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Athabasca Watershed Council
State of the Watershed Report: Phase 1

FINAL

March 2011

Prepared for:

Athabasca Watershed Council
Hinton, Alberta

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ATHABASCA WATERSHED COUNCIL STATE OF THE WATERSHED REPORT: PHASE 1

FINAL REPORT

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1.0 BACKGROUND

The Athabasca River is over 1,200 km in length and has a drainage area of approximately 100,000 km^2 (NRCan 2008). The headwaters of the watershed arise from the melting snow and ice of the Athabasca Glacier in Jasper National Park. The Athabasca River then flows northeast across Alberta, through the Peace-Athabasca Delta, and into Lake Athabasca. Approximately 90% of the Athabasca watershed is located within Alberta, with 10% falling within Saskatchewan.

The Athabasca watershed has unique attributes and environmental concerns. The Athabasca watershed contains several human settlements, including Fort McMurray, Hinton, Whitecourt, Edson, Jasper, and Athabasca, which all have municipal wastewater treatment plants discharging into the Athabasca River. Economic activity in the upper portion of the watershed is dominated by agriculture and forestry, as well as three active coal mines and one closed coal mine in the Edson/Hinton area (ERCB 2010). Forestry occurs throughout the watershed, while oil sands developments dominate the lower portion of the watershed.

The basin has been divided into 10 sub-watersheds for the purposes of this project, as outlined below.

Table 1 Sub-basins in the Athabasca watershed.

▪ Upper Athabasca	▪ La Biche
▪ McLeod	▪ Clearwater
▪ Pembina	▪ Lower Athabasca
▪ Central Athabasca – upper	▪ Lake Athabasca
▪ Central Athabasca – lower	▪ Lesser Slave (see note)

Note: The Lesser Slave sub-watershed has a separate WPAC and completed SOW Report. The geospatial data on the Lesser Slave sub-watershed is presented only for reference and to make linkages with the overall Athabasca watershed. The scope of work for Phase 2 excludes a detailed analysis of the Lesser Slave sub-watershed, given it has already been completed and can be referenced in the Athabasca SOW Report.

1.1 SCOPE OF WORK (PHASE 1)

The Government of Alberta has committed to protecting and managing the water resources of Alberta pursuant to the *Water for Life (WFL) Strategy* and *Water for Life Action Plan* (Government of Alberta 2003, 2008, 2009). Watershed Planning and Advisory Councils (WPACs) are designated in the *Water for Life Strategy* as multi-stakeholder, non-profit organizations responsible for assessing the condition of a watershed and developing a plan to address issues identified during the assessment. The Athabasca Watershed Council Watershed Planning and Advisory Council (AWC) was formed in late 2009 and was mandated with the development of a State of the Watershed (SOW) Report for the Athabasca watershed by 2012.

The AWC initiated this process to determine the condition of the watershed in June 2010 with the ***State of the Watershed - Phase 1 Project*** ("the Project"). The scope of work for Phase 1 included the identification and compilation of information and geospatial data relevant to the Athabasca watershed, to support the production of a public-facing SOW report in Phase 2, as well as development of suggested indicators for use in the final (Phase 2) SOW report, and a draft Terms of Reference document for Phase 2. Hatfield Consultants was retained by AWC to complete these Phase 1 tasks.

Specifically, the Project included the following components:

1. A comprehensive bibliography of non-spatial data (annotated where possible) relevant to understanding the "state of the watershed" (Appendix A1);

2. A preliminary Geospatial Atlas including spatial datasets (i.e., geodatabase), mapping products, and summary tables (Appendix A2);

3. A preliminary assessment of key issues, concerns, and major threats in the watershed as identified in the literature/spatial datasets, leading to the selection of proposed Watershed Health Indicators that may be used in Phase 2 of the Project to assess and track the ecological integrity and health of the watershed, in a final Athabasca State of the Watershed (SOW) Report, oriented toward the public and decision-makers;

4. A data and knowledge gap analysis, to identify information that is currently lacking or unavailable for use in developing a robust Phase 2 SOW report;

5. A draft Terms of Reference (TOR) for Phase 2 of the AWC State of the Watershed Report, which was provided to AWC under separate cover; and

6. A Traditional Ecological Knowledge (TEK) report, summarizing existing data describing the biophysical health of the watershed, including research, monitoring, reporting, and stewardship initiatives, which will be presented to AWC under separate cover.

Items 1, 2 and 5 are presented in Appendices A1 to A3, while the recommended indicators, key threats and pressures, and knowledge and data gaps are presented in the following sections. The bibliography also has been made available as a searchable, online database, as described in Section 2.1.

2.0 METHODOLOGY

A brief synopsis of work undertaken for Phase 1 is provided below of each project component. Issues encountered, data/knowledge gaps found, and recommendations for the AWC going forward into Phase 2 are later discussed in Sections 4 and 5.

2.1 BIBLIOGRAPHY

The bibliography of science-based information sources encompasses approximately 20,700 references. Materials include government, scientific and other publications, and various spatial and non-spatial data sets, compiled by Hatfield staff through investigation and compilation of current and historical information sources. Materials collected and compiled by Hatfield directly included approximately 220 references (excluding spatial data); where possible, these materials have been obtained in electronic form (typically PDFs) and included on DVD as a deliverable of this project (this includes nearly all references cited in Appendix 1). Where the original reference could not be obtained, or the reference was easily obtainable online, links were provided to facilitate user access. These directly-obtained references are included in the printed bibliography in Appendix A1.

The remainder of references compiled in this database came from the Bibliography of the Athabasca River Basin (BARB), an Excel-based list of references related to the Athabasca River basin, which includes approximately 20,500 entries and was produced by the Athabasca River Basin Research Institute (ARBRI).

As an additional deliverable of this project, a web-served, searchable form of the Phase 1 bibliography—integrating the full BARB database—was developed, and currently (as of March 2011) resides at the following web address:

http://www.hatfieldgroup.com/AthabascaBibliography

A search tool has been developed to allow for the full reference list to be searchable by key word.

This website was created using Microsoft.Net programming tools, and uses the MySQL open-source database engine. In the medium to long term, we anticipate that AWC may want to migrate hosting of this database from Hatfield's site to its own website, or to integrate this database with the existing BARB project at Athabasca University, which also has stated an interest in developing a web-served version of its database. Hatfield is available to assist AWC with such a migration if desired.

To host this database, the following systems are needed:

- Microsoft IIS webserver; and
- MySQL database engine.

2.2 TRADITIONAL ECOLOGICAL KNOWLEDGE REPORT

A separate TEK report, documenting publicly available sources of TEK with a short written summary, will be provided in a stand-alone report. In addition to being provided to the AWC, it also will be submitted directly to Treaty 8 First Nations of Alberta and Métis Nation of Alberta. This approach, agreed upon with the AWC during scoping of Phase 1, essentially separated TEK non-spatial information from science-based information sources.

The TEK report was compiled by Dr. Brenda Parlee, Assistant Professor and Canada Research Chair, Faculty of Native Studies, University of Alberta.

2.3 PRELIMINARY ATLAS / SPATIAL DATABASE

Spatial datasets describing features of the basin were compiled in the Preliminary Atlas, using the following guidance:

- The Handbook for State of the Watershed Reporting: A Guide for Developing State of the Watershed Reports in Alberta (AENV 2008);
- Various government and non-government agencies (specific sources are provided in Table 2, Appendix A2); and
- Relevant spatial data already collected and existing in Hatfield's internal geodatabase.

Alberta Environment (AWC representative: Richard Chabaylo) coordinated and streamlined efforts to collect data where possible.

Existing geo-spatial data and information were gathered for the select assessment features in Table 2.

Table 2 Assessment features included in the geodatabase.

A. Geology
B. Soils
C. Topography
D. Land Cover
E. Meteorology
F. Hydrology
G. Water Quality
H. Fisheries and Wildlife
I. Surface Water Use
J. Groundwater
K. Point Source Effluents
L. Land Use Indices – Linear
M. Land Use Indices – Area
N. Administrative

These data were gathered from readily available sources and federal, provincial and regional agencies, including Environment Canada, Natural Resources Canada, Agriculture and Agri-Food Canada, Alberta Geological Survey, Alberta Environment, Alberta Energy, Alberta Sustainable Resources Development, Alberta Biodiversity Monitoring Institute, Alberta Conservation Information Management System, Groundwater Information Centre, and the Regional Aquatics Monitoring Program.

Contact with data providers involved telephone calls, emails, and internet searches. Sources identified in the *Handbook for State of the Watershed Reporting: A Guide for Developing State of the Watershed Reports in Alberta* (2008) were investigated. Contacts and data provided by Environment Canada also were utilized.

Data custodians like GeoConnections, GeoBase, and GeoGratis shared data from government and non-government agencies.

Geospatial data were gathered in a number of formats, including AutoCAD drawing files, ESRI ArcGIS/Arcview shapefile, ArcGIS file geodatabase, ArcInfo coverages, and Microsoft Excel spreadsheets.

Spatial Data Compilation

Gathered data were reviewed for their coverage (complete or partial) of the study area, their age (current or out of date), their scale (1:2,000,000 or 1:50,000), and the data source (federal or provincial government or private organization).

Where metadata existed, it was organized and is delivered on DVD along with the file geodatabase. As the metadata were written by the original data creator (rather than Hatfield), these metadata exist in numerous formats, including XML, HTML, DOC, TXT, PDF. The completeness of metadata varied widely.

Table 2 in Appendix A2 summarizes the status of each feature in the geodatabase, its data source, coverage and completeness, the scale of the data, and whether metadata exist. As part of the Preliminary Atlas, all GIS data also has been provided to AWC on DVD with associated datasets and metadata, where available (DVD enclosed).

For data compatibility and ease of use, Hatfield has designed and created an ESRI File Geodatabase (version ArcGIS 9.3) to hold all the geospatial assessment features datasets.

Data modifications prior to importing into the file geodatabase included: (a) merging; (b) re-projecting the data; (c) subsetting the data to include only that within the study area; and (d) joining data tables. These steps are described below.

1. **Merging**

   Tiled datasets like the National Topographic Data Base were combined by merging in ArcGIS.

2. Projection

Data were re-projected NAD_1983_10TM_AEP_Forest. This is projection is used by the Alberta government and is useful for viewing data that stretches the width of the province. Details are provided below.

Projection:	Transverse_Mercator
False_Easting:	500000.000000
False_Northing:	0.000000
Central_Meridian:	-115.000000
Scale_Factor:	0.999200
Latitude_Of_Origin:	0.000000
Linear Unit:	Metre (1.000000)
Geographic Coordinate System:	GCS_North_American_1983
Angular Unit:	Degree (0.0174532925199433299)
Prime Meridian:	Greenwich (0.000000000000000000)
Datum:	D_North_American_1983
Spheroid:	GRS_1980
Semimajor Axis:	6378137.000000000000000000
Semiminor Axis:	6356752.314140356100000000
Inverse Flattening:	298.257222101000020000

3. Subsetting

Data were subset by clipping to the project study area. This made the data more manageable and focused on the area of interest. Raster (e.g., DEM, hillshade) datasets were not clipped. In addition, datasets with topology errors were not clipped, because these errors would each need to be resolved before clipping could occur. Some datasets exhibited hundreds of topology errors.

4. Joining Tables

Where appropriate, provided attribute data tables were joined to the GIS point/line/polygon dataset with location data only. This was done using a common unique identifier. One example is the soil drainage class dataset.

Note: no topology rules were applied because Hatfield was not the original creator of these data.

Creation of the Preliminary Atlas

A Preliminary Atlas of maps of created using the contents of the file geodatabase and the assessment features was created, including features listed in Table 3. Printed versions of these maps appear in Appendix A2.

ESRI ArcGIS project files (MXD) for the Atlas maps were delivered on DVD, which also included the file geodatabase and metadata.

Table 3 Assessment features included in the Preliminary Atlas.

Features Included in Preliminary Atlas
A. Geology (geologic era, geologic formation, surficial geology)
B. Soils (local surface form, coarse fragment content, soil drainage class)
C. Topography (DEM, hillshade, contours)
D. Land Cover (classification, wetlands, natural regions, green and white areas,)
E. Meteorology (mean annual temperature, total precipitation, monitoring sites)
F. Hydrology (watershed boundaries, stream flow gauges stations)
G. Water Quality (monitoring stations)
H. Fisheries and Wildlife (point data, species at risk, species present, important bird areas, monitoring sites)
I. Surface Water Use (allocation/withdrawals)
J. Groundwater (allocation/withdrawals, well density)
K. Point Source Effluents (type and volume)
L. Land Use Indices – Linear (pipelines, wells, roads, transmission lines, railway, cut line)
M. Land Use Indices – Area (oil sands Agreement, petroleum and natural gas agreement, metallic and industrial minerals agreement, coal license, coal categories, coal agreement, forest management agreement areas, registered fur management areas (trapline), Canada's forest heritage, converted and accessed forests, Canada's large remaining forested areas, Canada Land Inventory - agriculture/forest potential, parks and protects areas, First Nations reserves, treaty boundary, Land Use Framework Planning Regions, Integrated Resource Plan, Lower Athabasca Regional Plan
N. Administrative (Alberta township/range grid, Canadian geographic names)

2.4 INDICATORS OF WATERSHED HEALTH

The recommended Indicators of Watershed Health were largely developed through:

- Review of regulatory guidance from Alberta Environment (AENV);
- Review of stakeholder concerns from the AWC-WPAC and Watershed Stewardship Groups;
- Review of SOW reports produced by other WPACs, or similar types of reports produced by others;
- Assessment of current identifiable key anthropogenic threats and pressures, approved and proposed developments, and existing knowledge of the watershed;
- Identification of environmental resources of ecological or social importance that were deemed sensitive to change and could be reliably measured, using best professional judgment; and
- Feedback from AWC regarding on initial draft indicators.

A detailed description of the approach taken with the recommended indicators is provided in Section 3.

2.5 DRAFT PHASE 2 TERMS OF REFERENCE

A TOR for Phase 2 of the Project was drafted based on the outcomes from all other deliverables and in consultation with the AWC and their vision for Phase 2. The TOR for Phase 2 is provided to AWC under separate cover.

3.0 INDICATORS OF WATERSHED HEALTH

3.1 DEFINITION OF WATERSHED AND WATERSHED HEALTH

"Water" is defined by the ***Water Act*** as "all water on or under the surface of the ground, whether in solid or liquid state" (AENV 1998). A watershed, therefore, is the area of land where all water drains to the same destination and is defined by highpoints and ridgelines that descend into stream valleys. A watershed may encompass many ecosystems, while a large ecosystem may encompass multiple watersheds. These systems are the product of interactions between the flora, fauna, microorganisms, geological formations such as soil, rocks, and minerals, water sources and the local atmosphere.

The Government of Alberta is committed to the preservation of "healthy aquatic ecosystems" as outlined in its *WFL Strategy* (AENV 2003, 2008). In order to define 'watershed health', the terms ecosystem and watershed are used here interchangeably. The concept of ecosystem health emerged from research efforts to document changes in the environment resulting from human activity (Rapport et al. 1998). Generally, the term "ecosystem health" is used to describe an ecosystem's ability to maintain its structure and function while satisfying potentially stressful human use requirements (Postel *et al.* 2003, Costanza *et al.* 1997). For the purpose of State of the Watershed reporting, ecosystem/watershed health is best considered in the context of its ability to "remain sustainable and resilient to stress, and maintain its ecological structure and function over time, similar to the natural (undisturbed) ecosystems of the region, with the ability to recover from disturbance, while continuing to meet social needs and expectations (Stantec Consulting Ltd. 2005). Ecosystem health is the ultimate goal, or endpoint, of environmental management (Cash 1995); implicit to this is that processes important to an ecosystem's health can be identified and evaluated (Fairweather 1999).

3.2 DEFINITION OF WATERSHED HEALTH INDICATORS

Watershed health indicators are focused primarily on the aquatic environment, but also include terrestrial and anthropogenic factors that may relate to aquatic ecosystem health. For example, the physical state of an aquatic ecosystem (i.e., water and sediment quality, habitat features, and hydrological variables) can indicate activities that may be acting as stressors on aquatic organisms – these physical attributes are defined as ***'indicators'***. Biological indicators such as benthic invertebrate communities or fish populations reflect the overall condition of the aquatic environment and integrate the potential effects of complex and varied stressors over time. Although the term 'watershed' suggests an aquatic focus, terrestrial and anthropogenic factors should also be assessed such as biodiversity, water allocations, and municipal and industrial development in understanding the health of a watershed. This provides a more holistic understanding of the ecosystem and potential human effects on it.

3.2.1 Types of Indicators

Indicators can either be a single metric, such as pH or dissolved oxygen, or can be multi-metric, such as the River Nutrient Index, which includes a number of water quality variables summarized into a single number (AENV 2008). Furthermore, the nature of different indicators can be classified as follows (Jamison 2009):

- ***Condition indicators*** address the state of the environment;
- ***Pressure indicators*** indicate potential to cause negative impacts and describe the natural process or human influences that can impact environmental quality; and
- ***Response indicators*** describe actions or management plans intended to prevent or mitigate negative environmental impacts.

Each type of indicator is closely related. A ***pressure*** within the watershed may change a ***condition*** of the environment, which in turn may result in a ***response*** (i.e., restrictions on the discharge of pollutants). The most common types of state-of-the-environment indicators are condition and pressure; response indicators describe the state of management actions being taken to address environmental concerns.

3.2.2 Selection of Indicators

Due to complex and dynamic interactions between numerous influencing factors, one indicator alone is insufficient to measure the health of a watershed. Instead, a number of indicators are required to provide a representative image of a watershed (AENV 2008). In a report resulting from the Northern River Basins Study (NRBS), indicators of "aquatic ecosystem health" were proposed to be selected for each ecosystem on an individual basis, guided by the nature of that ecosystem and the stressors and issues acting on it (Cash *et al.* 1996). The number and type of indicators required or appropriate for a given assessment will vary, depending on the nature and scope of the assessment. Although the number of possible environmental indicators that could be used is nearly limitless, generally a minimum number of indicators should be used that capture meaningful information about environmental conditions of interest or concern, at a scale relevant to the assessment being conducted.

The selection of indicators for characterizing the health of a watershed is critical. These indicators must be comprehensive enough to capture major components and processes but must also be practical and measureable in scale and frequency. Well-chosen indicators will be measurable and interpretive, objective and comparable, reflective of how well the watershed is functioning, sensitive to stressors, reflective of stakeholder concerns, cost effective to monitor, and can summarize large amounts of information into an easily understood and concise format (AENV 2010). In order to meet all of these requirements an indicator must also be:

- **Relevant:** Has the ability to provide information about the watershed that stakeholders need to know;
- **Understandable:** Is easy to understand by non-technical experts;
- **Reliable:** The information that the indicator provides is trustworthy;
- **Timely:** The information provided is available while there is still time to act (Alberta Environmental Protection 1996 in Aquality Environmental Consulting Ltd. 2009); and
- **Comparable:** Can be evaluated against existing guidelines, thresholds, targets or historical trends, where possible (AENV 2010).

For the purposes of this SOW report, relevant indicators must also have **pre-existing and readily available data**, with appropriate spatial and temporal coverage, given the AWC will not collect new (primary) data for its SOW report.

Regulatory guidance to developing indicators and existing SOW reports for watersheds in Alberta provided direction when choosing the indicators for the Athabasca watershed. Specifically, the draft indicators were developed from the following sources:

- Draft Guide to Foundational Indicators for State of the Watershed Reporting (2010) (Section 2.1);
- The Keepers of the Athabasca Report (2008) (Section 2.2);
- Select AENV WPAC SOW reports for watersheds in Alberta (Section 2.3);
- State of the Aquatic Environment Report for the Peace-Athabasca Delta (2002) (Section 2.4); and
- WPAC member and stakeholder input and concerns:
    - Summary of Stakeholder and Aboriginal Community Concerns from WPAC Development Process (Athabasca Watershed Council, n.d.) (Section 3.7);
    - Watershed Stewardship Group Sector Report #3-Summary Report and Contract/Distribution List (Simmons 2010) (Section 2.5); and
    - Direct input Athabasca WPAC Technical Committee members.

3.3 DRAFT GUIDE TO FOUNDATIONAL INDICATORS FOR STATE OF THE WATERSHED REPORTING (DRAFT 2011)

The *Guide to Foundational Indicators for State of the Watershed Reporting* is being developed by AENV to establish a set of core indicators to be used by WPACs in Alberta when developing SOW reports. These core indicators of watershed health are not comprehensive, but provide a basis for the development of watershed-specific indicators. Recommended foundational indicators include:

- Nutrient concentrations;
- Bacteria concentrations;
- Surface water allocations (withdrawals);
- Variation of annual flow and/or lake levels;
- Flow commitments;
- Groundwater allocations;
- Groundwater well density;
- Land use/land cover;
- Riparian health; and
- Biotic integrity.

These foundational indicators have been considered in the draft list of indicators proposed herein and are included, where applicable to the Athabasca watershed in order to maintain consistency within the province.

3.4 KEEPERS OF THE ATHABASCA REPORT

The State of the Athabasca Watershed Report was prepared by the Canadian Parks and Wilderness Society (Northern Alberta) for the Keepers of the Athabasca (Walsh 2008). The report was intended as a SOW report and identifies numerous environmental and social concerns in the Athabasca watershed (Table 4), with much of its content drawn directly from other reports. It should be noted that the Keepers *State of the Athabasca Watershed Report* includes downstream portions of the watershed within Saskatchewan, unlike the proposed AWC-WPAC SOW which only includes the Alberta portion of the watershed.

Table 4 Key concerns expressed in the Keepers of the Athabasca Watershed report (Walsh 2008).

Concern	Activity	Stated Contaminants / Concerns
Human and aquatic life	Pulp mill effluent discharges	Increased phosphorus and nitrogen concentrations.
	Wastewater treatment facility effluent discharges	Increased nitrogen concentrations.
	PCB contamination in Hardisty Creek	Source of contamination is unknown (Swan Hills facility suspected).
	Swan Hills facility effluent discharges	Dioxin/furan concentrations.
	Concentrations of mercury in fish	Mercury released by various industries.
	Metals contamination due to mining activities	Elevated selenium concentrations downstream of open pit coal mines (i.e., upper Athabasca, Saskatchewan portion of basin – uranium mining).

Table 4 (Cont'd.)

