77 |
| Lower Headwaters | Medicine | 2676.3 | 2864.2 | 0.93 |
| Lower Headwaters | Raven | 651.8 | 935.7 | 0.70 |
| Upper Headwaters | James | 798.2 | 1531.4 | 0.52 |
| Upper Headwaters | Panther | 155.7 | 2243.7 | 0.07 |
| | | | | |
| | | | | |
| | | **Total Road/Rail segment length Km** | **LUnit Area Km2** | **Linear Density (km per km2)** |
| | | | | |
| Central Agricultural | | 15254.8 | 18300.0 | 0.83 |
| Central Urbanizing | | 3558.8 | 2829.4 | 1.26 |
| Dry Grasslands | | 9033.1 | 17801.9 | 0.51 |
| Lower Headwaters | | 6184.6 | 7501.6 | 0.82 |
| Upper Headwaters | | 953.9 | 3775.1 | 0.25 |
| | | | | |
| **TOTAL (ENTIRE WATERSHED)** | | 34985.2 | 50208.0 | 0.70 |