Concern	Activity	Stated Contaminants / Concerns
Human and aquatic life	Contamination due to oil sands activities	Polycyclic Aromatic Hydrocarbons (PAHs) and naphthenic acids.
	Arsenic contamination in lower Athabasca	Elevated arsenic concentrations may be due to various activities (i.e. burning of fossil fuels, oil sands, metal mining, agricultural pesticide application, burning of waste, etc).
	Pesticide contamination	Use of pesticides on agricultural lands (i.e., Pembina sub-watershed).
	Uranium contamination	Uranium mining in the Saskatchewan portion of the watershed.
	Surface Water allocations	Minimum flows (Instream Flow Needs – IFNs) required for health of aquatic life.
	Groundwater allocations	Oil sands activities create drawdown effect on aquifers and can decrease flows in watercourses, lakes, and wetlands.
Groundwater contamination	Various contaminants migrating into the groundwater	Pipeline leaks/spills, storage lagoons, farming, municipalities, mining operations, oil/gas production wells.
Decreased dissolved oxygen concentrations	Pulp mill and wastewater treatment facility effluent discharges	Oxygen consuming substances in effluents lower dissolved oxygen levels stressing aquatic life.
Acid rain	Occurrence of acid rain from industrial/non-industrial activities (i.e., oil sands)	Result from discharges of sulphur dioxides (SO_2), nitrogen oxides (NO_x), and water.
Proposed nuclear plant (Whitecourt area)	Significant water consumption requirements	Decrease in flows in the Athabasca.
	Operation includes various air and groundwater emissions	Air and groundwater emissions of radio nuclides, heavy metals, toxic organic compounds (dioxins/furans, hexachlorobenzene, ammonia).
	Disposal of radioactive waste	It is not known how nuclear waste can be ultimately stored.
Proposed nuclear plant (Whitecourt area)	Human health concerns	Studies have shown occurrences of cancer of those living close to nuclear facilities.
Climate change	Increased temperatures	May affect stream flows.
Land impacts	Conventional oil & gas activities	Seismic lines and well sites remove forested areas impacting runoff, flow conditions, and water quality.
	Oil sands	Wetlands that typically regulate surface and groundwater flows and act as a natural filter are drained for oil sands activities.
	Forestry	Increases water flow and flooding when water is plentiful, and decreases water flow in dry conditions.

3.5 OTHER WPAC SOW REPORTS

The Lesser Slave, Red Deer River and Old Man River SOW reports are good examples of SOWs created for watersheds in Alberta, which portray a comprehensive analysis of the health of the overall watershed and aquatic eco-system. Indicators chosen in these reports are easily understandable and relevant to the watershed.

The Lesser Slave watershed is a sub-watershed of the Athabasca watershed, and therefore has been included in the development of the draft indicators herein. Indicators in that SOW report were chosen to be indicative of changes related to the predominant pressures in the watershed including timber production, oil and gas exploration and development, livestock grazing, surface material removal, agriculture, recreation and settlement (Jamieson 2009). The indicators were identified and then classified as condition, pressure or response indicators, though no response indicators were chosen.

Table 5 Lesser slave SOW indicators of watershed health and metrics (Jamison 2009).

Indicator Category		Metric	Indicator Type
Water	Water Quality	River Water Quality Index/Lake Trophic Status	Condition
		Escherichia coli	Condition
		Nutrient budget (P:N ratio)	Condition
		Sediment contamination	Condition
	Water Quantity	Water allocation (surface/ground/wastewater return)	Pressure
Land use		Riparian Health	Condition
		Linear Development - Stream Crossings	Pressure
		Land use inventory	Condition/Pressure
		Livestock density	Pressure
		Wetland inventory	Condition
Biological		Fish (population estimates)	Condition
		Blue/green algae outbreaks (lake only)	Condition

The Red Deer River watershed is the largest sub-watershed in the South Saskatchewan River basin (Aquality 2009). Originating in the Rocky Mountains the river flows through a diverse landscape which includes residential areas, oil and coal deposits, forests and croplands. About 43% of the land area in the watershed is used to raise crops and there are about 13,000 farms in the watershed making agriculture and its related impacts a dominant concern. In the Red Deer River SOW report, indicators were chosen to reflect the ecological integrity of the watershed and were categorized as condition indicators or risk indicators, condition indicators make comparisons against guidelines whereas risk indicators are comparative with other sub-watersheds (Table 6).

Table 6 Indicators used in the Red Deer River SOW report.

Condition Indicators	Risk Indicators	Other (Water quality, water quantity and biological)
Wetland loss	Manure production	Pipeline crossings and other structures
Riparian health	Urban, agricultural and recreational developments	Pollution from point sources
Linear developments	Oil and gas activity	Water discharge rates
Total phosphorus and total nitrogen		Area of sub-watershed contributing to drainage
Bacteria		Water allocations
Parasites		Groundwater discharge/recharge areas
Pesticides		Wildlife diversity
Land cover		Species listed under the Species at Risk Act
Minimum flow		

The Oldman watershed health indicators were chosen "as general measures of environmental quality to show trends in environmental conditions" (OWC 2010). These indicators were chosen to measure aquatic health in relation to the predominant uses and concerns of the basin. Irrigated agriculture is the primary use of water in the watershed, with about 60% of the land devoted to agriculture, representing 40% of all irrigated land in Alberta (OWC 2010). The chosen indicators function much like performance measures and are broken down under the major topic headings of Terrestrial and Riparian Ecology, Water Quantity and Water Quality (OWC 2010). Indicators were also dependent on their potential to link to water management actions and are listed in the table below (Table 7).

Table 7 Oldman watershed indicators (OWC 2010).

Terrestrial and Riparian Ecology	Water Quantity	Water Quality
Land cover	Trends in natural flow	Nutrients (nitrogen and phosphorus)
Soil erosion rates	Licensed allocation vs. natural flow	Total Suspended Solids (TSS)
Riparian health	Actual use vs. natural flow	E.coli /fecal coliform
Land use	Ability to meet Instream objectives and Water conservation objectives in recent years	
	Irrigation and municipal water use efficiency	

3.6 PEACE-ATHABASCA DELTA STATE OF THE AQUATIC ENVIRONMENT REPORT

In 2002, a *State of the Aquatic Environment Report* was developed specifically for the Peace-Athabasca Delta, in response to the Northern River Basins Study.

This report developed and applied seven measurable indicators of ecosystem integrity (Donald *et al.* 2002). If one of the seven indicators was altered, then the integrity of the Peace-Athabasca Delta environment was also judged to be susceptible to change. These indicators were supported by a number of measurable variables and were chosen using eight criteria, including their relevance to the public, linkages to other components of the ecosystem, and availability of historical information.

Relative to other WPAC SOW reports that encompass entire watersheds and terrestrial and aquatic indicators, the indicators in this report were specific to the Peace-Athabasca Delta (PAD) and to the aquatic environment (Table 8). As the Athabasca watershed encompasses the PAD, these aquatic environment indicators were considered in the broader set of draft of indicators proposed herein.

Table 8 PAD state of the aquatic environment indicators.

Physical/Chemical	Structural	Functional
Climate and atmospheric contaminants Water quality Lake Claire water levels	Clam shrimp abundance Fish community structure (Mamawi and Claire lakes) Goldeye abundance Walleye and goldeye commercial catch	None chosen though functional linkages exist between the chosen indicators

3.7 SUMMARY OF CONCERNS

3.7.1 WPAC Development Process and Technical Committee

During the development of the Athabasca WPAC, members of the Council were asked to express their concerns (WPAC 2010). As well, during Phase 1, Technical Committee members provided key concerns found within the region were also considered (Hayward 2010). The highlighted concerns are outlined in the table below (Table 9). These concerns/issues were incorporated, where applicable and appropriate, in the draft indicators.

Table 9 WPAC member issues and concerns (WPAC 2010).

Concern	Issue
Environmental	Acid deposition from oil sands air emissions
	Aquatic ecosystem health (a key indicator of watershed sustainability)
	Ecological benchmark/reserve sites required
	Biodiversity loss
	Climate Change
	Cumulative environmental effects over long term
	Lack of data/information/facts
	Invasive species (plant and animal)
	Landscape sensitivity and protection of ecological significant areas
	Pollution (water and air)
	Reclamation of land (timing)
	Stream erosion and sediment loads
	Tailings pond leakage and reclamation
	Vegetation communities and riparian habitat health
	Water quality impacts
	Water quantity impacts (water levels and flow)
	Wetlands restoration
	Wildlife, species at risk

Table 9 (Cont'd.)

Concern	Issue
Socio/Economic	Lack of awareness/education
	Lack of communication
	Development/land use – overdevelopment and lack of planning
	Human health – downstream effects from tar sands and tailings ponds
	Hunting and overhunting
	Recreation – maintain trail and lake access and concern of OHV use of riparian areas
	Social justice – downstream effects on FN/Métis communities
	Water allocation/use and conservation
	Watershed management – balance between environment and economic development

3.7.2 Watershed Stewardship Group Sector Report #3

In the winter/spring of 2010 Watershed Stewardship Group (WSG) representatives within the Athabasca watershed were interviewed to find out their concerns. Concerns relevant to the development of SOW report indicators included, but were not limited to:

- The use of the Athabasca River and the portion of the watershed in Jasper National Park, and associated environmental impacts;
- Climate change impacts on the Athabasca glacier;
- Water allocation and the impacts of water withdrawals;
- The impacts of new industrial development on water quality, watershed health, community sustainability, fish and wildlife, local landscape aesthetics, character and traditional use;
- Cumulative effects of contaminants released to the river;
- Water quality and quantity (low flows);
- Preservation of biological diversity; and
- Concerns about reports of elevated cancer rates in communities.

3.8 KEY THREATS AND PRESSURES IN THE ATHABASCA WATERSHED

Based on the various reports reviewed (as noted in Section 3.3 to 3.7, above), and other research completed during Phase 1 of the Project, key threats and pressures identified include the following:

- ***Projects Approved by AENV (EIAs) –*** Since 2007, 11 projects (subject to Environmental Impact Assessments [EIAs]) within the watershed have been approved (AENV 2010b). All of these major projects fall within the lower Athabasca sub-watershed, with the exception of one coal mine expansion in the upper sub-watershed. The majority of the lower watershed projects were oil-sands developments (Steam Assisted Gravity Drainage (SAGD)/mines), with one limestone quarry/quick lime plant;

- ***Proposed Project (AENV EIAs) -***As of December 2010, AENV has 14 current projects in various stages of review under the EIA process with all falling within the lower Athabasca sub-watershed, including 11 SAGD facilities/expansions and 3 oil-sands surface mines;
- ***Coal mines*** - Expansion of Sherritt Coal Valley mine and renewed operations in 2009 at the Obed mine in the McLeod sub-watershed, existing operations at Cardinal River (Cheviot) mine within the Upper Athabasca, and closure of Gregg River coal mine in the McLeod sub-watershed (ERCB 2010);
- ***Forestry Industry/Pulpmills*** – The Government of Alberta has predicted the forestry industry will continue to grow, at approximately 7% annually for the next three years (Government of Alberta 2010). Wastewater effluent is discharged from 4 existing pulpmills within the upper and middle portions of the watershed. Total production from the pulp and paper sector in Alberta increased approximately 9% from the 3rd quarter in 2009 to one year later in 2010 (AFPA 2010);
- ***Expanding human settlements*** – Fort McMurray experienced a growth rate of approximately 100% from 1999 to 2008 (RMWB 2010). In May 2010, a new sewage treatment plant was commissioned to serve a population of 100,000 with the option for expansion by another 33,000 as needed (Gilbert 2010). The next most significant growth rate was the town of Edson which grew by 16% over approximately 10 years from early in 2000 (Town of Edson 2009);
- ***Proposed Enbridge Northern Gateway Pipeline*** - Near Whitecourt, the proposed Northern Gateway Pipeline will transect the Athabasca watershed, with approximately 100 km of affected land and pipeline crossing of the Athabasca River and numerous other tributaries (ENGP 2010);
- ***Swan Hills Special Waste Treatment Facility*** – In 1996, there was a malfunction of a transformer furnace which caused process gases containing polychlorinated biphenyls (PCBs) and dioxins and furans (PCDD/Fs) to be released into the ambient air, which resulted in a fish consumption advisory. Although regular monitoring is done of the facility, the facility presents environmental risks, given it treats and manages hazardous waste (MRB 2003, AHW 2004);
- ***Proposed Uranium Mines (Saskatchewan) –*** Cameco Millennium Mine and Midwest Mining and Milling Project at McLean Lake are two proposed uranium mines in the Saskatchewan portion of the Athabasca watershed, upstream of Lake Athabasca.

Other factors such as growth rates of other major centres have been considered, with most centres falling more within a typical range: Athabasca, Whitecourt, Hinton have expanded from 5-10% (City of Hinton 2009; Whitecourt 2009; Town of Athabasca 2010). High Prairie and Slave Lake have seen growth rates below 5%.

These activities noted above have the potential to negatively affect the watershed's water quality, water quantity, undeveloped land base, and biodiversity. Indicators of these potential effects should be monitored to determine the extent of actual effects and/or provide a record of present conditions to be used comparatively in any future comparisons. The proposed set of indicators have been chosen to account for the current key pressures in the watershed, which may change over time.

3.9 RECOMMENDED INDICATORS OF WATERSHED HEALTH FOR THE AWC STATE OF THE WATERSHED REPORT

3.9.1 Core (Basin-wide) Indicators

Recommended core (basin-wide) indicators of the state of the Athabasca watershed, for use in the Phase 2 AWC State of the Watershed report, are outlined in Table 10. These indicators are applicable to the entire watershed as a whole. Indicators specific to sub-watersheds are discussed in Section 3.9.2. It should be noted that, although a proposed nuclear power plant was identified as a key concern in Section 3.8, environmental impacts such as radioactive waste are not considered in the proposed indicators, given such a facility is still in the feasibility stages. If this becomes a reality, additional sub-watershed specific indicators may be required.

The watershed and sub-watershed draft indicators are outlined in Table 10 and were largely derived by:

- Assessing current anthropogenic activities and their spatial distribution in the watershed;
- Reviewing stakeholder concerns both from the 2008 Keepers of the Athabasca Report and from the AWC-WPAC and Watershed Stewardship Groups;
- Reviewing key research and literature conducted to-date in the watershed;
- Reviewing approved and proposed developments in the watershed; and
- Identification of environmental resources of ecological or social importance that were sensitive to change and could be reliably measured (see selection criteria in Section 2.2.2).

The metrics used to measure each indicator, relevant standards for comparison (where applicable), temporal periods for analyses, types of analyses, and suitability of data will be determined during Phase 2. Any limitations on the interpretation of existing data will be presented during Phase 2 of the Project, and is further discussed in Section 3.9.3.

Table 10 Proposed core (basin-wide) indicators for Athabasca SOW report.

Themes	Indicator	Details	Type of Indicator	Rationale
Surface Water Quality	Alberta River Water Quality Index (RWQI)*	Metals Pesticides Nutrients/Related Variables[2] Bacteria (Fecal coliforms, *E. coli*)	Condition	Industrial, municipal, agricultural impacts
	Lake Water Quality (Trophic Status)*	Chlorophyll a Phosphorus	Condition	Industrial, municipal, agricultural impacts
Surface Water Quantity	Annual River Flow Quantity Index*	Average natural flow vs. actual flows on a two-season basis (May–Sept and Oct–April) [3]	Condition	Industrial & municipal pressures
	Allocations vs. Average Annual Flow*	Surface water licenses as a percentage of the total volume of surface water available at a given time	Condition	Industrial pressures
	Historical Lake Level Index*	For Lakes AENV has already calculated index (http://environment.alberta.ca/01719.html) (i.e. Lake Athabasca, Lac Claire, Gregoire Lake, Lesser Slave Lake etc)	Condition	Water usage and climate change impacts
	Flow vs. Water Conservation Objective (WCO)*[4]	Flow vs. WCO which is set based on society's expectations and desired outcomes	Condition	Industrial & municipal pressures
Sediment	Quality	Metals Pesticides PAHs	Pressure	Industrial & municipal pressures, high natural levels in some areas (metals, PAHs)
Groundwater	Groundwater Quality[5]	Metals Pesticides Nutrients/Related Variables Bacteria (*E. coli*)	Condition	Agricultural, industrial, conventional oil and gas/oil sands impacts
	Well density*[6]	All licensed and unlicensed groundwater usage	Condition	Industrial, agricultural, municipal impacts
Fisheries	Mercury in Fish	Mercury concentrations in fish	Pressure	Industrial Activity (mining), human health effects, high background levels, global atmospheric deposition
	Fish communities[7]	Abundance and diversity of fish populations	Condition	Industrial, municipal, agricultural impacts
Wildlife	Terrestrial ranges	Size of ranges	Condition	Industrial, municipal impacts
	Waterfowl/bird abundance	Waterfowl/bird inventory	Condition	Industrial, municipal impacts
Anthropogenic activities	Land use*	Oil/Gas well and pipeline densities	Pressure	Industrial impacts
		Petroleum and natural gas agreements	Pressure	Industrial impacts
		Converted and Accessed Forested Areas	Pressure	Industrial, municipal, agricultural impacts
		Road Densities	Pressure	Industrial, municipal pressures
Climate change		Mean Annual and Seasonal Temperature (air)	Condition	Industrial, municipal, agricultural impacts
		Precipitation as Snow (%) and total annual/seasonal (mm)	Condition	Industrial, municipal, agricultural impacts

Table 10 (Cont'd.)

* AENV Draft Foundational Indicator.

[1] The AENV RWQI consists of four sub-indices calculated annually for four variable groups (metals, nutrients, bacteria, and pesticides) and combines these values into a single descriptor of water quality. The AENV RWQI may not be applicable to all watersheds as the full suite of information may not be available to calculate an RWQI. During Phase 2 with a full data and literature review, it may be deemed more appropriate to report on water quality conditions using the individual sub-indices, most relevant to the issues in each sub-watershed. See http://environment.alberta.ca/01275.html for full list of variables within the AENV RWQI.

[2] River Nutrient Index includes nitrogen, phosphorus, dissolved oxygen and pH. It is recommended these be reported for individually and as a sub-index.

[3] This index should not be applied to any site with less than 30 consecutive years of flow data, ideally . 50 years of data is recommended by AENV.

[4] Based on the future determination of a WCO for the Athabasca watershed and/or sub-watersheds.

[5] The same variables are proposed for groundwater as those listed for the AENV RWQI, both as sub-indices and individual concentrations, where applicable to each sub-watershed as determined during Phase 2. TEK indicators have not been incorporated, but should be considered, where possible and appropriate, in development of the final set of indicators for Phase 2.

[6] Water well density should include all known wells and unlike groundwater allocations/licenses is an indicator of total licensed and unlicensed water use as a reflection of the overall intensity of pressure on the resource (The *Water Act* states people may withdraw 1,250 m^3 annually for domestic/household use without the requirement for a license). It should be noted that mandatory reporting of water well drilling was only introduced in the late 1970s.

[7] May not be suitable as an indicator in all watersheds due to lack of available data.

3.9.2 Sub-Basin-Specific Indicators

Indicators are proposed for specific sub-watersheds of the Athabasca basin that are specifically relevant to pressures in that sub-watershed rather than to the entire watershed (Table 11).

Table 11 Additional sub-watershed indicators for Athabasca SOW report.

Themes	Indicator	Details	Type of Indicator	Rationale	Sub-watershed
Surface Water	Quality*	Selenium	Pressure	Coal mine impacts	McLeod
		Naphthenic acids**, PAHs	Pressure	Oil-sands impacts	Lower Athabasca, Clearwater
Groundwater	Groundwater allocations*[1]	Volumes allocated annually over time	Pressure	SAGD impacts	Lower Athabasca, Clearwater
Anthropogenic Activities*	Land Use	Approved and proposed oil-sands leases	Pressure	Oil sands impacts	Lower Athabasca, Clearwater
		Coal agreements	Pressure	Coal mining impacts	Upper Athabasca, McLeod

* AENV Draft Foundational Indicator.

** Data accuracy and availability consideration (see Section 3.9.3).

[1] Groundwater allocations are an indicator of total licensed volumes. It does not include unlicensed volumes (i.e., exemptions for 1,250 m3 for household/domestic use). No data is available to compare the allocated volume and the volume of the source.

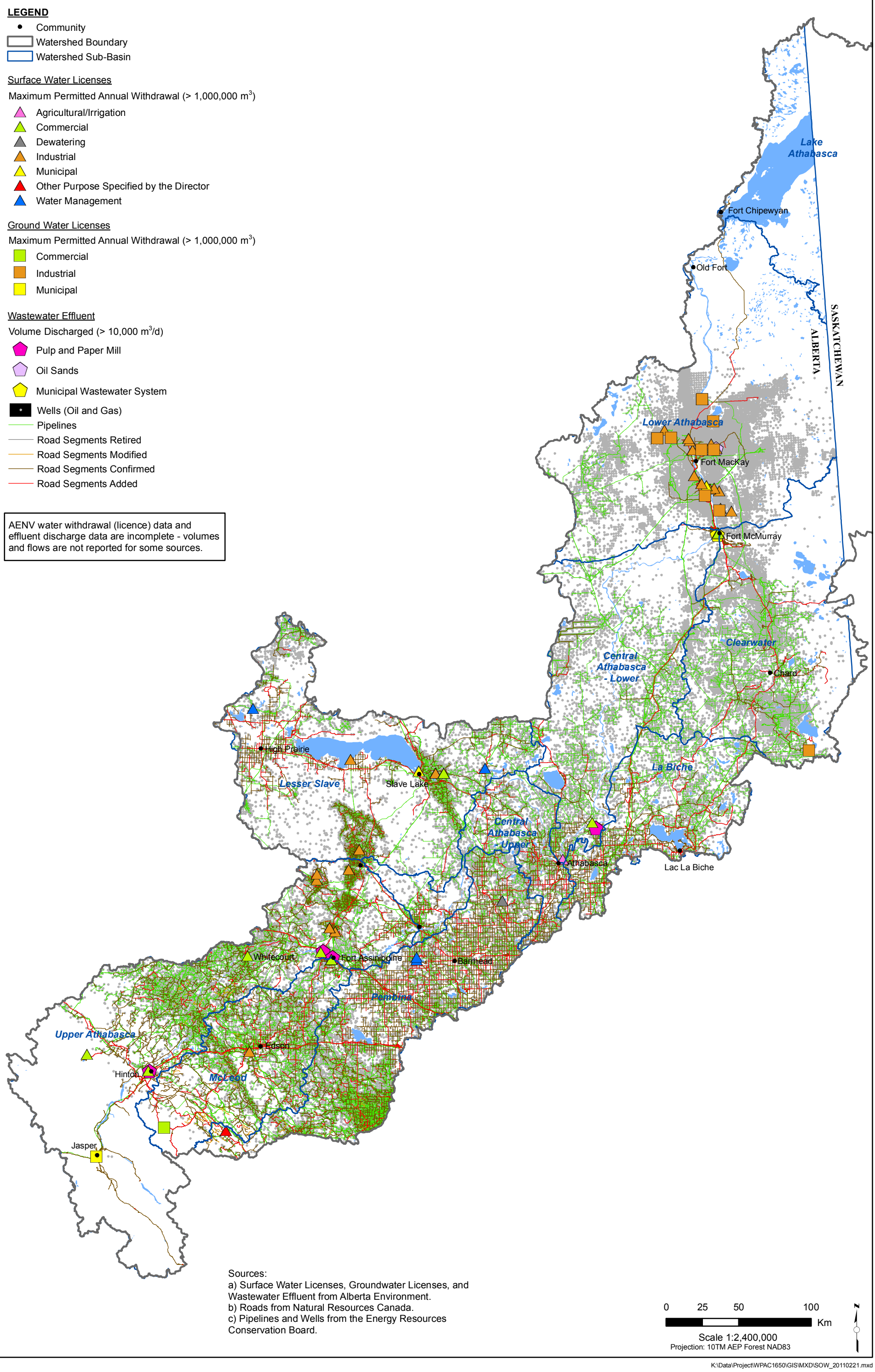
By looking at the indicators at a sub-watershed level, primary concerns can be examined on a more manageable scale and can be put into context relative to their immediate environment. Once the immediate (local) impacts are assessed, then downstream and cumulative impacts in the entire watershed can be better understood.

These sub-watershed indicators are predominantly in the lower portion of the watershed, with pressure-type indicators from industrial and agricultural activities. Aquifer drawdown is primarily a concern in the lower portion of the watershed due to the abundance of SAGD facilities which are water-intensive; therefore, groundwater allocations/withdrawals are a sub-watershed indicator for the Lower Athabasca and Clearwater sub-watersheds. Also in the Lower Athabasca, Central Athabasca (Lower), Clearwater, Lake Athabasca sub-watersheds, wetlands and oil-sands leases are interspersed throughout and are proposed as pressure-type indicators of watershed health.

The only sub-watershed specific indicator proposed outside of the lower portion of the watershed is livestock distribution, which is predominantly relevant in the Pembina sub-watershed, and portions of the Central Athabasca – Upper, and La Biche.

Figure 1 provides a summary of some of the key pressures within the watershed and proposed indicators of watershed health. The Preliminary Atlas in Appendix A2 provides further details on all attributes of the watershed.

Figure 1 Athabasca Watershed water withdrawal, effluent discharge, and land use pressures.



3.9.3 Data Accuracy and Availability, and "Future Considerations"

As will be described in Section 4 (gap analysis), numerous indicators exist that may be useful for SOW reporting and tracking in the future, but may not be appropriate for immediate use in the Phase 2 SOW report, for reasons of data availability, inconsistency, or (less frequently) uncertainty. Two specific examples are given below, but many different datasets would qualify for inclusion in this list from a data availability/compatibility perspective.

Naphthenic acids in surface waters (lower Athabasca River): Naphthenic acids, a group of carboxylic acids described by the chemical formula $C_nH_{2n+Z}O_2$, are thought to occur at relatively high concentrations in regional groundwater and particularly oil-sands tailings ponds in the lower Athabasca basin. As such, they have potential to be good indicators of any influences of tailings water that may occur in local surface waters. However, the current analytical science related to these compounds is in considerable flux. Recent studies using high-resolution methods (Grewer *et al.* 2010) have indicated that the majority of acid-extractable organic compounds previously measured as "naphthenic acids" in oil-sands tailings ponds, river waters, and even in commercial naphthenic acids preparations, are not actually naphthenic acids at all, but various other organic acids; in river waters, most compounds measured by this test may be environmentally ubiquitous fatty acids unrelated to oil-sands chemistry. Multiple commercial, academic and government laboratories are currently developing different analytical methods that may yield values from the same water samples that differ by orders of magnitude (see RAMP 2011 *in prep.* for further discussion). Because of this uncertainty in the analytical chemistry, there also are no longer meaningful toxicological benchmarks that may be used to properly assess these data. Therefore, although naphthenic acids may be a good indicator for use in future SOW reports (once the science has been clarified and new data have been collected), it may not be a good indicator to use at present.

Benthic invertebrate community structure (basin-wide): The structure and function of benthic invertebrate communities have historically been used as indicators or stress or effect in aquatic environments. Although numerous studies exist throughout different sub-basins of the Athabasca watershed that could be drawn on to assess aquatic ecosystem health in the Phase 2 SOW report, these datasets have not been collected using consistent methods or analytical approaches (i.e., sieve sizes, taxonomic resolution, etc.), and are not warehoused in any consistent (digital) data format in the province that would be available to the AWC for use in the Phase 2 SOW report. However, basin-wide collections of benthic invertebrate community data using standardized field, analytical, and reporting methods (typically collectively referred to as "regional bio-assessment" protocols) are an emerging monitoring tool in several large watersheds in Canada and elsewhere, and would be a meaningful approach to pursue in the Athabasca watershed from headwaters to mouth. However, this would require a very large data-collection effort that has not occurred to date. As such, this is a good indicator for future consideration. Fish-community data may be another example of a potentially meaningful basin-wide indicator that cannot yet be included in SOW reporting for similar reasons.

3.10 DEVELOPMENT OF A FINAL LIST OF INDICATORS FOR PHASE 2

It should be noted that these watershed health indicators are considered preliminary, as they are based primarily on the scope of Phase 1, namely the spatial data collected, and a review of literature in the compiled bibliography. A thorough review of the bibliography will be required during Phase 2, which may require the indicators be revised. Pressures change and evolve over time and may also contribute to the need for revisiting the indicators during Phase 2.

As the TEK report has not yet been completed, TEK indicators have not been incorporated here. However, any TEK indicators suggested in the TEK report should be considered by AWC in the development of the final Phase 2 Terms of Reference.

Lastly, the number of indicators proposed above is much greater than the number of indicators typically included by other WPACs in their final SOW reports. A public report such as this must be short, concise, and engaging to the public, as well as being technically accurate and thorough. There is a trade-off between completeness and readability that must be considered by AWC when defining the final set of indicators for the Phase 2 report. As such, the list of suggested indicators presented in this Phase 1 report should, perhaps, be considered as a "long list", from which a shorter list of representative and meaningful indicators may be drawn.

4.0 DATA AND KNOWLEDGE GAP ASSESSMENT

Based on the spatial data collected and Hatfield's knowledge of the Athabasca watershed, preliminary knowledge and data gaps have been identified which are essential to completion of Phase 2. These gaps were identified based on the availability of scientific data and a cursory literature review of the compiled bibliography. Gaps in TEK are identified in a separate TEK report. During Phase 2, with a thorough review of the bibliography and TEK sources, additional knowledge gaps may be identified and may need addressing.

In this context, missing "data" is intended to indicate a lack of specific observations describing a given feature, process, or activity. Missing "knowledge", in contrast, is intended to indicate a lack of general understanding of a feature or process. Knowledge gaps may be more serious than data gaps, and are usually more difficult and time-consuming to fill.

The gaps described herein include: general issues and challenges encountered during Phase 1 data collection; spatial data which were available but unobtainable; and gaps present in existing data and knowledge where future monitoring or research is recommended to provide a better understanding the state of the watershed.

4.1 OVERARCHING ISSUES

The overall issues and challenges encountered in data collection during Phase 1 include the following:

- General lack of publicly available government data in electronic form; lack of data-sharing between government agencies/departments;
- Lack of integration/harmonization of existing work being done within the watershed by various agencies, departments, stakeholders, academics, etc;
- Lack of a centralized location to obtain data;
- Lack of knowledge of cumulative effects at sub-watershed and whole watershed scales (e.g., instream flow needs [IFN], land fragmentation, climate change);
- Lack of knowledge and disagreement on ways to separate natural conditions from anthropogenic effects; and
- Lack of up-to-date baseline data that reflects current conditions and keeps pace with development (particularly with respect to land use, land cover).

4.2 SPECIFIC GAPS

Table 12 outlines data which were obtained but are considered 'incomplete' or could not be obtained in time for reporting, while Table 13 presents data/knowledge which currently does not exist in sufficiently comprehensive or useable form but would be valuable for future SOW reporting, and for environmental/watershed planning and management generally.

Table 12 Preliminary data and knowledge gaps: incomplete information.

Feature	Gaps (Data/Knowledge)
Surface Water	**Data:** Incomplete datasets (allocations, consumptive use)
Groundwater	**Data:** Aquifer type, groundwater levels, quality1
Wastewater Effluent	**Data:** Incomplete datasets (volume of discharge)
Land	**Data:** Vegetation/peatland inventory 2, wetland inventory 3, livestock distribution

[1] Compiled data of all groundwater wells within the watershed from Alberta Water Well Information Database (AWWID) was requested but not obtained, however, the link to a limited number of AENV groundwater observation network wells within the watershed, with aquifer type and depth, is provided in the bibliography.

[2] Alberta Vegetation Inventory (AVI) is limited to areas of First Nation Reserves, Métis Settlements, and Parks. Forest Management Agreement (FMA) holders own the rights to their own AVI data, each FMA holder would need to be contacted individually to release their data.

[3] Data were requested but not obtained from Ducks Unlimited for coarse wetland ground cover classification (Contact: Al Richard, A_Richard@ducks.ca (780) 489-8110). There is also a peatland inventory completed by the University of Alberta from the mid-1990s, which could not be obtained during Phase 1 (Contact: Richard Chabaylo, AENV).

Table 13 Preliminary data and knowledge gaps: limited or no information.

Feature	Gaps (Data/Knowledge)
Surface Water	**Data:** Watershed-wide baseline water quality/aquatics data
	Data: Fish species life histories
	Data: Groundwater/surface water connections
	Data: Drinking water quality on federal lands (reserves)
	Data: PAHs in water (lower Athabasca River tributaries)
	Knowledge: Naphthenic acids (basic science)
	Knowledge: Tailings pond seepage, rates/effects (GW)
	Knowledge: Oil sands/coal mine reclamation issues
	Knowledge: Agricultural effects on water (withdrawals, releases)
Groundwater	**Data:** Unlicensed quantity (household/domestic use);
	Knowledge: Groundwater management framework/cumulative impacts – quality/quantity
	Knowledge: Tailings pond seepage, rates/effects
Land	**Data**: Up-to-date current land cover
	Knowledge: Oil sands/coal mine reclamation issues (liability, status)
	Knowledge: Regularly updating of land use changes (disturbed vs. reclaimed lands), land use plan
Air	**Data:** Aerial deposition sources and effects (esp. organics and metals), air-surface water connections
People	**Data**: Epidemiological data
	Knowledge: Human health effects of development
	Knowledge: Traditional land use/knowledge

5.0 CONCLUSIONS AND RECOMMENDATIONS

The Athabasca watershed covers many biophysical zones and pressures including human settlements with municipal wastewater treatment plants, agriculture, forestry, and industrial activity (i.e., conventional oil and gas, oil sands facilities, and coal mines). These attributes vary significantly from the upper portion to the lower end of the watershed. As a result, the knowledge and data available varies significantly throughout the watershed and will make it challenging to assess the watershed as a whole during Phase 2.

As a result, suggested Watershed Health Indicators have been chosen both on a whole watershed, and sub-watershed specific basis and will be used in Phase 2, along with the compiled spatial and non-spatial science-based knowledge and TEK, to develop publicly oriented Athabasca State of the Watershed (SOW) Report.

A draft Terms of Reference for Phase 2 was presented separately to assist the AWC as a basis for moving forward with this next and final phase of SOW report development.

In the process of developing a State of the Watershed report—particularly in a watershed as large and complex as the Athabasca, and especially under the guidance of a large, multi-stakeholder committee—it will be easy and tempting to over-reach and try to include "everything important" in the report. Although it obviously is important to capture all key issues, it is equally important to ensure the report is written for its target audience: the engaged public. The SOW report, in its initial and future iterations, should be a mechanism for broader public and stakeholder engagement in watershed matters, not simply another long technical report filled with complex terminology that few people have the training or stamina to read.

Given the rapidly changing state of knowledge in the Athabasca watershed, particularly in its lower reaches, development of an SOW report that can be easily and quickly updated and revised in the future should be an explicit consideration of the form and structure of the Phase 2 report. As discussed in Hatfield's proposal for this Phase 1 study, we feel that an interactive, web-served SOW report, rather than a static, paper report, best serves the dual purposes of encouraging the broadest stakeholder and public engagement and making the SOW a living document that can routinely be updated and modified as new information or knowledge emerges, and as conditions on the ground in the basin change.

6.0 CLOSURE

I trust the above Final Phase 1 Report meets your requirements and will provide a basis for discussion for Phase 2 with AWC. If any clarifications are required please contact the undersigned.

HATFIELD CONSULTANTS:

Approved by: _____ March 16, 2011

Martin Davies
Project Manager

Date

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APPENDICES

Appendix A1

Athabasca Watershed Council
State of the Watershed Report
Phase 1: Bibliography

PHASE 1: BIBLIOGRAPHY FOR AWC STATE OF THE WATERSHED REPORT

ATHABASCA WATERSHED

No.	Title	Author	Year	Journal / Publication	Accessed / Found
1.	An Initial Assessment of Aquatic Ecosystem Health in Alberta	Alberta Environment (AENV), Edmonton, AB. Prepared by Anderson, A.-M., R. Casey, L.R. Noton, D. McDonald, C. Fraser, M. Raven, and North South Consultants Inc.	n.d.	---	Document provided on CD. Accessed at: http://environment.gov.ab.ca/info/library/8023.pdf
2.	Trends in historical annual flows for major rivers in Alberta. Technical Report AE T/749.	AENV, Edmonton, AB, Canada.	2004	---	Accessed at: http://www.environment.gov.ab.ca/info/library/6792.pdf.
3.	Information Synthesis and Initial Assessment of the Status and Health of Aquatic Ecosystems in Alberta, Surface Water Quality, Sediment Quality and Non-Fish Biota. Technical Report #278/279-01.	AENV, Water for Life, Edmonton, AB. Prepared by North/South Consultants Inc., Clearwater Environmental Consultants Inc. and Patricia Mitchell Environmental Consulting.	2007	---	Accessed at: http://www.environment.alberta.ca/01300.html.
4.	Analysis of Water Quality Conditions and Trends for the Long-Term River Network: Athabasca River, 1960-2007	AENV	2009	---	Document provided on CD
5.	Groundwater Observation Well Network	AENV	2010		Accessed at: http://www.environment.alberta.ca/apps/GOWN/map.aspx

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No.	Title	Author	Year	Journal / Publication	Accessed / Found
6.	Long-Term River Network and tributary water quality data	AENV	2010	---	Documents provided on CD. Sent as Microsoft Excel files by D.LeClair, Surface Water Data Specialist, Alberta Environment, to A.Gilbride Hatfield Consultants. November 8, 2010.
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8.	Fish conservation strategy for Alberta: 2006-2010	Alberta Sustainable Resource Development (ASRD)	2006	Obtained from ASRD. Date: November 2006: 30 pp	Accessed at: http://www.srd.alberta.ca/ManagingPrograms/FishWildlifeManagement/FisheriesManagement/documents/FishConservStrategy2006.pdf
9.	ASRD website: Status of Alberta Fish	ASRD	2010a	---	Accessed at: http://www.srd.alberta.ca/BioDiversityStewardship/SpeciesAtRisk/SpeciesSummaries/StatusOfAlbertaFish/Default.aspx.
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No.	Title	Author	Year	Journal / Publication	Accessed / Found
11.	Bibliography of Athabasca River Basin (BARB)	Athabasca River Basin Research Institute (ARBRI). Provided by Robert Holmberg, Ph.D., Professor Emeritus, Biology, Athabasca University E-mail: robert@athabascau.ca Telephone: (780) 675-6596	2010	20,500 references provided within from ARBRI.	Document provided on CD
12.	Report of the Commissioner of the Environment and Sustainable Development to the House of Commons. The Commissioner's Perspective Main Points – Chapters 1 to 3 Appendix	Auditor General of Canada	2010	---	Document provided on CD
13.	A comparison of trends in hydrological variables for two watersheds in the Mackenzie River basin	Burn, D.H., O.I.A. Aziz and A. Pietroniro	2004	Canadian Water Resources Journal 29(4):283-298	Accessed at: http://www.ngps.nt.ca/Upload/Proponent/Imperial%20Oil%20Resources%20Ventures%20Limited/River_Crossings/Documents/MGP_River_Crossings_Appendix_C1.pdf
14.	Climatic influences on streamflow timing in the headwaters of the Mackenzie River Basin	Burn, D.H.	2008	Journal of Hydrology 352:225-238	Document provided on CD
15.	The Athabasca River	Canadian Heritage Rivers System (CHRS)	2009	---	Also accessible at: http://www.chrs.ca/Rivers/Athabasca/Athabasca-F_e.htm.
16.	Distribution of Contaminants in the Water, Sediment, and Biota in the Peace, Athabasca, and Slave River Basins: Present Levels and Predicted Future Trends	Carey, J.H. Northern River Basins Study.	1997	---	Asked Heather if she has a hardcopy Available at a cost: http://publications.gc.ca/site/eng/64321/publication.html

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19.	Northern Rivers Ecosystem Initiative: Nutrients and Dissolved Oxygen-Issues and Impacts	Chambers, P.A., J.M. Culp, N.E. Glozier, K.J. Cash, F.J. Wrona, and L. Norton.	2006	Environmental Monitoring and Assessment 113:117-141	Accessed at: http://www.environmental-expert.com/Files/6063/articles/8584/1.pdf
20.	Mackenzie Basin Impact Study (MBIS) Final Report	Cohen, S.J. (Ed.). University of British Columbia and Environment Canada	1997	---	Document provided on CD. Also accessed at: http://www.taiga.net/mbis/MBIS_Final_Report.pdf
21.	Cumulative effects assessment for the Northern River Basins Study	Culp, J.M., K.J. Cash and F.J. Wrona	2000	Journal of Aquatic Ecosystem Stress and Recovery (Formerly Journal of Aquatic Ecosystem Health) Volume 8, Number 1, 87-94	Available at a cost: http://www.springerlink.com/content/x3w112x8u912x236/
22.	River2D. Two-Dimensional Depth Averaged Model of River Hydrodynamics and Fish Habitat. Introduction to Depth Averaged Modeling and User's Manual	Cumulative Environmental Management Association (CEMA). Prepared by Steffler, P. and J. Blackburn.	2002	---	Document provided on CD
23.	Temporal variations in river-ice break-up over the Mackenzie River basin, Canada	de Rham, L.P., T.D. Prowse and B.R. Bonsal	2008	Journal of Hydrology 349:441-454	Document provided on CD

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24.	Contaminants in environmental samples: mercury in the Peace, Athabasca and Slave Rivers. Project Report No. 105. Edmonton.	Donald, D.B., H.L. Craig and J. Syrgiannis	1996	---	Available at a cost: https://isbndb.com/d/book/contaminants_in_environmental_samples_a01.html
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26.	Climatic and hydrologic variability during the past millennium in the eastern Rocky Mountains and northern Great Plains of western Canada	Edwards, T.W.D., S.J. Birks, B.H. Luckman, and G.M. MacDonald	2008	Quaternary Research (ScienceDirect)	Document provided on CD
27.	Northern Ecosystem Initiative Final Report: Building Capacity and Delivering Results	Environment Canada	2004	---	Accessed at: http://www.ec.gc.ca/nature/default.asp?lang=En&n=18938173-1.
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29.	Elevated mercury concentrations in fish in lakes in the Mackenzie River Basin: The role of physical, chemical and biological factors	Evans, M.E., W.L. Lockhart, L. Doetzel, G. Low, D. Muir, K. Kidd, G. Stephens, and J. Delaronde	2005	Science of The Total Environment 351-352:479-500	Available at a cost: http://www.ncbi.nlm.nih.gov/pubmed/16183101
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38.	Meteorological Survey of Canada Climate Data	Meteorological Survey of Canada	Up to 2007	Description: Canadian Daily Climate Data (Temperature, Precipitation, Depth of Snow on the Ground)	Data up to 2007 provided in geodatabase. Downloaded filename: CDCD_DCQC_2007.zip Current data available at: http://climate.weatheroffice.gc.ca/climateData/canada_e.html
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41.	The Cumulative Effects of Climate Warming and Other Human Stresses on Canadian Freshwaters in the New Millennium	Schindler, D.W.	2001	Canadian Journal of Fisheries and Aquatic Science 58:18-29	Document provided on CD. Also accessible at: http://beyondfactoryfarming.org/documents/Schindler_climate_change.pdf.
42.	An Impending Water Crisis in Canada's Western Prairie Provinces	Schindler, D.W. and W.F. Donahue	2006	Proc Natl Acad Sci USA 103:7210-7216	Accessed at: http://www.gordonfn.org/resfiles/Schindler.pdf.
43.	Cumulative effects of climate warning and other human activities on freshwaters of Arctic and Subarctic North America	Schindler, D.W. and J.P. Smol	2006	Ambio 35(4):160-168	Available at a cost: http://www.ncbi.nlm.nih.gov/pubmed/16944640
44.	An approach for assessing cumulative effects in a model river, the Athabasca River basin	Squires, A.J., C.J. Westbrook and M.G. Dubé	2009	Integrated Environmental Assessment and Monitoring 6(1):119-134	Document provided on CD
45.	State of the Athabasca Watershed 2008	Walsh, H. Contributed to Keepers of the Water by Canadian Parks and Wilderness Society Northern Alberta.	2008	---	Document provided on CD
46.	Water Survey of Canada Hydrometric Data	Water Survey of Canada	1813 - 2010	Description: National Water Data Archive (HYDAT Database)	Data up to 2010 provided in geodatabase. Downloaded filename: HYDAT_20100907.zip Web link to Real-time Hydrometric Data: http://www.wateroffice.ec.gc.ca/index_e.html

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47.	Climate-driven shifts in quantity and seasonality of river discharge over the past 1000 years from the hydrographic apex of North America	Wolfe, B.B., R.I. Hall, T.W.D. Edwards, S.R. Jarvis, R.N. Sinnatamby, Y. Yi, and J.W. Johnston	2008	Geophysical Research Letters 35	Accessed at: http://individual.utoronto.ca/john_johnston/pdfs/Wolfe_et_al_2008_GRL_v35_pL24402.pdf.
48.	Streamflow in the Mackenzie Basin, Canada	Woo, M.K. and R. Thorne	2003	Arctic 56:328-340	Document provided on CD
49.	Canada's Rivers at Risk: Environmental Flows and Canada's Freshwater Future	World Wildlife Fund (WWF), Toronto, ON, Canada	n.d.	---	Document provided on CD. Accessed at: http://assets.wwf.ca/downloads/canadas_rivers_at_risk.pdf
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51.	MacKay River Commercial Project (vol 3-Hydrogeology, Hydrology, Surface Water Quality, Aquatic Ecology). Environmental Impact Assessment	Athabasca Oil Sands Corp.	2009	---	Document provided on CD
52.	Narrows Lake Project. Environmental Impact Assessment Application 1. Aquatic Resources Assessment 2. Introduction Volume 2	Cenovus FCCL Ltd.	2010	---	Documents provided on CD. Documents available at: http://www.cenovus.com/operations/oil/narrows-lake-expansion.html.
53.	Great Divide SAGD Expansion Project Submission of Application and Environmental Impact Assessment	Connacher Oil and Gas Ltd.	2010	---	Document provided on CD
54.	Devon Jackfish 3 Project (Application for Approval) 1. Volume 2- Environmental Impact Assessment 2. Volume 2- Environmental Impact Assessment (Appendices)	Devon NEC Corporation	2010	---	Documents provided on CD
55.	Christina Lake Thermal Expansion Project. December 2009. Phases 1E, 1F and 1G- Environmental Impact Assessment (Vol 4).	EnCana FCCL Ltd.	2009	---	Document provided on CD
56.	Summary of environmental assessment activity - current projects	Government of Alberta	2011	---	Available at: http://environment.alberta.ca/02313.html.
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59.	Blackgold Expansion Project (Vol 2- Environmental Impact Assessment) (Application for Approval)	Korea National Oil Corp. (KNOC)	2009	---	Document provided on CD
60.	Parsons Creek Aggregates Project: Consultant Report No. 11- Surface Aquatic Resources	Parsons Creek Aggregates. Prepared by Hatfield Consultants.	2010	---	Document provided on CD
61.	Parsons Creek Aggregates Project Hydrogeological Impact Assessment	Parsons Creek Aggregates. Prepared by Millenium EMS Solutions Ltd.	2010	---	Document provided on CD
62.	Parsons Creek Resources Project Surface Water Hydrology Assessment	Parsons Creek Aggregates. Prepared by Northwest Hydraulic Consultants.	2010	---	Document provided on CD
63.	Jackpine Mine Expansion and Pierre River Mine Project. Base Case Report	Shell Canada Limited. Prepared by Worley Parsons Komex.	2007	---	Document provided on CD
64.	Jackpine Mine Expansion Project and Pierre River Mine Project. Environmental Impact Assessment (Application for Approval) 1. Vol 4A: Aquatic Resources 2. Vol 4B: Aquatic Resources (Appendices)	Shell Canada Limited. Submitted to Alberta Energy and Utilities Board and Alberta Environment.	2007	---	Documents provided on CD
65.	Surface Water Environmental Setting for the Jackpine Mine Expansion Project and Pierre River Mine Project	Shell Canada Limited. Prepared by Golder Associates Ltd.	2007	---	Document provided on CD

EIAS IN ATHABASCA WATERSHED (CURRENT TO JANUARY 1, 2011)

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66.	Suncor Voyageur South Project: 1. Fish and Fish Habitat Environmental Setting Report 2. Hydrogeology Environmental Setting Report 3. Surface Water Hydrology Environmental Setting Report 4. Water Quality and Aquatic Health Environmental Setting Report 5. Noise, Environmental Health and Aquatics, Volume 3	Suncor Energy Inc. Prepared by Golder Associates Ltd.	2007	---	Documents provided on CD

UPPER AND CENTRAL ATHABASCA SUB-WATERSHED

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67.	The Upper Athabasca River Information System: Overview of Basin Characteristics and Data Completeness	Alberta Environment. Prepared by North/South Consultants Inc.	2005	---	Document provided on CD
68.	Use of tree ring reconstructed streamflows to assess drought	Bonin, D.V. and D.H. Burn	2005	Canadian Journal of Civil Engineering. 32: 1114-1123	Document provided on CD
69.	Climatic and hydrologic variability during the past millenium in the eastern Rocky Mountains and northern Great Plains of western Canada	Edwards, T.W.D., S.J. Birks, B.H. Luckman, and G.M. MacDonald	2008	Quaternary Research, doi: 10.1016/j.yqres.2008.04.013	Available at a cost: http://www.sciencedirect.com/
70.	Water Quality Characteristics and Trends for Banff and Jasper National Parks: 1989-2006	Glozier, N.E., R.W. Crosley, L.A. Mottle, D.B. Donald. Saskatoon (CA): Ecological Science Division, Environmental Conservation Branch, Environment Canada	2009	---	Document could not be found
71.	The Way Forward: A Strategic Plan for the Management of Selenium at Teck Coal Operations	Strategic Advisory Panel on Selenium Management	2010	Prepared for Teck Coal Limited	Document provided on CD
72.	Federal Pulp & Paper Environmental Effects Monitoring (EEM) Programs	Various	1993 to present, reported in 3 or 4 year cycles	---	Electronic data produced for EEM studies are not publically available for download, but may be requested from Environment Canada (http://www.ec.gc.ca/esee-eem/default.asp?lang=En&n=66BBE42B-1). Mill-specific interpretive reports may be requested for review from individual pulpmills, or regional offices of Environment Canada (Prairie & Northern Region)

LOWER ATHABASCA SUB-WATERSHED

No.	Title	Author	Year	Journal / Publication	Accessed / Found
73.	Coupled fluid flow, heat and mass transport, and erosion in the Alberta basin: implications for the origin of the Athabasca oil sands	Adams, J.J., B.J. Rostron and C.A. Mendoza	2004	Canadian Journal of Earth Sciences 41:1077-1095	Document provided on CD. Also accessible at: http://article.pubs.nrc-cnrc.gc.ca/ppv/RPViewDoc?issn=1480-3313&volume=41&issue=9&startPage=1077
74.	Cancer incidence in Fort Chipewyan, Alberta 1995-2006	Alberta Cancer Board, Division of Population Health and Information Surveillance. Prepared for Alberta Health Services, Nunee Health Board Society, Alberta Health and Wellness, and Health Canada.	2009	---	Document provided on CD
75.	Water Quality of the Athabasca Oil Sands Area: A Regional Study	Alberta Environment (AENV), Edmonton, AB.	1985	Alberta Oil Sands Environmental Research Program (AOSERP) Report L-85.	Document provided on CD**.** Accessed at: http://environment.gov.ab.ca/info/library/8251.pdf
76.	Technical Support Document for the Regional Sustainable Development Strategy for the Athabasca Oil Sands Area	AENV, Edmonton, AB	1999	---	Document provided on CD
77.	Overview of water quality In the Muskeg River Basin July 1972 to March 2001	AENV	2002	---	Document provided on CD. Also accessible at: http://www.environment.gov.ab.ca/info/posting.asp?assetid=6622&searchtype=advanced
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No.	Title	Author	Year	Journal / Publication	Accessed / Found
79.	Muskeg River Interim Management Framework for Water Quantity and Quality	AENV	2008	---	Document provided on CD
80.	Muskeg River Watershed Integrated Water Quality Monitoring Program Annual Report	AENV	2009	---	Document provided on CD
81.	Regional Sustainable Development Strategy for the Athabasca Oil Sands Area Progress Report	Alberta Environment and Alberta Sustainable Resource Development	2001	---	Document provided on CD
82.	Water Management Framework: Instream Flow Needs and Water Management System for the Lower Athabasca River	Alberta Environment and Fisheries and Oceans Canada	2007	---	Document provided on CD
83.	Process water treatment in Canada's oil sands industry: 1. Target pollutants and treatment objectives	Allen, E.W.	2008	Journal of Environmental Engineering and Science 7:123-138	Document provided on CD
84.	A literature review and intensity analysis of resource use in the Regional Municipality of Wood Buffalo	AMEC, Highwood, and Clark	2003	---	Available through the CEMA online library: http://library.cemaonline.ca/ Requires CEMA login.
85.	Possible Contaminates in fish species of the Wood Buffalo Region, Alberta, Canada.	Health Canada. Prepared by Athabasca Tribal Council (ATC). First Nations Environmental Contaminants Program.	2003	---	Document provided on CD

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86.	Sensory analyses of naphthenic acids as potential compounds for fish tainting	Barona Salazar, B.M.	2010	Thesis for MSc. Food Science and Technology, University of Alberta	Document provided on CD
87.	Attenuation of contaminants in groundwater impacted by surface mining of oil sands, Alberta, Canada	Barker, J., D. Rudolph, T. Tompkins, A. Oiffer, F. Gervais, and G. Ferguson	2007	Presentation given at the International Petroleum Environmental Conference, Houston, TX. November 2007.	Document provided on CD
88.	Water use in Canada's oil sands.	Canadian Association of Petroleum Producers (CAPP)	2009	---	Document provided on CD
89.	Syncrude ducks death trial	Canadian Broadcasting Corporation (CBC)	2010	---	Accessed at: http://www.cbc.ca/canada/edmonton/story/2010/03/24/f-edmonton-indepth-syncrude-duckstrial.html.
90.	One D Model In The Lower Athabasca River	Cumulative Environmental Management Association (CEMA). Prepared by Environment Canada.	2002	---	Document provided on CD
91.	Fish Overwintering Use of the Lower Athabasca River. 2001 - 2003	CEMA. Prepared by RL&L Environmental Services Ltd. and Golder Associates.	2003	---	Document provided on CD
92.	Regional Municipality of Wood Buffalo Recreational Demand Assessment	CEMA, Sustainable Ecosystems Working Group. Prepared by Greystone and Westwind Resources Group Ltd.	2003	---	Document provided on CD

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No.	Title	Author	Year	Journal / Publication	Accessed / Found
93.	Review and assessment of environmental effects information for wildlife and fish indicators in the Regional Sustainable Development Strategy (RSDS) Study Area within the Athabasca Oil Sands Region (AOSR)	CEMA, Wildlife and Fish Sub-Group. Prepared by URSUS Ecosystem Management Ltd. and Salmo Consulting Inc. by Collister, D.M., J.L. Kansas, T. Antoniuk, and B.J. Power.	2003	---	Document provided on CD
94.	Wood Buffalo Region Manual of River Ice Analysis.	CEMA. Prepared by KGS Group.	2003	---	Document provided on CD
95.	Benthic, Invertebrate, Fish, Physical, Water Quality databases	CEMA	2004	---	Document provided on CD
96.	Fish overwintering use of the lower Athabasca River 2001 to 2004	CEMA, Water Working Group, IFN Sub-Group. Prepared by Golder Associates Ltd.	2004	---	Document provided on CD
97.	Open Water Survey of Athabasca River at Bitumount (Reach #4)	CEMA. Prepared by Trillium Engineering and Hydrographics Inc.	2004	---	Document provided on CD
98.	A compilation of information and data on water supply and demand in the lower Athabasca River reach	CEMA Surface Water Working Group. Prepared by Golder Associates Ltd.	2005	---	Document provided on CD
99.	Athabasca River Reach 4 Fish Habitat IFN Assessment – Final Report	CEMA. Prepared by Golder Associates Ltd.	2005	---	Document provided on CD

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No.	Title	Author	Year	Journal / Publication	Accessed / Found
100.	CEMA Instream Flow Needs Determination Workshop – Athabasca River, September 22-23, 2005 in Fort McMurray, Alberta	CEMA	2006	---	Document provided on CD
101.	Flow simulations and fish habitat evaluation for the Athabasca River at Poplar Point (Reach 3) for summer flow conditions	CEMA, Surface Water Working Group. Prepared by northwest hydraulic consultants ltd.	2007	---	Document provided on CD
102.	Lower Athabasca River Habitat Surveys – 2007 Winter Water Levels and Rating Curves	CEMA. Prepared by northwest hydraulic consultants.	2007	---	Document provided on CD
103.	Reach-specific water quality objectives for the lower Athabasca River	CEMA. Prepared by Golder Associates Ltd.	2007	---	Document provided on CD
104.	Segmentation Analysis and Bathymetric Surveys of the Athabasca River – Segment 1	CEMA. Prepared by Golder Associates Ltd.	2008	---	Document provided on CD
105.	State of the Muskeg River Watershed	CEMA. Prepared by Dillon Consulting Ltd.	2008	---	Document provided on CD
106.	A review of existing models and potential effects of water withdrawals on semi-aquatic mammals in the lower Athabasca River	CEMA, Surface Water Working Group. Prepared by Hood, G., C. Bromley and N.T. Kur	2009	---	Document provided on CD
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109.	Wildlife movement and habitat connectivity monitoring guidelines for the Regional Municipality of Wood Buffalo. Task 1: Literature Review.	CEMA, Wildlife Movement Task Group, Sustainable Ecosystems Working Group. Prepared by Jacques Whitford AXYS Ltd.	2009	---	Document provided on CD
110.	Regional Groundwater Quality Study and Monitoring Network Design in the Athabasca Oil Sands: Phase 1, Technical Summary	CEMA. Prepared by WorleyParsons Resources & Energy.	2010	---	Document provided on CD
111.	Toxicity of oil sands to early life stages of fathead minnows (Pimephalas promelas)	Colavecchia, M.V., S.M. Backus, P.V. Hodson, and J.L. Parrott	2004	Environmental Toxicology and Chemistry 23(7):1709-1718	Document provided on CD
112.	CYP1A induction and blue sac disease in early life stages of white suckers (Catostomus commersoni) exposed to oil sands	Colavecchia, M.V., P.V. Hodson and J.L. Parrott	2006	Journal of Toxicology and Environmental Health, Part A 69:967-994	Available at a cost: http://www.ncbi.nlm.nih.gov/pubmed/16728374
113.	The relationships among CYP1A induction, toxicity, and eye pathology in early life stages of fish exposed to oil sands	Colavecchia, M.V., P.V. Hodson and J.L. Parrott	2007	Journal of Toxicology and Environmental Health, Part A (70):1542-1555	Document provided on CD
114.	Characterizing sediment sources and natural hydrocarbon inputs in the lower Athabasca River, Canada	Conly, F.M., R.W. Crosley and J.V. Headley	2002	Journal of Environmental Engineering and Science 1:187-199	Document provided on CD

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116.	Watered Down: Overcoming Federal Inaction on the Impact of Oil Sands Development to Water Resources	Droitsch, D. Water Matters Society of Alberta, Canmore, AB.	2009	---	Document provided on CD. Also Accessible at: http://www.water-matters.org/docs/watered-down.pdf.
117.	Minister says toxic watershed result of bitumen-rich land.		2009	Edmonton Journal. December 9, 2009.	Document provided on CD
118.	Public Zone Oil sands	Energy Resources Conservation Board (ERCB)	2006	---	Accessed at: http://www.ercb.ca/portal/server.pt?open=512&objID=249&PageID=0&cached=true&mode=2.
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120.	Hydrodynamics of a large oil sand tailings impoundment and related environmental implications	Ferguson, G.P., D.L. Rudolph and J.F. Barker	2009	Canadian Geotechnical Journal 46:1446-1460	Document provided on CD

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121.	Trace metals in traditional foods within the Athabasca oil sands area. Draft report **(DO NOT CITE OR REFERENCE)** – *provided for information only*	Fort McKay Environmental Services and Wood Buffalo Environmental Association, Terrestrial Environmental Effects Monitoring Science Subcommittee. Prepared by Golder Associates Ltd.	2003	---	Document provided on CD
122.	2010: A guide to Fort McMurray and the Wood Buffalo Region	Fort McMurray Tourism	2010	---	Accessed at: http://www.fortmcmurraytourism.com/
123.	Population structure and growth of walleye in Gregoire, Ethel, and Hilda lakes, Alberta, 2007	Ganton, B.	2008	Data report, D-2008-006, produced by the Alberta Conservation Association, Sherwood Park, Alberta, Canada. 19 pp + App.	Document provided on CD. Also accessible at: http://www.ab-conservation.com/go/default/custom/uploads/reportseries2/Pop-Strc-Grwth-WalE-Goire,Ethl-Hlda-L,AB,07.pdf
124.	Alberta oil sands development	Giesy, J.P., J.C. Anderson and S.B. Wiseman	2010	Proceedings of the National Academy of Sciences 107(3):951-952	Document provided on CD
125.	Wood Buffalo National Park Water Quality: Status and Trends from 1989-2006 in Three Major Rivers; Athabasca, Peace and Slave	Glozier, N.E., D.B. Donald, R.W. Crosley, and D. Halliwell.	2009	Environment Canada, Saskatoon, SK. May 2009.	Document provided on CD
126.	Investing in our Future: Responding to the Rapid Growth of Oil Sands Development, Final Report	Government of Alberta	2006	---	Accessed at: http://alberta.ca/home/395.cfm?
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129.	Alberta's Oil Sands 2008	Government of Alberta, Department of Energy, Edmonton, AB	2009	---	Document provided on CD
130.	Environmental Management of Alberta's Oil Sands: Resourceful. Responsible.	Government of Alberta	2009	---	Document provided on CD
131.	Facts about tailings management	Government of Alberta	2009	---	Document provided on CD
132.	Human Health Risk Assessment Mercury in Fish. The Regional Aquatics Monitoring Program (RAMP).	Government of Alberta	2009	---	Document provided on CD
133.	Oil Sands Environmental Management Quick Facts	Government of Alberta	2009	---	Document provided on CD
134.	Profile of the lower Athabasca region	Government of Alberta	2009	---	Document provided on CD
135.	Talk About Oil sands	Government of Alberta	2009	---	Accessed at: www.oilsands.alberta.ca.
136.	Alberta’s Leased Oil Sands Area map	Government of Alberta	2010	---	Document provided on CD. Accessed at:http://www.energy.alberta.ca/LandAccess/pdfs/OSAagreesStats_July2010.pdf
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139.	Troubled Waters, Troubling Trends. Technology and Policy Options to Reduce Water Use in Oil and Oil Sands Development in Alberta	Griffiths, M., A. Taylor, and D. Woynillowicz. The Pembina Institute, Drayton Valley, AB.	2006	---	Document provided on CD. Also accessible at: http://www.pembina.org/pub/612
140.	Have atmospheric emissions from the Athabasca Oil Sands impacted lakes in northeastern Alberta, Canada?	Hazewinkel, R.R.O., A.P. Wolfe, S. Pla, C. Curtis, and K. Hadley	2008	Canadian Journal of Fisheries and Aquatic Sciences 65:1554-1567	Document provided on CD
141.	Preliminary characterization and source assessment of PAHs in tributary sediments of the Athabasca River, Canada	Headley, J.V., C. Akre, F.M. Conly, K.M. Peru, and L.C. Dickson	2001	Environmental Forensics 2:335-345	Available at a cost: http://www.sciencedirect.com/
142.	Origin of polycyclic aromatic hydrocarbons in lake sediments of the Mackenzie Delta	Headley, J.V., P. Marsh, C.J. Akre, K.M. Peru, and L. Lesack	2002	Journal of Environmental Science and Health A37(7):1159-1180	Document provided on CD.
143.	The characterization and distribution of inorganic chemicals in tributary waters of the lower Athabasca River, oilsands region, Canada	Headley, J.V., B. Crosley, F.M. Conly, and E.K. Quagraine	2005	Journal of Environmental Science and Health A40:1-27	Document provided on CD
144.	The Athabasca Oil Sands - a Regional Geological Perspective, Fort McMurray Area, Alberta, Canada	Hein, FJ. and D.K. Cotterill	2006	Natural Resources Research 15:85-102	Available at a cost: http://www.springerlink.com/content/y0vl15x748728xq5/
145.	The Waters that Bind Us: Transboundary Implications of Oil Sands Development	Holroyd, P. and T. Simieritsch. The Pembina Institute, Drayton Valley, AB.	2009	---	Document provided on CD

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146.	Application of floodplain stratigraphy to determine the recurrence of ice-jam flooding along the lower Peace and Athabasca rivers, Alberta	Hugenholtz, C.H., D.G. Smith and J.M. Livingston	2009	Canadian Water Resources Journal 34(1):1-16	Document provided on CD
147.	Oil sands development contributes polycyclic aromatic compounds to the Athabasca River and its tributaries	Kelly, E.N., J.W. Short, D.W. Schindler, P.V. Hodson, M. Ma, A.K. Kwan, and B.L. Fortin	2009	Proceedings of the National Academy of Sciences 106 (52):22346-51	Document provided on CD
148.	Oil sands development contributes elements toxic at low concentrations to the Athabasca River and its tributaries 1. Supporting Information	Kelly, E.N., D.W. Schindler, P.V. Hodson, J.W. Short, R. Radmanovich, and C.C. Nielsen	2010	Proceedings of the National Academy of Sciences 107(37): 16178-16183	Document provided on CD. Document with supplemental information provided on CD Datasets accessible at: http://www.pnas.org/content/suppl/2010/08/26/1008754107.DCSupplemental
149.	Cumulative Effects Assessment and EIA Follow-up: A Proposed Community-based Monitoring Program in the Oil Sands Region, Northeastern Alberta	Lawe L.B., J. Wells and Mikisew Cree First Nations Industry Relations Corporation	2005	Impact Assessment & Project Appraisal 23:205-209	Available at a cost: http://cemaonline.ca/traditional-environmental-knowledge-tek/index.php?option=com_jombib&task=showbib&id=447&catid=263. Requires CEMA login.
150.	Toxic Liability. How Albertans Could End Up Paying for Oil Sands Mine Reclamation.	Lemphers, N., S. Dyer and J. Grant	2010	---	Document provided on CD
151.	The ecological effects of naphthenic acids and salts on phytoplankton from the Athabasca oil sands region	Leung, S.L., M.D. McKinnon and R.E.H. Smith	2003	Aquatic Toxicology 62(1):11-26	Available at a cost: http://www.ncbi.nlm.nih.gov/pubmed/12413790
152.	Reproductive and stress hormone levels in goldfish (Carassius auratus) exposed to oil sands process-affected water	Lister, A., V. Nero, A. Farwell, D.G. Dixon, and G. Van Der Kraak	2008	Aquatic Toxicology 87:170-177	Document provided on CD

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154.	How long must northern saxicolous lichens be immersed to form a waterbody trimline?	Marsh, J.E. and K.P. Timoney	n.d.	---	Document provided on CD.
155.	Submission for intervention re: Kearl Oil Sands Project	Mikisew Cree First Nation. Submitted by Prowse Chowne LLP, Edmonton, AB.	2006	---	Document provided on CD
156.	Drilling Deeper: The In Situ Oil Sands Report Card	Moorhouse, J., M. Huot and S. Dyer	2010	---	Document provided on CD
157.	Canada's Oil Sands Opportunities and Challenges to 2015: An Update	National Energy Board, Calgary, AB	2006	---	Document provided on CD
158.	Oil sands water toxicity: A critical review	Natural Resources Canada, CanmetENERGY	2010	---	Document provided on CD
159.	Ecological risk assessment and polycyclic aromatic hydrocarbons in sediments: identifying sources and ecological hazard	Neff, J.M., S.A. Stout and D.G. Gunster	2005	Integrated Environmental Assessment and Management 1(1):22-33	Available at a cost: http://onlinelibrary.wiley.com/doi/10.1897/IEAM_2004a-016.1/pdf
160.	Gill and liver histopathological changes in yellow perch (Perca flavescens) and goldfish (Carassius auratus) exposed to oil sands process-affected water	Nero, V., A. Farwell, A. Lister, G. Van Der Kraak, L.E.J. Lee, T. Van Meer, M.D. MacKinnon, and D.G. Dixon	2006	Ecotoxicology and Environmental Safety 63:365-377	Document provided on CD

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162.	An overview of water quality in the Fort Chipewyan area	Noton, L.R.	1988	Presented at the Fort Chipewyan-Fort Vermilion Bicentennial Conference, Provincial Museum of Alberta, September 23-25, 1988. Alberta Environment.	Document provided on CD Also accessible at: http://environment.gov.ab.ca/info/library/8248.pdf
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164.	Phase 2 Framework Committee Report	Ohlson, D., G. Long and T. Hatfield	2010	---	Document provided on CD
165.	Letter re oil sands mining water management agreement for the 2008-2009 winter period	Oil Sands Developers Group	2008	---	Document provided on CD.
166.	Duck Deaths Confirm First Nations' Fears	Oil Sands Truth: Shut Down the Tar Sands	2008	---	Accessed at: http://oilsandstruth.org/duck-deaths-confirm-first-nations039-fears.
167.	Oil sands regulator does not enforce toxic tailings rules	Oil Sands Watch	2010	---	Accessed at: http://www.oilsandswatch.org/media-release/2004. Individual operator submissions to ERCB available at: http://www.ercb.ca/.
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170.	2010 Regional Aquatics Monitoring Program (RAMP) Scientific Review	RAMP Review Panel: Burn, Dixon, Dube, Flotemersch, Franzin, Gibson, Munkittrick, Post, Watmough. Submitted by Main, C. at Alberta Innovates – Technology Futures.	2011	---	Document provided on CD. Also accessible on RAMP website: (www.ramp-alberta.org)
171.	Oil sands Regional Aquatics Monitoring Program (RAMP) Five Year Report	RAMP Steering Committee. Submitted by Golder Associates Ltd., Calgary, AB.	2003	---	Available at: http://www.ramp-alberta.org/ramp/results.aspx
172.	Oil Sands Regional Aquatic Monitoring Program (RAMP) Scientific Peer Review of the Five Year Report (1997-2001)	RAMP Steering Committee. Submitted by Ayles, G.B., M. Dubé and D. Rosenberg	2004	---	Accessed at: http://www.andrewnikiforuk.com/Dirty_Oil_PDFs/RAMP%20Peer%20review.pdf.
173.	RAMP 2003 Technical Report	RAMP Steering Committee. Prepared by Hatfield Consultants Ltd., Jacques Whitford Environment Ltd., Mack, Slack & Associates Inc., and Western Resource Solutions.	2004	---	Available at: http://www.ramp-alberta.org/ramp/results.aspx

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175.	RAMP 2005 Technical Report	RAMP Steering Committee. Prepared by Hatfield Consultants Ltd., Stantec Consulting Ltd., Mack, Slack & Associates Inc., and Western Resource Solutions.	2006	---	Available at: http://www.ramp-alberta.org/ramp/results.aspx
176.	RAMP 2007 Technical Report	RAMP Steering Committee. Prepared by the RAMP 2007 Implementation Team.	2008	---	Available at: http://www.ramp-alberta.org/ramp/results.aspx
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180.	Fish Health Program (RAMP website)	Regional Aquatics Monitoring Program (RAMP)	2010	---	Accessed at: http://www.ramp-alberta.org/ramp/community/abnormalities.aspx
181.	Environmental and Health Impacts of Canada's Oil Sands Industry 1. Report 2. Executive Summary	The Royal Society of Canada (RSC)	2010	---	Document provided on CD
182.	Section 1: Future Water Flows and Human Withdrawals in the Athabasca River	Schindler, D.W., W.F. Donahue, and J.P. Thompson. University of Alberta.	2007	In: Running Out of Steam? Oil Sands Development and Water Use in the Athabasca River Watershed: Science and Market-based Solutions.	Accessed at: http://www.ualberta.ca/~ersc/water.pdf
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187.	Guilty verdict in Syncrude Ponds Tailing Case	The Green Pages, June 25, 2010.	2010	---	Accessed at: http://thegreenpages.ca/portal/ab/2010/06/guilty_verdict_in_syncrude_pon.html.
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189.	Levels of polycyclic aromatic hydrocarbons and dibenzothiophenes in wetland sediments and aquatic insects in the oil sands area of Northeastern Alberta	Wayland, M., J.V. Headley, K.M. Peru, R. Crosley, and B.G. Brownlee	2008	Environmental Monitoring and Assessment 136:167-182	Document provided on CD
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193.	Saxicolous lichen trimlines in the Peace-Athabasca Delta of northern Alberta: flora, growth rates, establishment and persistence, and history of water levels.	B.C. Hydro. Prepared by Marsh, J.E. and K.P. Timoney	2004	---	Document provided on CD
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197.	Winter and Summer Hydrometric Surveys and Modeling in the Athabasca Delta: 1. Summer Survey Reports 2. Hydrodynamic & Habitat Modeling Report	CEMA. Prepared by AMEC Earth and Environmental and northwest hydraulic consultants.	2009	---	Document provided on CD

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201.	1. Differentiating lake water balances in the Peace-Athabasca Delta using isotope tracers. 2. Posters: Quantifying transient water balances in floodplain lakes in Peace-Athabasca Delta, Alberta, Canada using isotope tracers	Falcone, M., T.W.D. Edwards and B.B. Wolfe	2004	International Association for Great Lakes Research 47th Annual Conference: Great Lakes Need Great Watersheds, University of Waterloo, May 24-28, 2004	Document provided on CD
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203.	Hydraulic Impact of Flow Regulation on the Peace-Athabasca Delta	Farley, D.W. and H. Cheng	1986	Canadian Water Resources Journal 11(1):27-42	Available at: http://onlinelibrary.wiley.com/doi/10.1002/hyp.6420/abstract. Need to login.

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208.	Peace Athabasca Delta Waterbird Inventory: 1999 Surveys, Final Report	Pollard, J.B., M. Gendron, S.A. Smyth, A.J. Richard, and G.R. Stewart. Ducks Unlimited, Edmonton, AB	2000	---	Document provided on CD
209.	Synthesis of Ecological Information Related to the Peace-Athabasca Delta	Public Works and Government Services Canada. Prepared by AECOM.	2010	---	Document provided on CD
210.	Reconstruction of past hydrology and climate from stable isotope records of a closed-drainage lake in the Peace-Athabasca Delta, Alberta, Canada	St. Amour, N.A., T.W.D. Edwards and B.B. Wolfe	2004	Poster presentation, International Association for Great Lakes Research 47th Annual Conference: Great Lakes Need Great Watersheds, University of Waterloo, May 24-28, 2004	Document provided on CD

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213.	Three centuries of change in the Peace-Athabasca Delta, Canada	Timoney, K.	2009	Climatic Change (2009) 93:485–515.	Document provided on CD
214.	The status of muskrats on the Peace-Athabasca Delta, 2000-2001 survey.	Westworth, D. and R. Wiacek	2002	Report for B.C. Hydro.	Document provided on CD
215.	The status of muskrats in the Peace-Athabasca Delta, Wood Buffalo National Park.	Wiacek, R. and D. Westworth	1999	Final report for B.C. Hydro and Parks Canada.	Document provided on CD
216.	The status of muskrats in the Peace-Athabasca Delta, 1999-2000 surveys.	Wiacek, R., D.L. Skinner and D. Westworth	2001	Report for B.C. Hydro	Document provided on CD
217.	Impacts of climate and river flooding on the hydro-ecology of a floodplain basin, Peace-Athabasca Delta, Canada, since AD 1700	Wolfe, B.B., T.L. Karst-Riddoch, S.R. Vardy, M.D. Falcone, R.I. Hall, and T.W.D. Edwards	2005	Quaternary Research 64:147-162	Document provided on CD
218.	Climate-driven shifts in quantity and seasonality of river discharge over the past 1000 years from the hydrographic apex of North America	Wolfe, B.B., R.I. Hall, T.W.D. Edwards, S.R. Jarvis, R.N. Sinnatamby, Y. Yi, and J.W. Johnston	2008	Geophysical Research Letters 35:L24402	Document provided on CD
219.	Classification of hydrological regimes of northern floodplain basins (Peace-Athabasca Delta, Canada) from analysis of stable isotopes (d18O, d2H) and water chemistry	Wolfe, B.B., T.L. Karst-Riddoch, R.I. Hall, T.W.D. Edwards,M.C. English, R. Palmini, S. McGowan, P.R. Leavitt, and S.R. Vardy	2007	Hydrological Processes 21:151-168	Document provided on CD

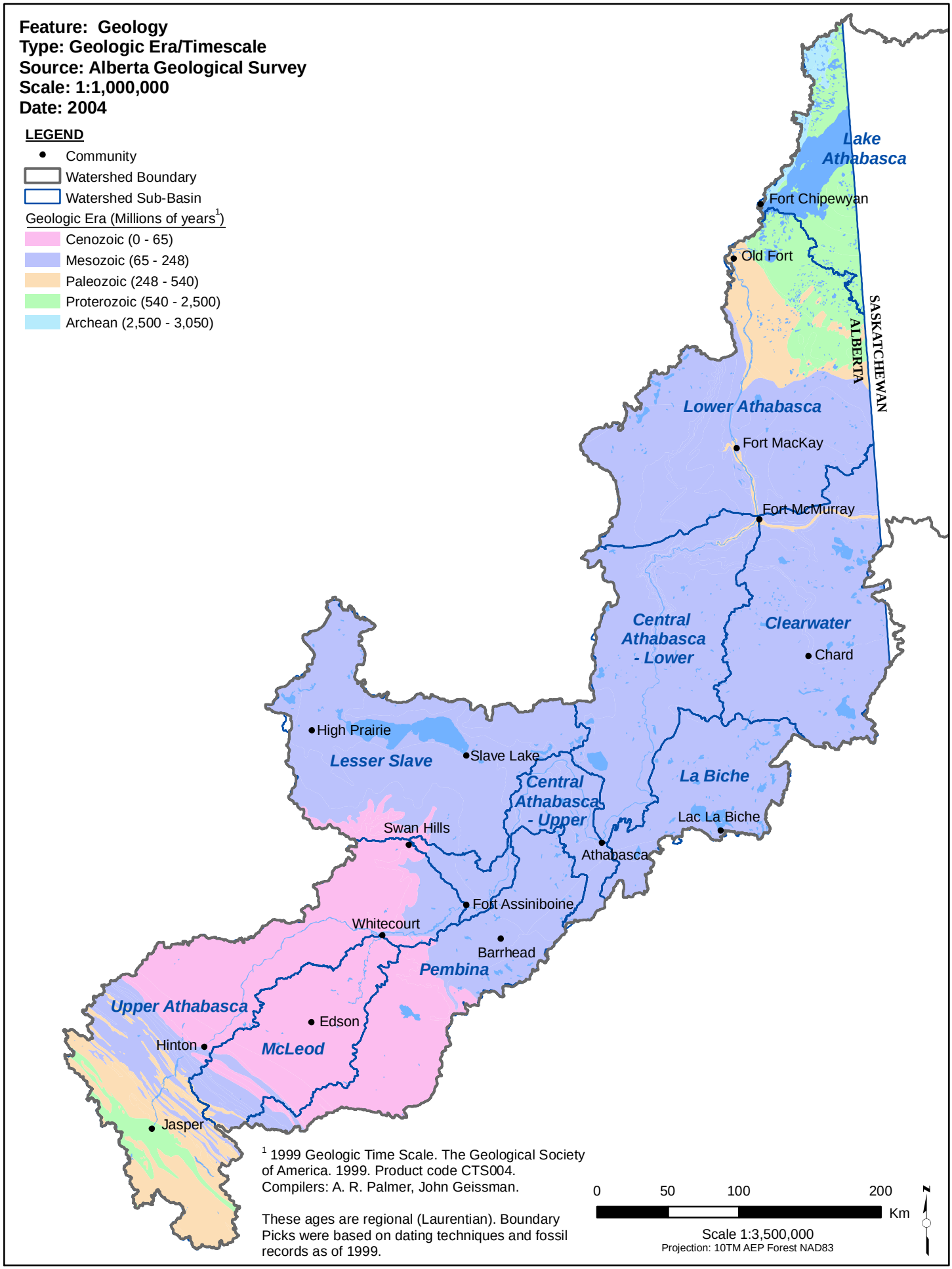
PEACE-ATHABASCA DELTA

No.	Title	Author	Year	Journal / Publication	Accessed / Found
220.	Reconstruction of multi-century flood histories from ox-bow lake sediments, Peace Athabasca Delta, Canada	Wolfe,B, Hall, R, Last, W, Edwards, T, English M, Karst-Riddoch T, Paterson A, Palmini R	2005	Hydrological Processes, Vol 0, 4131-4153	Document provided on CD
221.	Hydroecological responses of the Athabasca Delta, Canada, to changes in river flow and climate during the 20th century	Wolfe, B.B., R.I. Hall, T.W.D. Edwards, S.R. Vardy, M.D. Falcone, C. Sjunneskog, F. Sylvestre, S. McGowan, P.R. Leavitt, and P. van Driel	2008	Ecohydrology 1:131-148	Document provided on CD
222.	Isotopic Responses of Lakes to a Summer Flood Event (2001), Peace-Athabasca Delta, Canada	Yi, Y., M. Falcone, B.B. Wolfe, and T.W.D. Edwards	2004	International Workshop on the Application of Isotope Techniques in Hydrological and Environmental Studies, UNESCO, Paris, France, September 6-8, 2004	Document provided on CD
223.	A coupled isotope tracer method to characterize input water to lakes	Yi, Y., B.E. Brock, M.D. Falcone, B.B. Wolfe, and T.W.D. Edwards	2007	Journal of Hydrology 350:1-13	Document provided on CD

Appendix A2

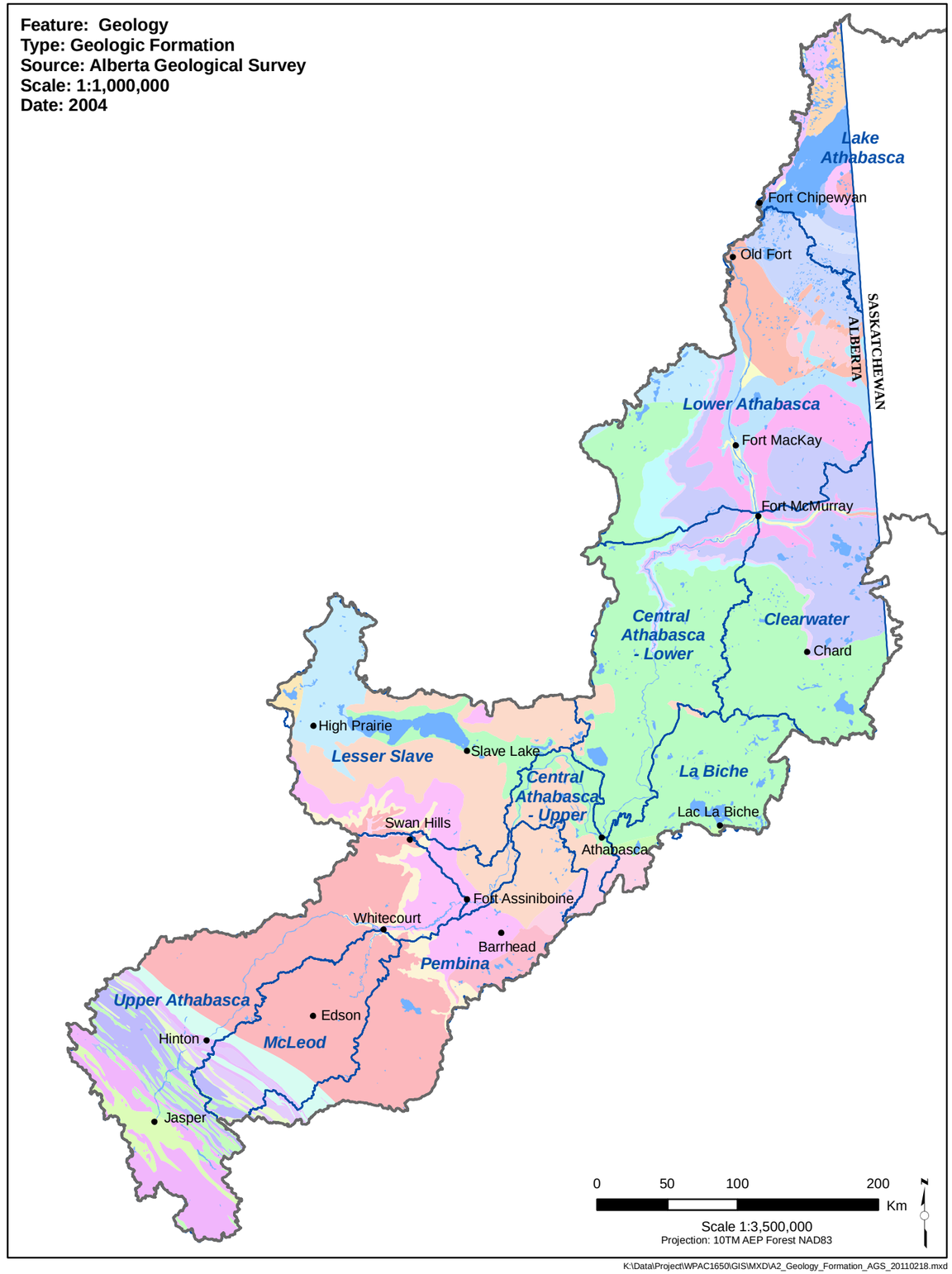
Athabasca Watershed Council State of the Watershed Report Phase 1: Maps from Preliminary Atlas

Feature: Geology
Type: Geologic Era/Timescale
Source: Alberta Geological Survey
Scale: 1:1,000,000
Date: 2004



K:\Data\Project\WPAC1650\GIS\MXD\A1_Geology_Era_AGS_20110218.mxd

Feature: Geology
Type: Geologic Formation
Source: Alberta Geological Survey
Scale: 1:1,000,000
Date: 2004



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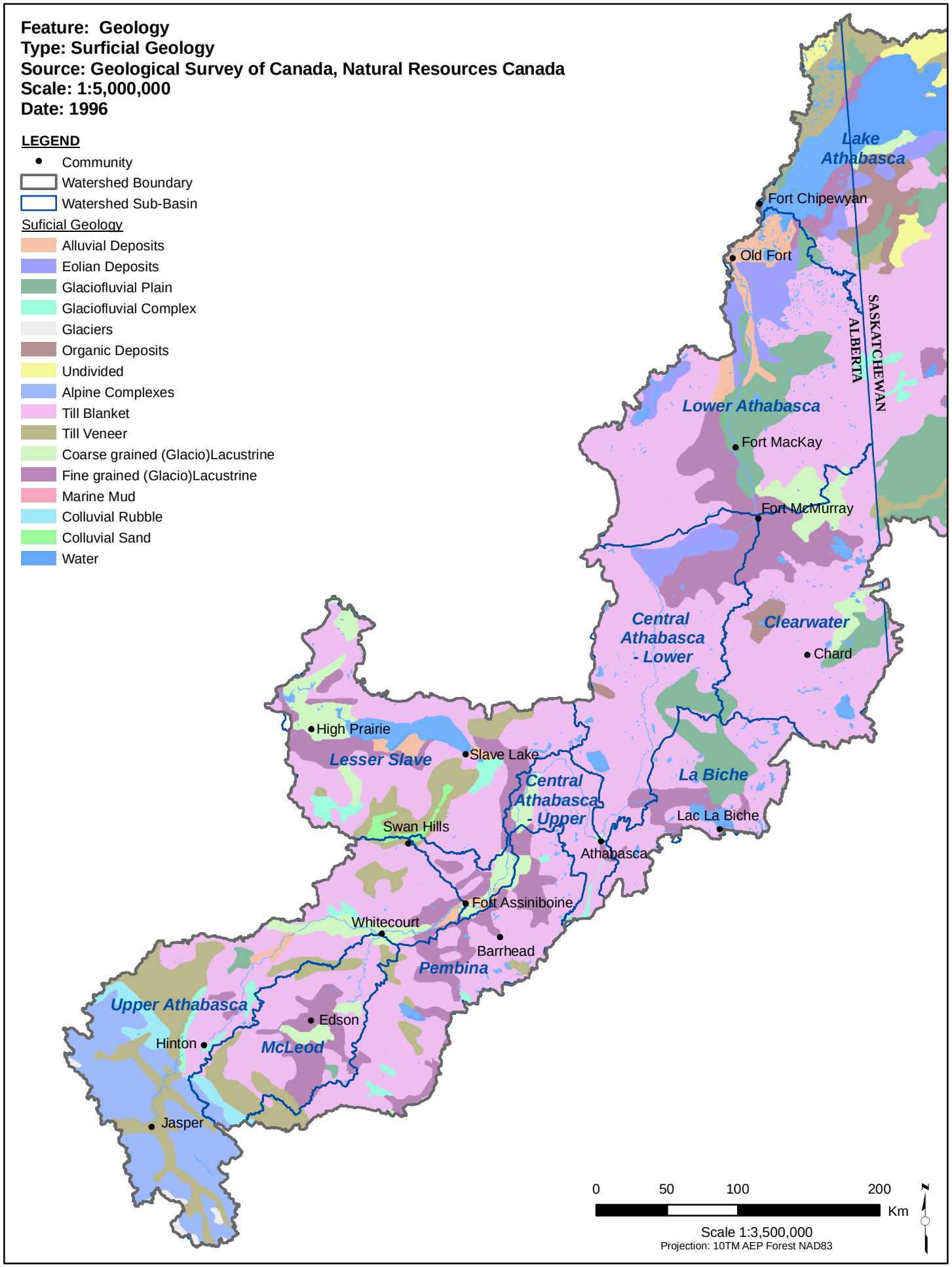
LEGEND

- Community
- Watershed Boundary
- Watershed Sub-Basin

Geologic Formation

- Alberta Group
- Alkali feldspar-rich granitoid
- Arch Lake Granitoids
- Basal Cretaceous
- Bearpaw Formation
- Belly River Group
- Belly River-St.Mary River Succession
- Blood Reserve Formation
- Brazeau Formation
- Charles Lake Granitoids
- Chinchaga Formation
- Chipewyan Red Granite
- Clearwater Formation
- Coalspur Formation
- Colin Lake Granitoids
- Cypress Hills Formation
- Del Bonita Gravels
- Dunvegan Formation
- Eastend Formation
- Fitzgerald Formation
- Foremost Formation
- Fort Vemilion Formation
- Grand Rapids Formation
- Granite gneiss
- Grey foliated Granitoid
- Grosmont Formation
- Hand Hills Formation
- Hay River Formation
- High grade metasedimentary rocks
- Horseshoe Canyon Formation
- Ireton Formation
- Joli Fou Formation
- Kaskapau Formation
- Keg River Formation
- Labiche Formation
- Lea Park Formation
- Locker Lake Formation
- Loon River Formation
- Low grade metasedimentary rocks of Waugh Lake & Burnt Lake Groups
- Lower Mesozoic-Lower Cretaceous
- Lower Paleozoic
- Manitou Falls Formation
- McMurray Formation
- Middle Devonian
- Miette Group
- Mikkwa Formation
- Milk River Formation
- Muskeg Formation
- Nyarling Formation
- Oldman Formation
- Otherside Formation
- Pakowki Formation
- Paskapoo Formation
- Paskapoo Formation, lower
- Paskapoo Formation, upper
- Peace River Formation
- Pelican Formation
- Porcupine Hills Formation
- Porcupine Hills Formation, upper
- Purcell Supergroup
- Puskwaskau Formation
- Ravenscrag Formation
- Recrystallized mylonitic rocks
- Scollard Formation
- Shaftesbury Formation
- Slave Granitoids
- Slave Point Formation
- Smoky Group
- St. Mary River Formation
- Swan Hills Gravels
- Sweetgrass Hills Diorite Intrusives
- Sweetgrass Hills Minette Intrusives
- Upper Paleozoic
- Wapiti Group
- Wapiti Group, lower
- Wapiti Group, upper
- Waterways Formation
- Willow Creek Formation
- Wolverine Point Formation, lower
- Wolverine Point Formation, upper
- Wylie Lake Granitoids

Feature: Geology
Type: Surficial Geology
Source: Geological Survey of Canada, Natural Resources Canada
Scale: 1:5,000,000
Date: 1996



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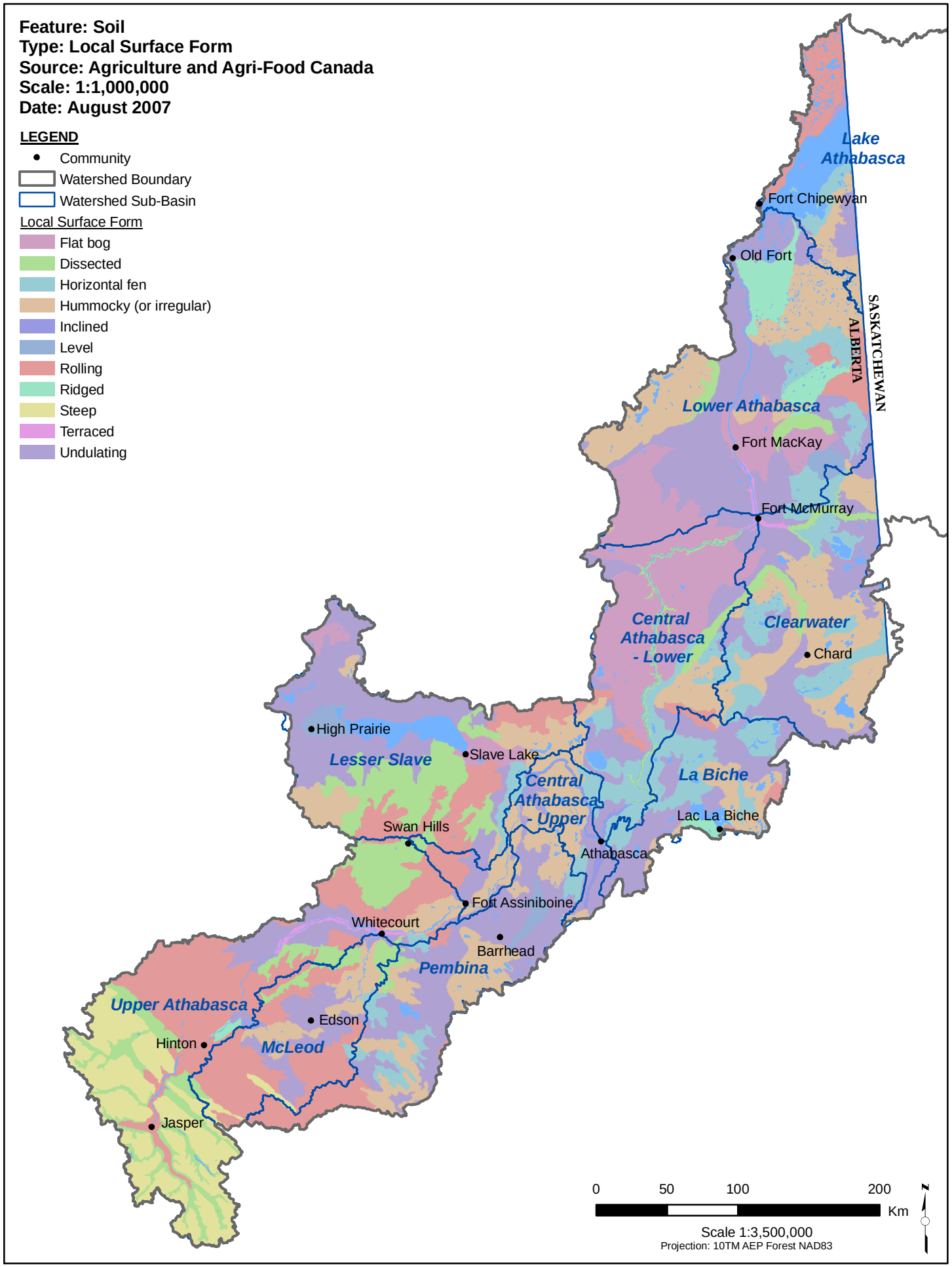
Feature: Soil
Type: Local Surface Form
Source: Agriculture and Agri-Food Canada
Scale: 1:1,000,000
Date: August 2007



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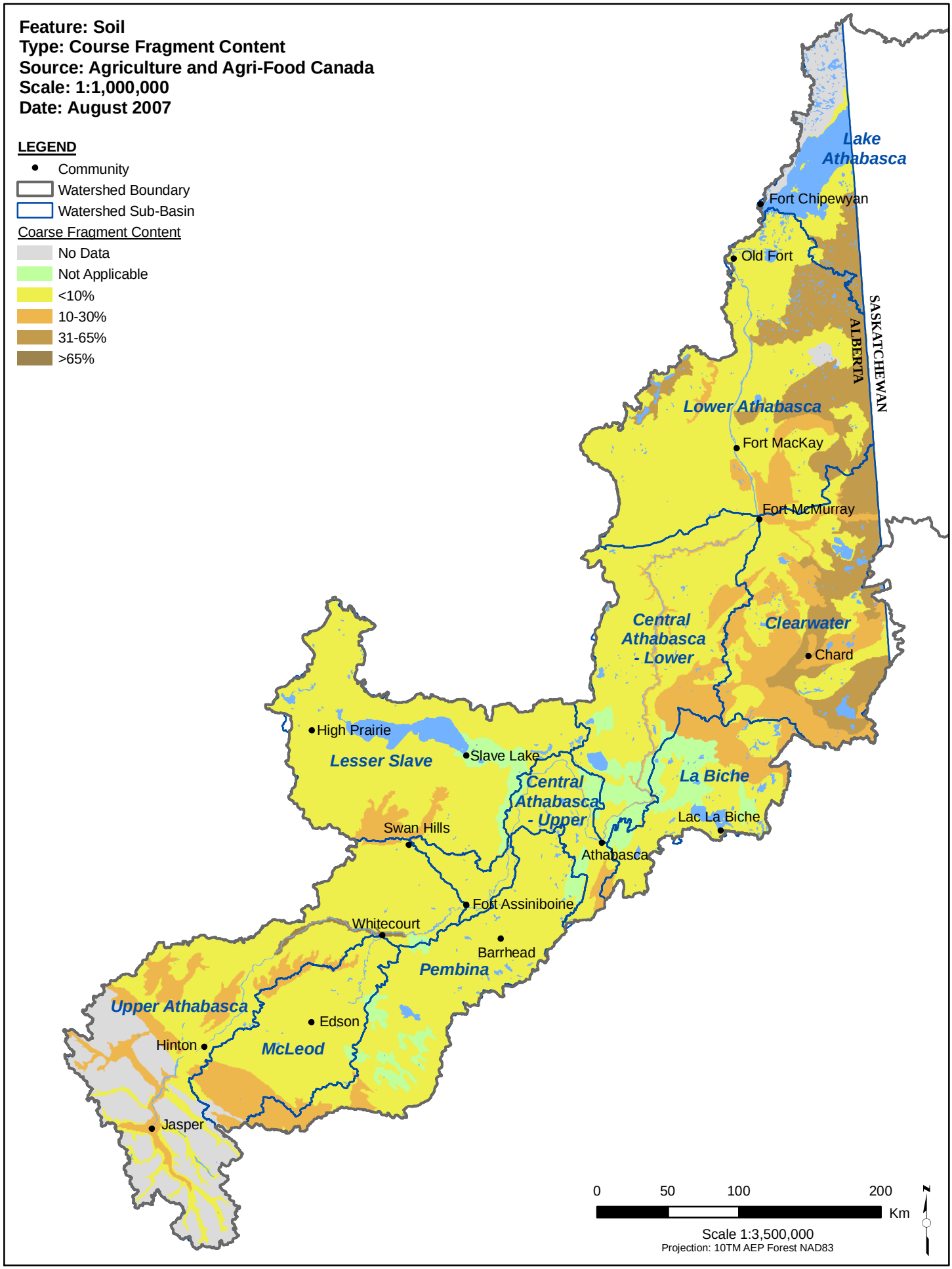

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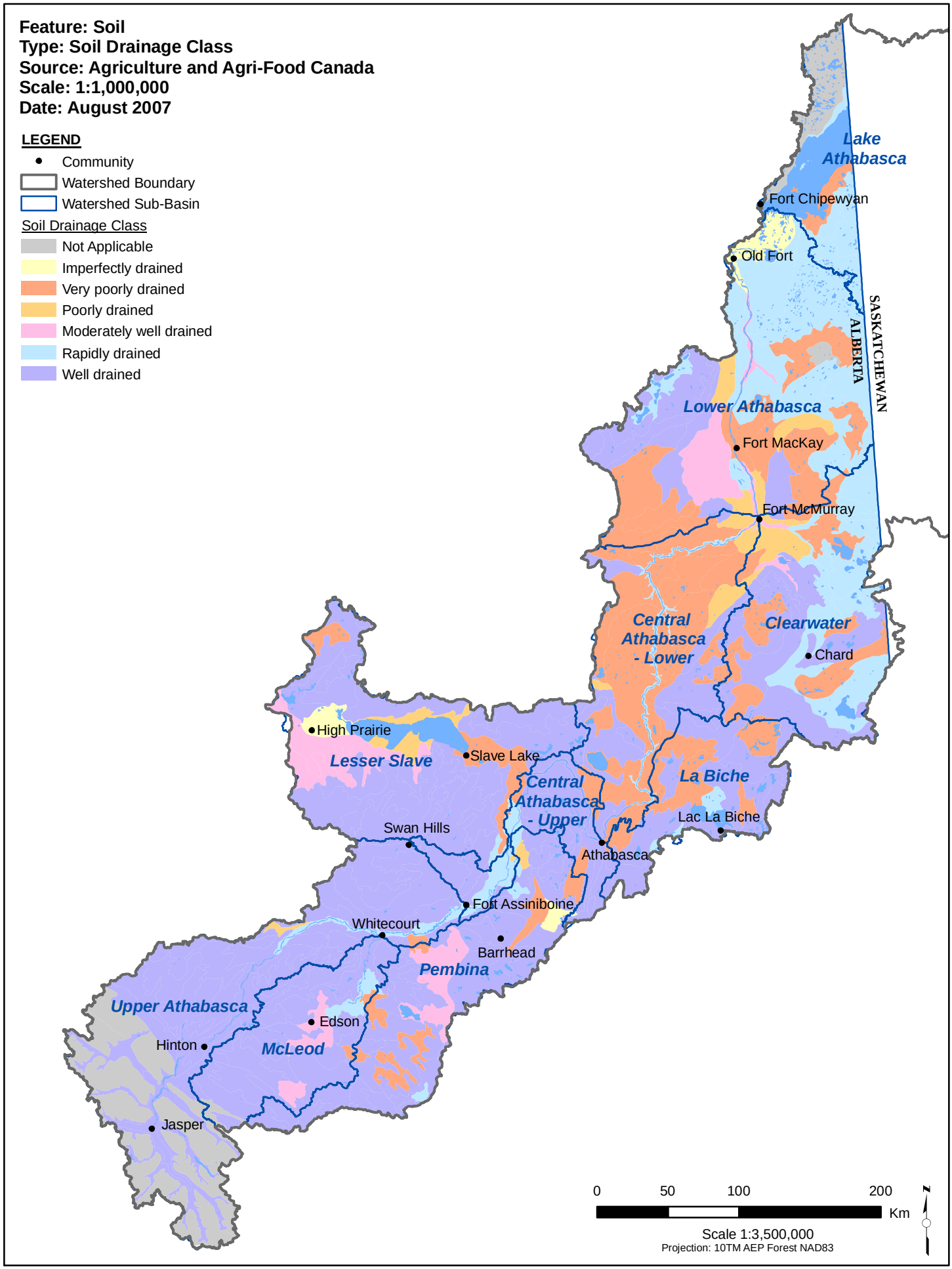
Feature: Soil
Type: Soil Drainage Class
Source: Agriculture and Agri-Food Canada
Scale: 1:1,000,000
Date: August 2007



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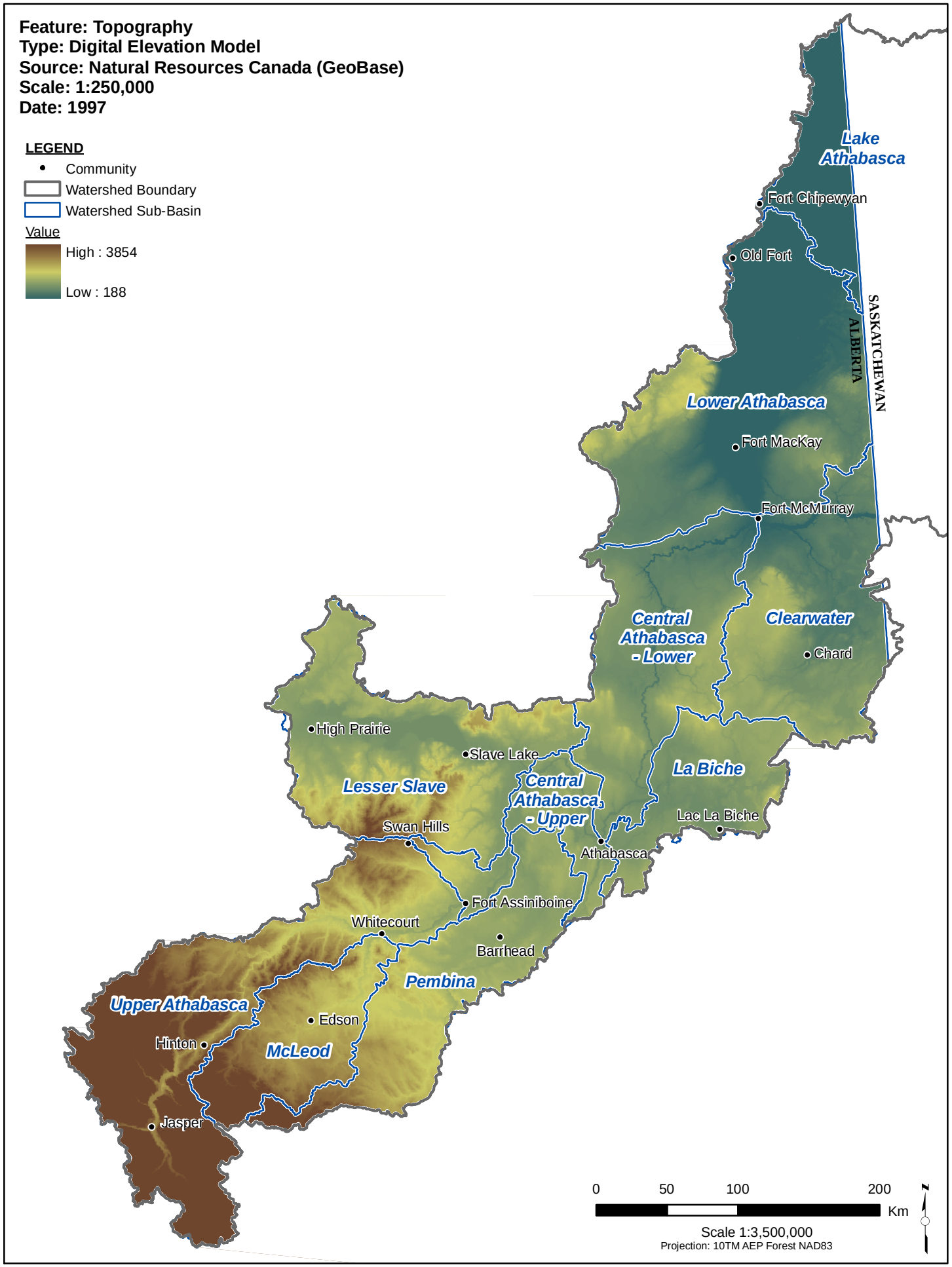
Feature: Topography
Type: Digital Elevation Model
Source: Natural Resources Canada (GeoBase)
Scale: 1:250,000
Date: 1997



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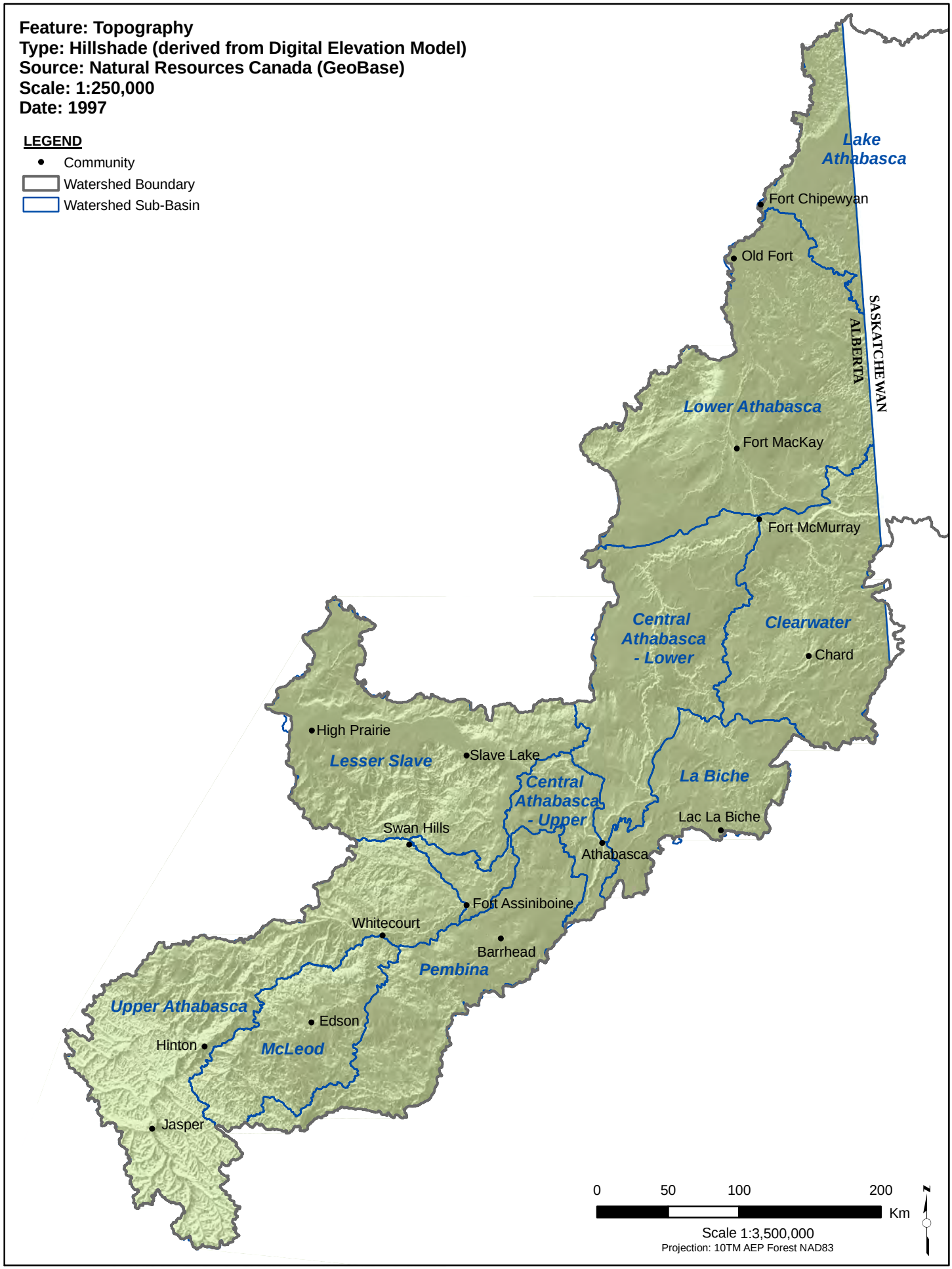
Feature: Topography
Type: Hillshade (derived from Digital Elevation Model)
Source: Natural Resources Canada (GeoBase)
Scale: 1:250,000
Date: 1997
LEGEND
Community
Watershed Boundary
Watershed Sub-Basin
Lake Athabasca
Fort Chipewyan
Old Fort
ALBERTA
SASKATCHEWAN
Lower Athabasca
Fort MacKay
Fort McMurray
Central Athabasca - Lower
Clearwater
Chard
High Prairie
Lesser Slave
Slave Lake
Central Athabasca - Upper
La Biche
Lac La Biche
Swan Hills
Athabasca
Fort Assiniboine
Whitecourt
Barrhead
Pembina
Upper Athabasca
Edson
Hinton
McLeod
Jasper
0
50
100
200
Km
Scale 1:3,500,000
Projection: 10TM AEP Forest NAD83
N
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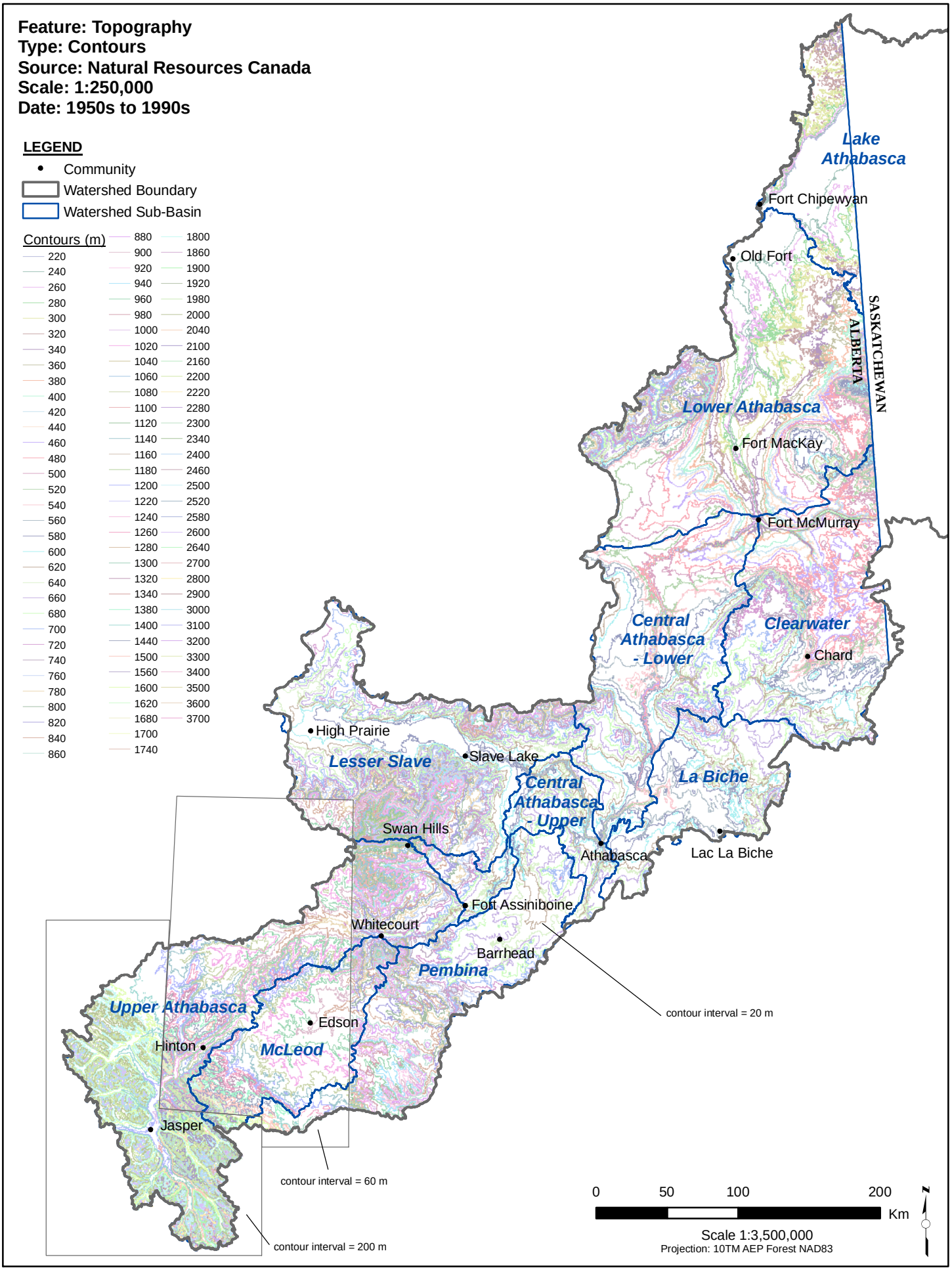
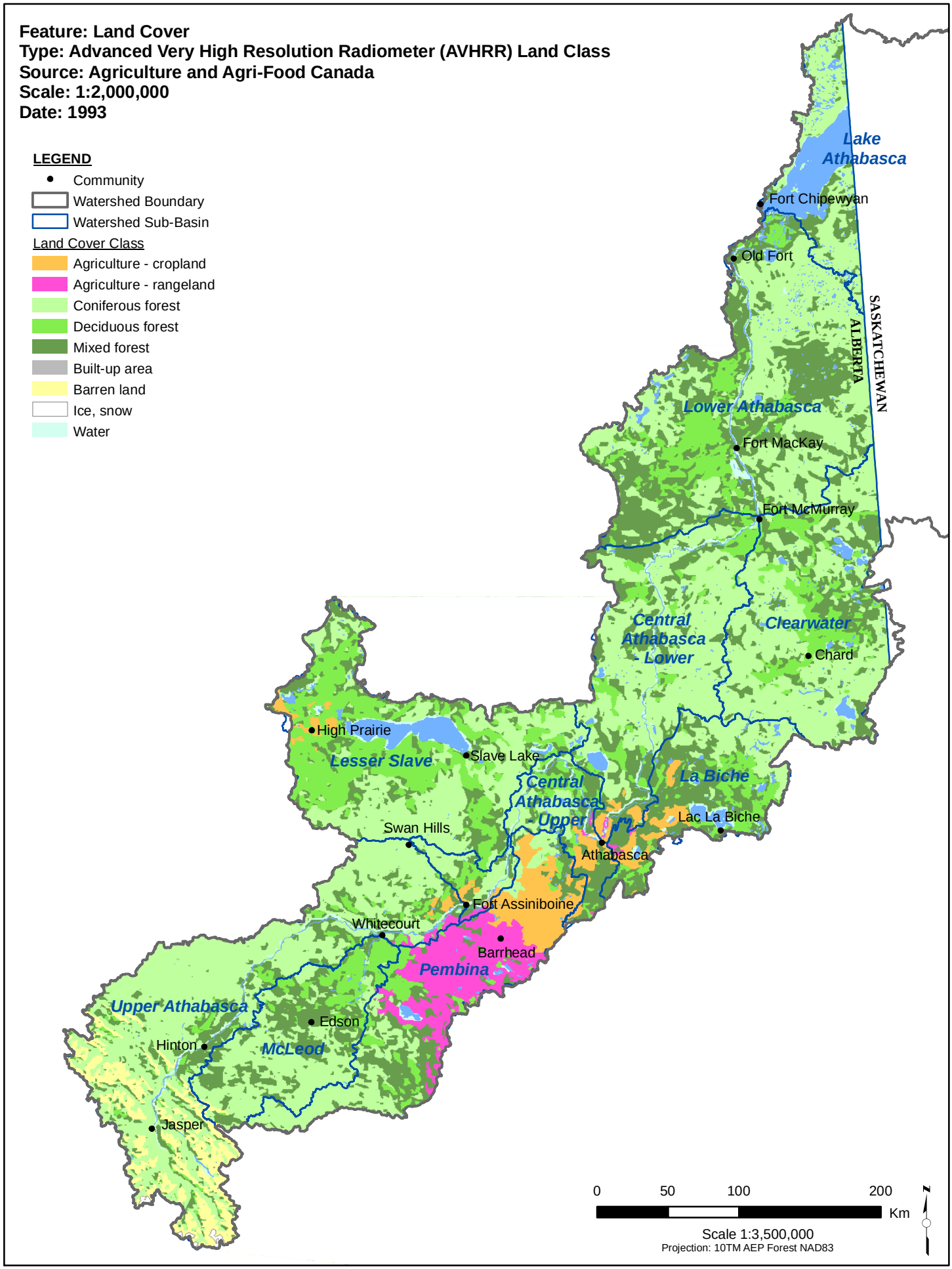

Feature: Topography
Type: Contours
Source: Natural Resources Canada
Scale: 1:250,000
Date: 1950s to 1990s
LEGEND
Community
Watershed Boundary
Watershed Sub-Basin
Contours (m)
220 240 260 280 300 320 340 360 380 400 420 440 460 480 500 520 540 560 580 600 620 640 660 680 700 720 740 760 780 800 820 840 860
880 900 920 940 960 980 1000 1020 1040 1060 1080 1100 1120 1140 1160 1180 1200 1220 1240 1260 1280 1300 1320 1340 1380 1400 1440 1500 1560 1600 1620 1680 1700 1740
1800 1860 1900 1920 1980 2000 2040 2100 2160 2200 2220 2280 2300 2340 2400 2460 2500 2520 2580 2600 2640 2700 2800 2900 3000 3100 3200 3300 3400 3500 3600 3700
Lake Athabasca
Fort Chipewyan
Old Fort
ALBERTA
SASKATCHEWAN
Lower Athabasca
Fort MacKay
Fort McMurray
Central Athabasca - Lower
Clearwater
Chard
High Prairie
Lesser Slave
Slave Lake
Central Athabasca - Upper
La Biche
Swan Hills
Athabasca
Lac La Biche
Fort Assiniboine
Whitecourt
Barrhead
Pembina
Upper Athabasca
Edson
Hinton
McLeod
Jasper
contour interval = 20 m
contour interval = 60 m
contour interval = 200 m
0 50 100 200
Km
Scale 1:3,500,000
Projection: 10TM AEP Forest NAD83
N
K:\Data\Project\WPAC1650\GIS\MXD\C3_Topography_Contours_20110218.mxd

Feature: Land Cover
Type: Advanced Very High Resolution Radiometer (AVHRR) Land Class
Source: Agriculture and Agri-Food Canada
Scale: 1:2,000,000
Date: 1993



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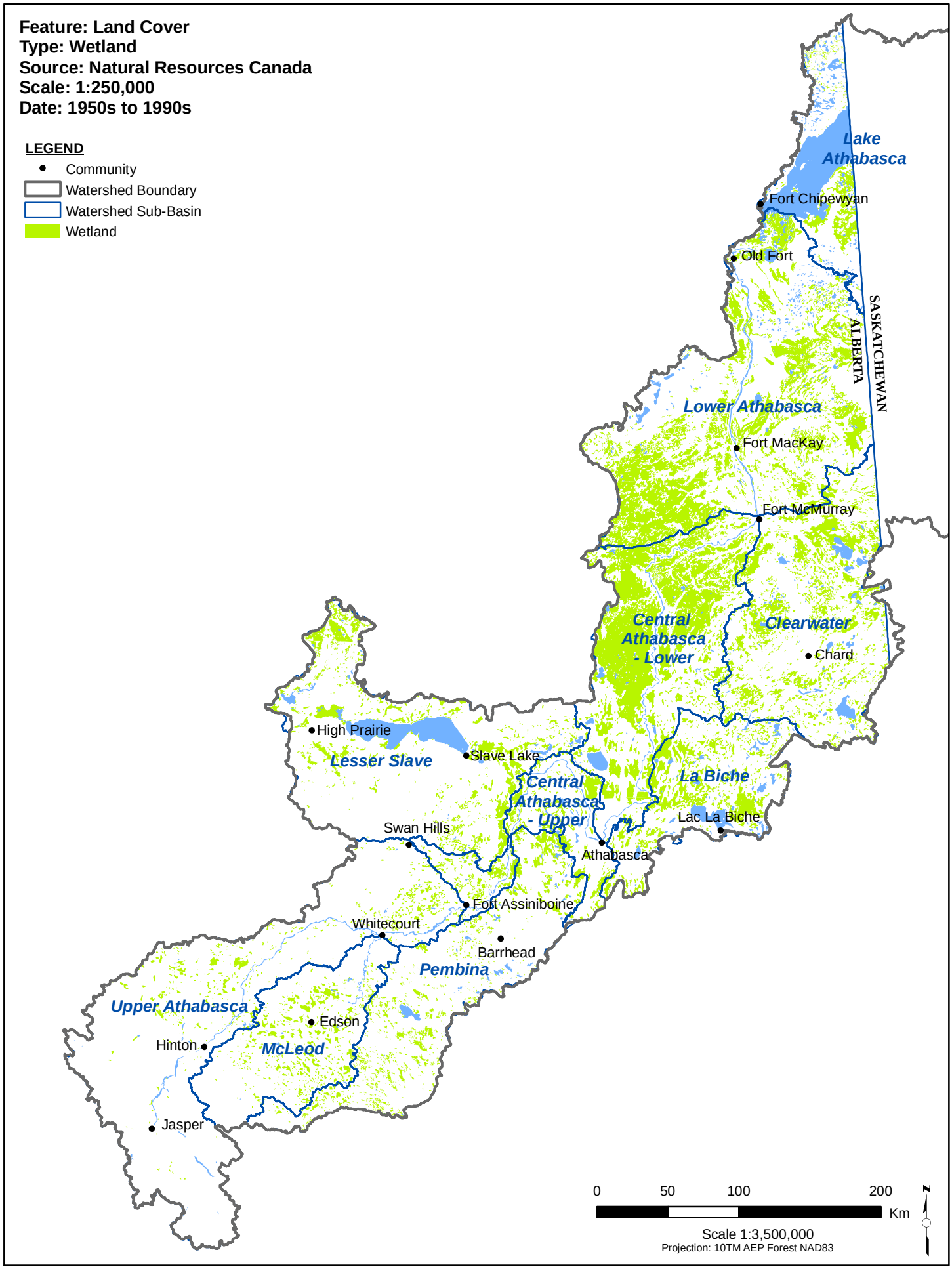
Feature: Land Cover
Type: Wetland
Source: Natural Resources Canada
Scale: 1:250,000
Date: 1950s to 1990s
LEGEND
Community
Watershed Boundary
Watershed Sub-Basin
Wetland
Lake Athabasca
Fort Chipewyan
Old Fort
ALBERTA
SASKATCHEWAN
Lower Athabasca
Fort MacKay
Fort McMurray
Central Athabasca - Lower
Clearwater
Chard
High Prairie
Lesser Slave
Slave Lake
La Biche
Central Athabasca - Upper
Lac La Biche
Swan Hills
Athabasca
Fort Assiniboine
Whitecourt
Barrhead
Pembina
Upper Athabasca
Edson
Hinton
McLeod
Jasper
0
50
100
200
Km
Scale 1:3,500,000
Projection: 10TM AEP Forest NAD83
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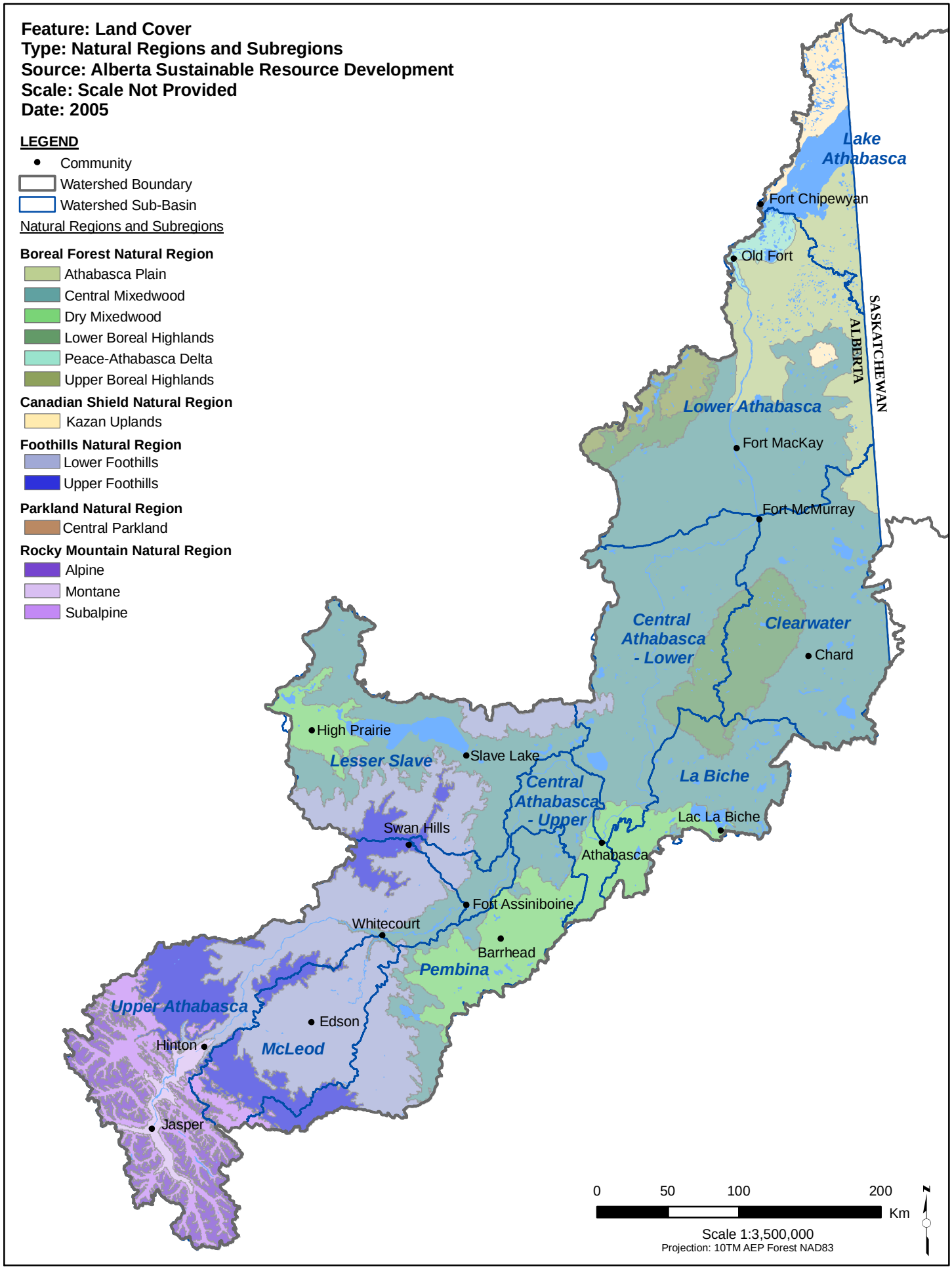
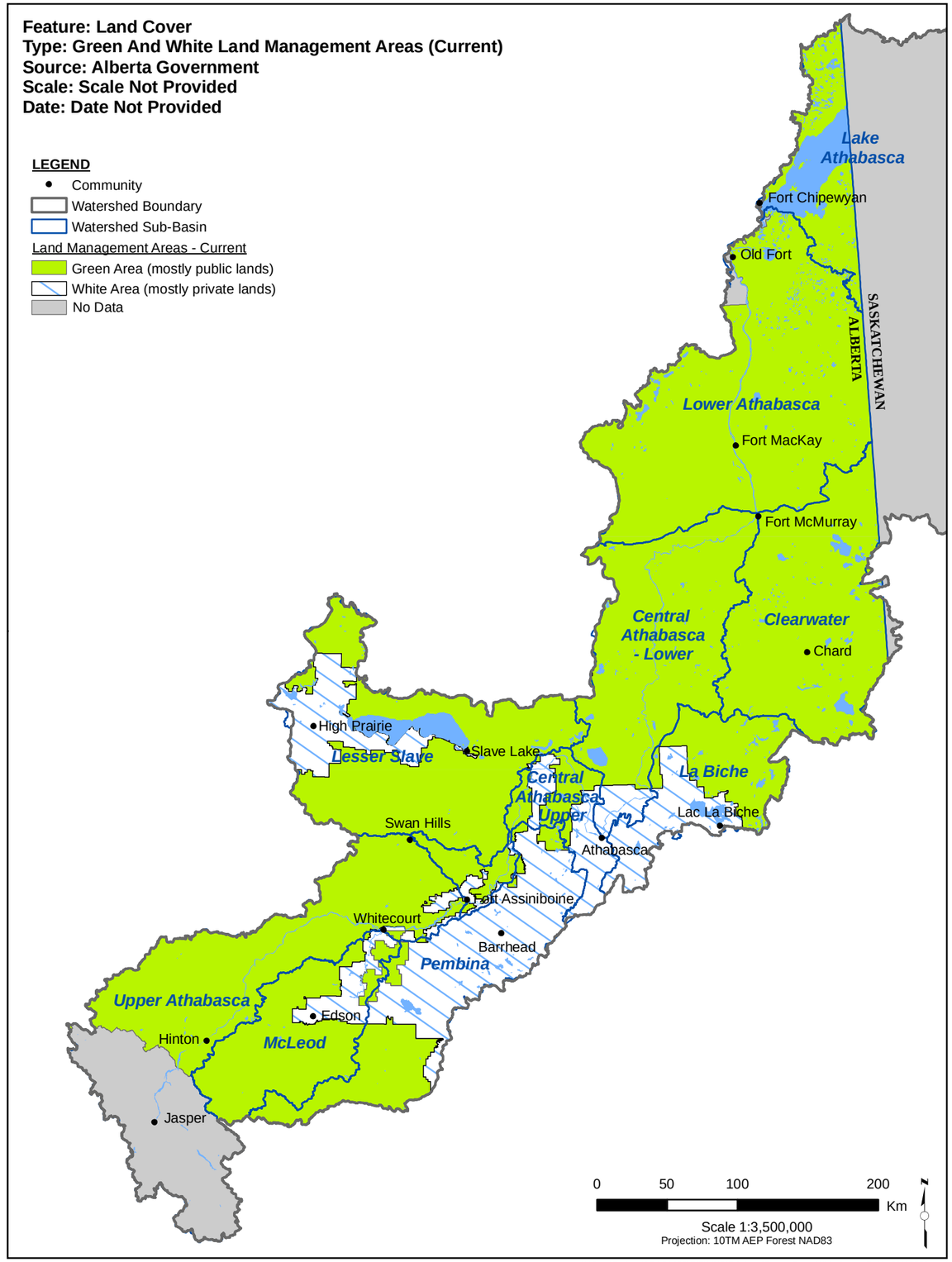
Feature: Land Cover
Type: Natural Regions and Subregions
Source: Alberta Sustainable Resource Development
Scale: Scale Not Provided
Date: 2005



K:\Data\Project\WPAC1650\GIS\MXD\D3_LandCover_RegionsSubregions_ASRD_20110218.mxd

Feature: Land Cover
Type: Green And White Land Management Areas (Current)
Source: Alberta Government
Scale: Scale Not Provided
Date: Date Not Provided



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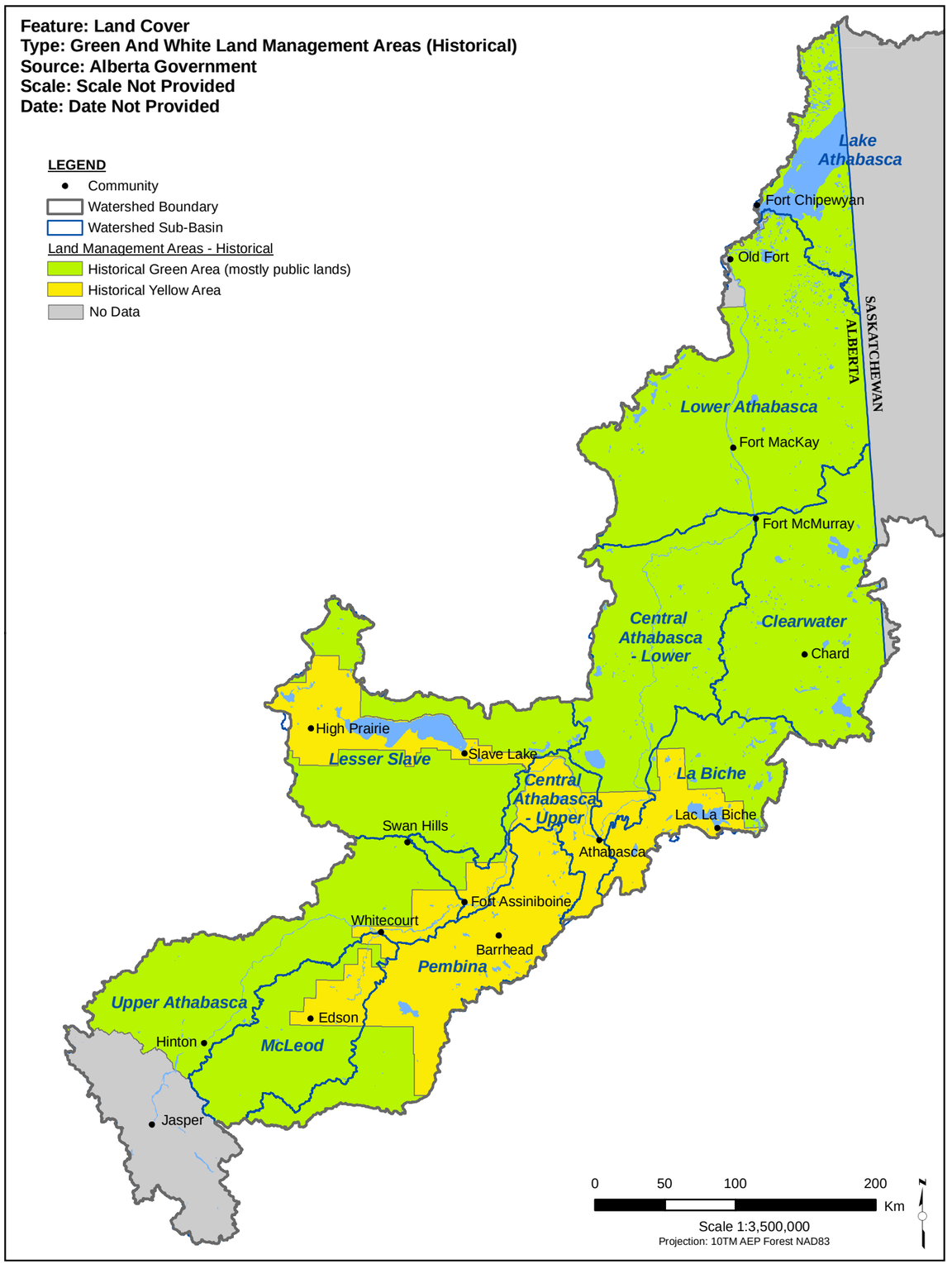
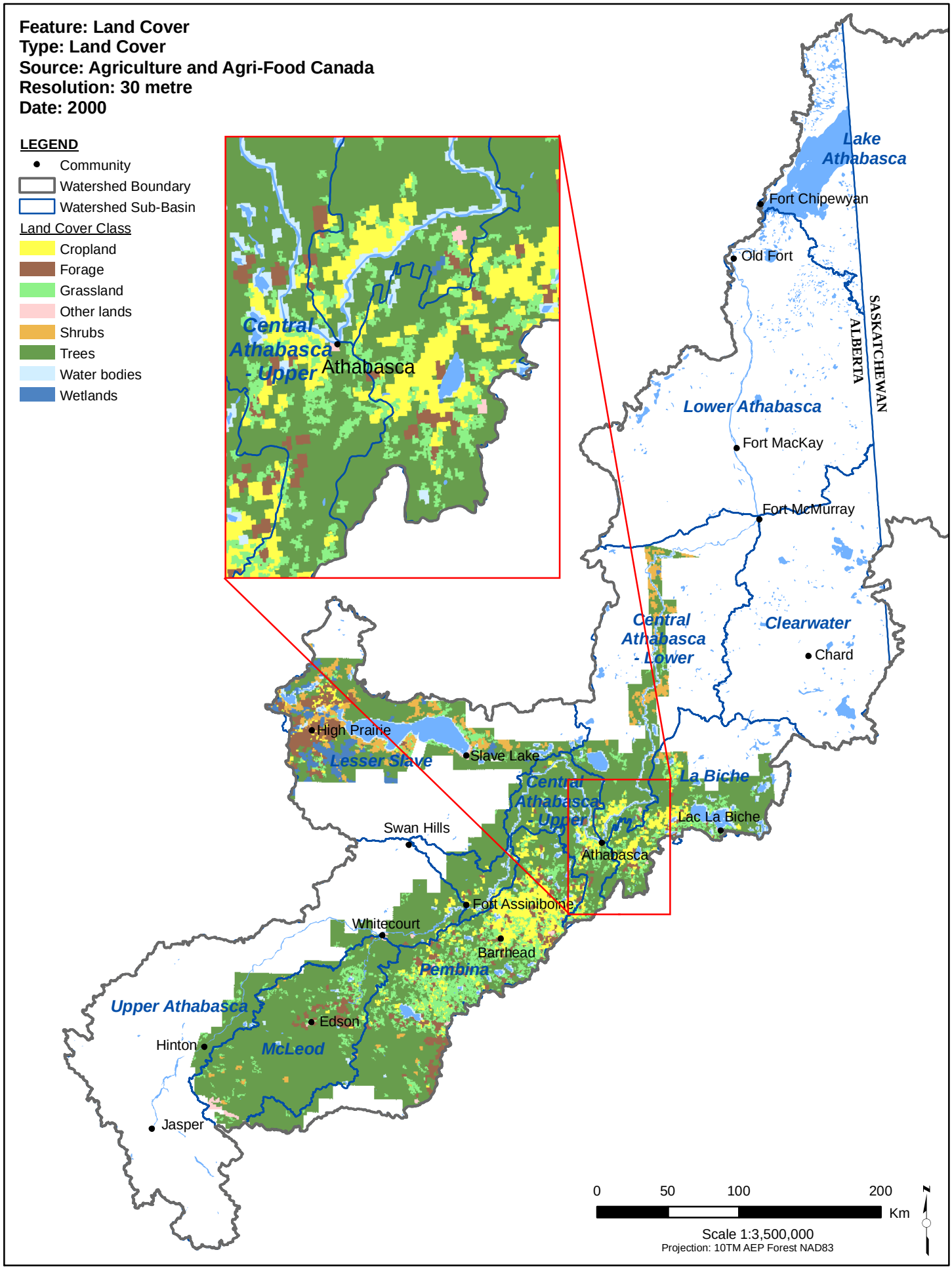
Feature: Land Cover
Type: Green And White Land Management Areas (Historical)
Source: Alberta Government
Scale: Scale Not Provided
Date: Date Not Provided



Feature: Land Cover
Type: Land Cover
Source: Agriculture and Agri-Food Canada
Resolution: 30 metre
Date: 2000



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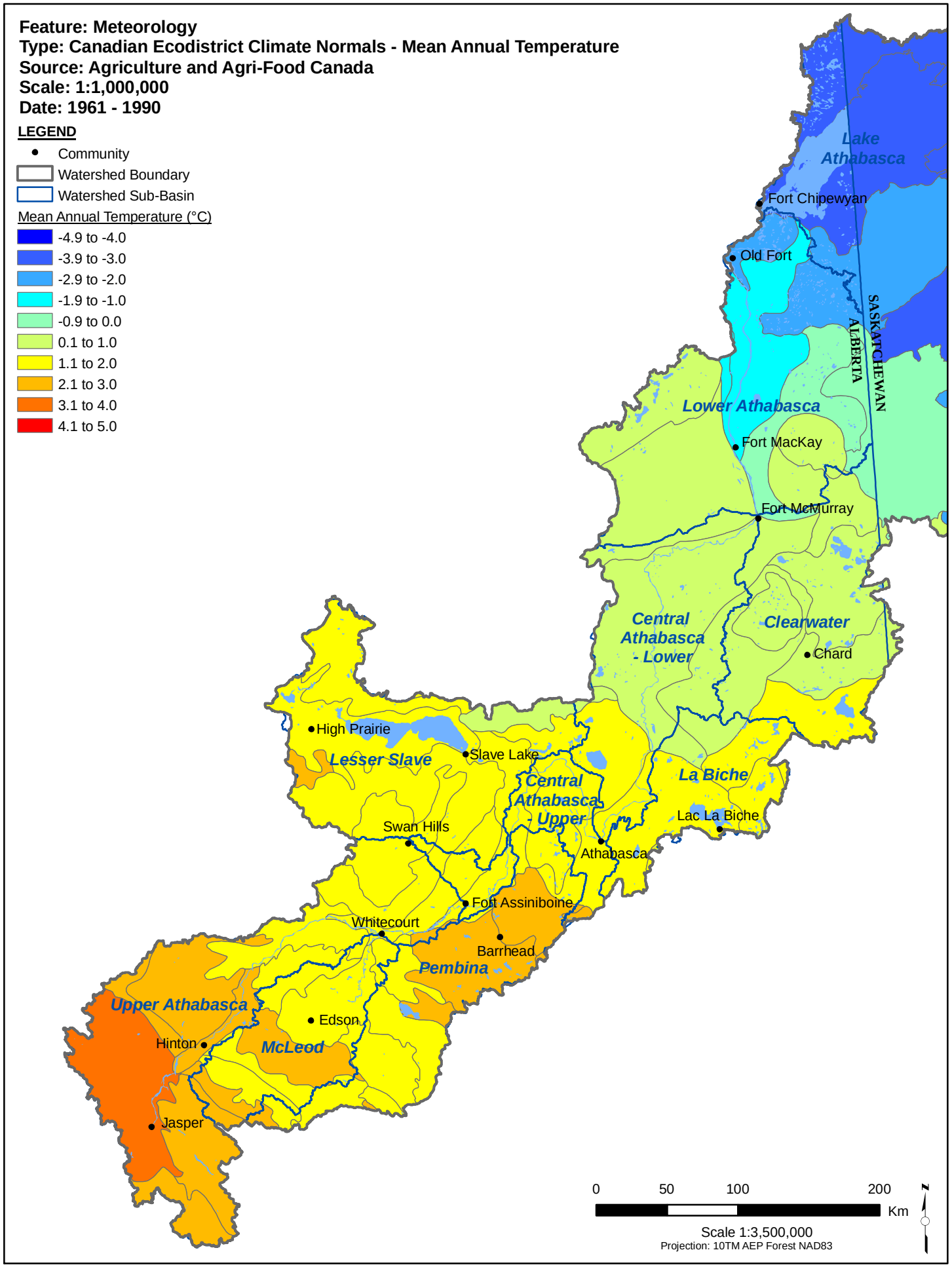
Feature: Meteorology
Type: Canadian Ecodistrict Climate Normals - Mean Annual Temperature
Source: Agriculture and Agri-Food Canada
Scale: 1:1,000,000
Date: 1961 - 1990



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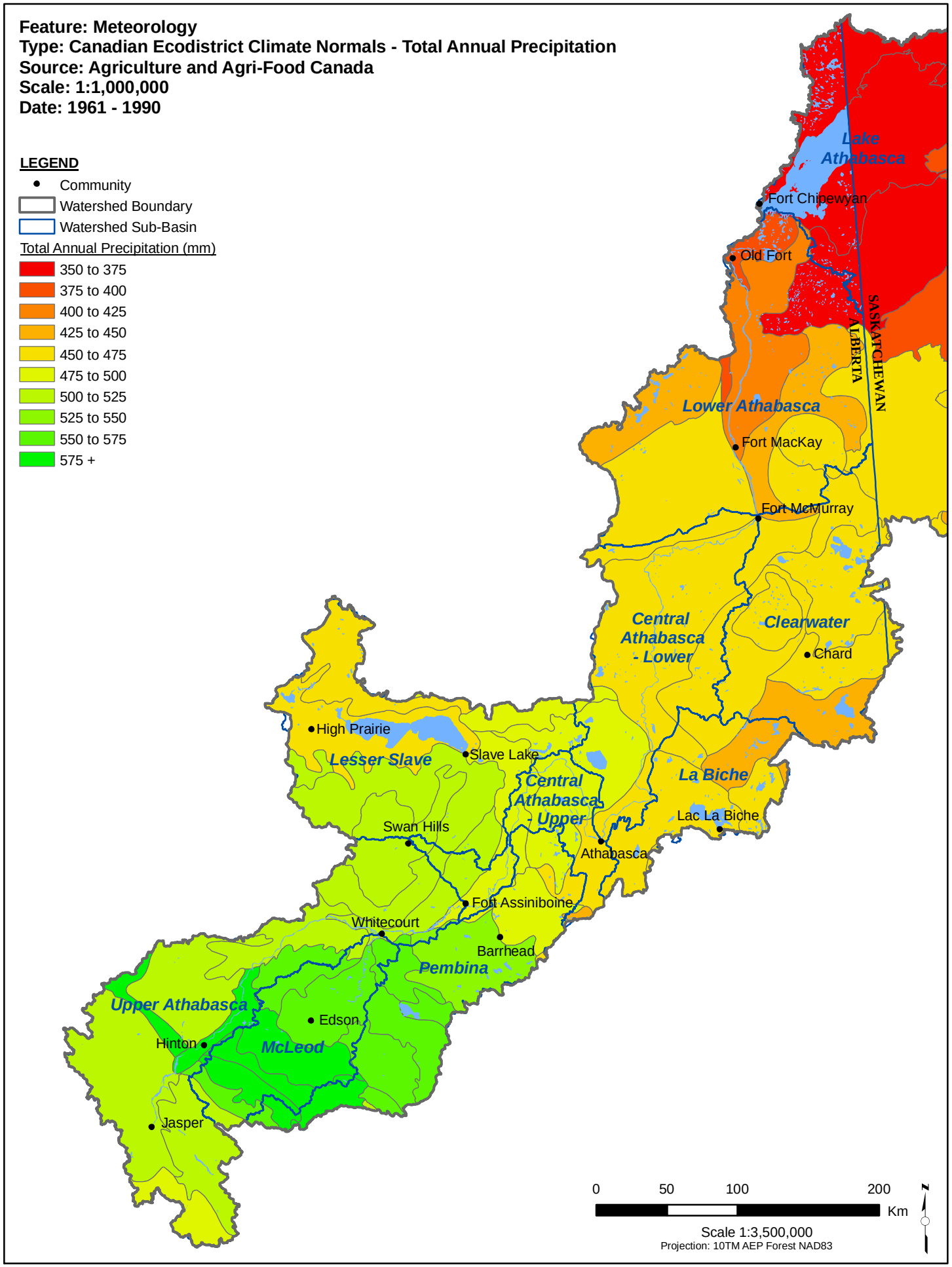
Feature: Meteorology
Type: Canadian Ecodistrict Climate Normals - Total Annual Precipitation
Source: Agriculture and Agri-Food Canada
Scale: 1:1,000,000
Date: 1961 - 1990



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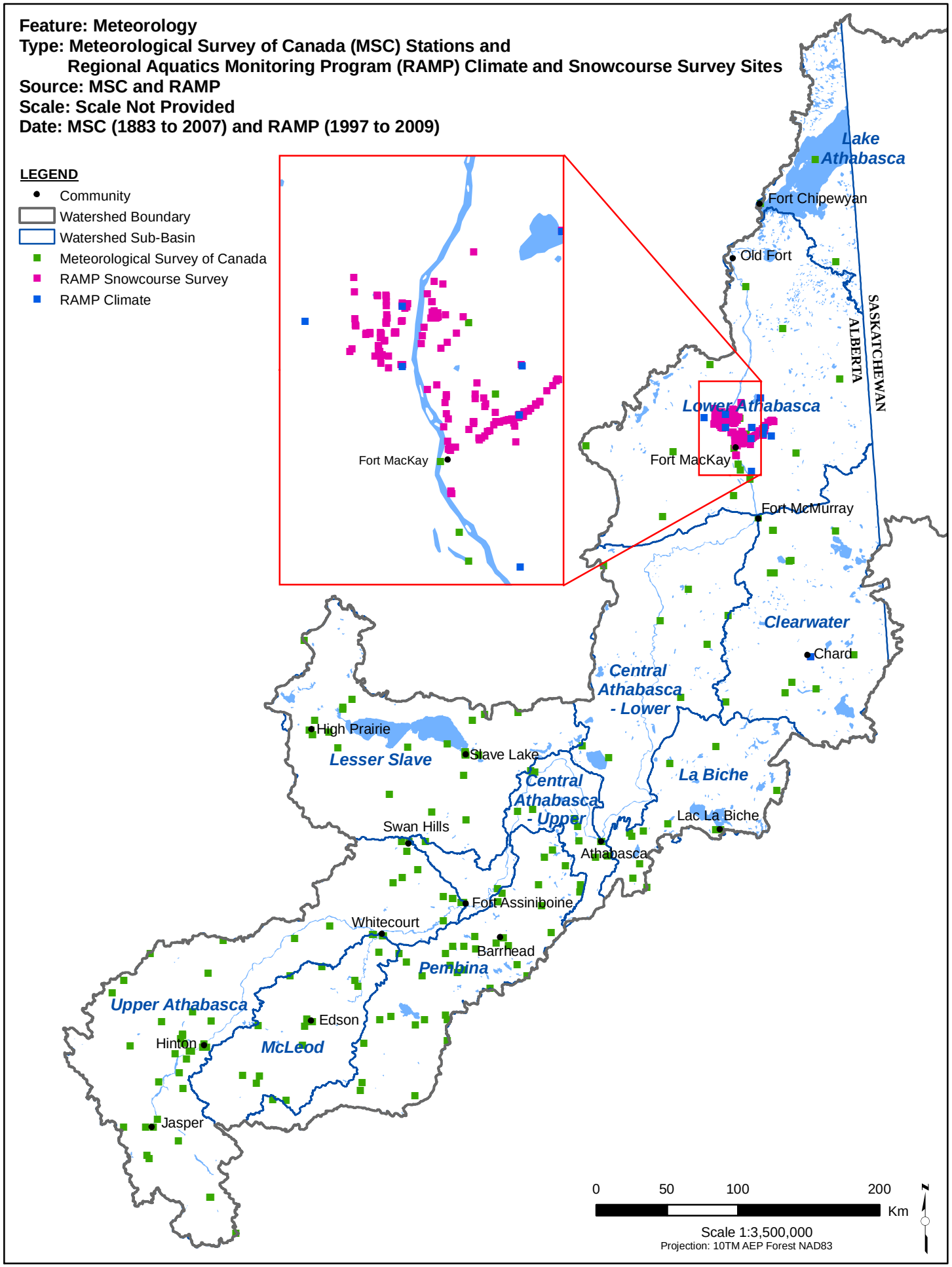
Feature: Meteorology
Type: Meteorological Survey of Canada (MSC) Stations and
Regional Aquatics Monitoring Program (RAMP) Climate and Snowcourse Survey Sites
Source: MSC and RAMP
Scale: Scale Not Provided
Date: MSC (1883 to 2007) and RAMP (1997 to 2009)



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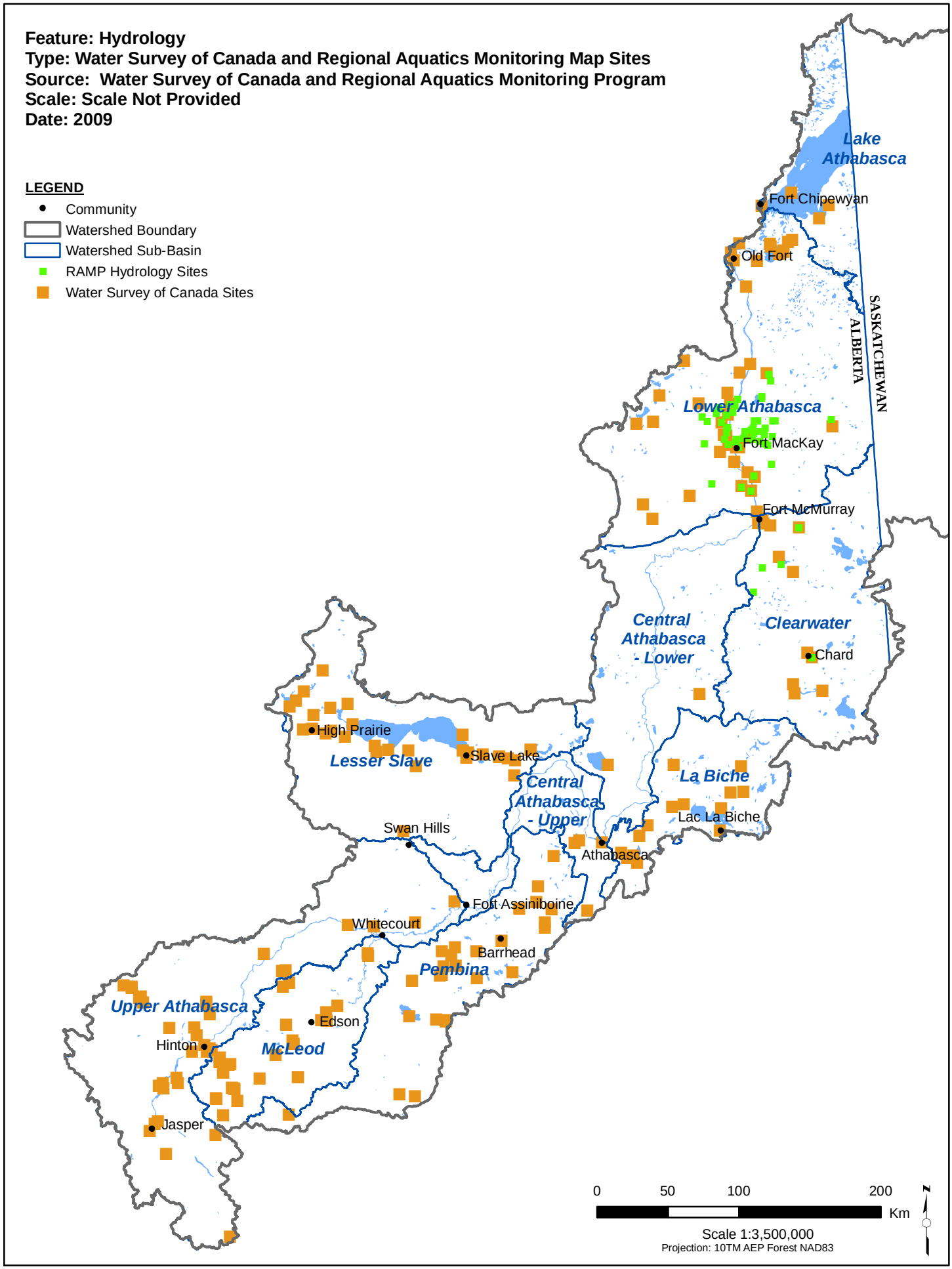
Feature: Hydrology
Type: Water Survey of Canada and Regional Aquatics Monitoring Map Sites
Source: Water Survey of Canada and Regional Aquatics Monitoring Program
Scale: Scale Not Provided
Date: 2009



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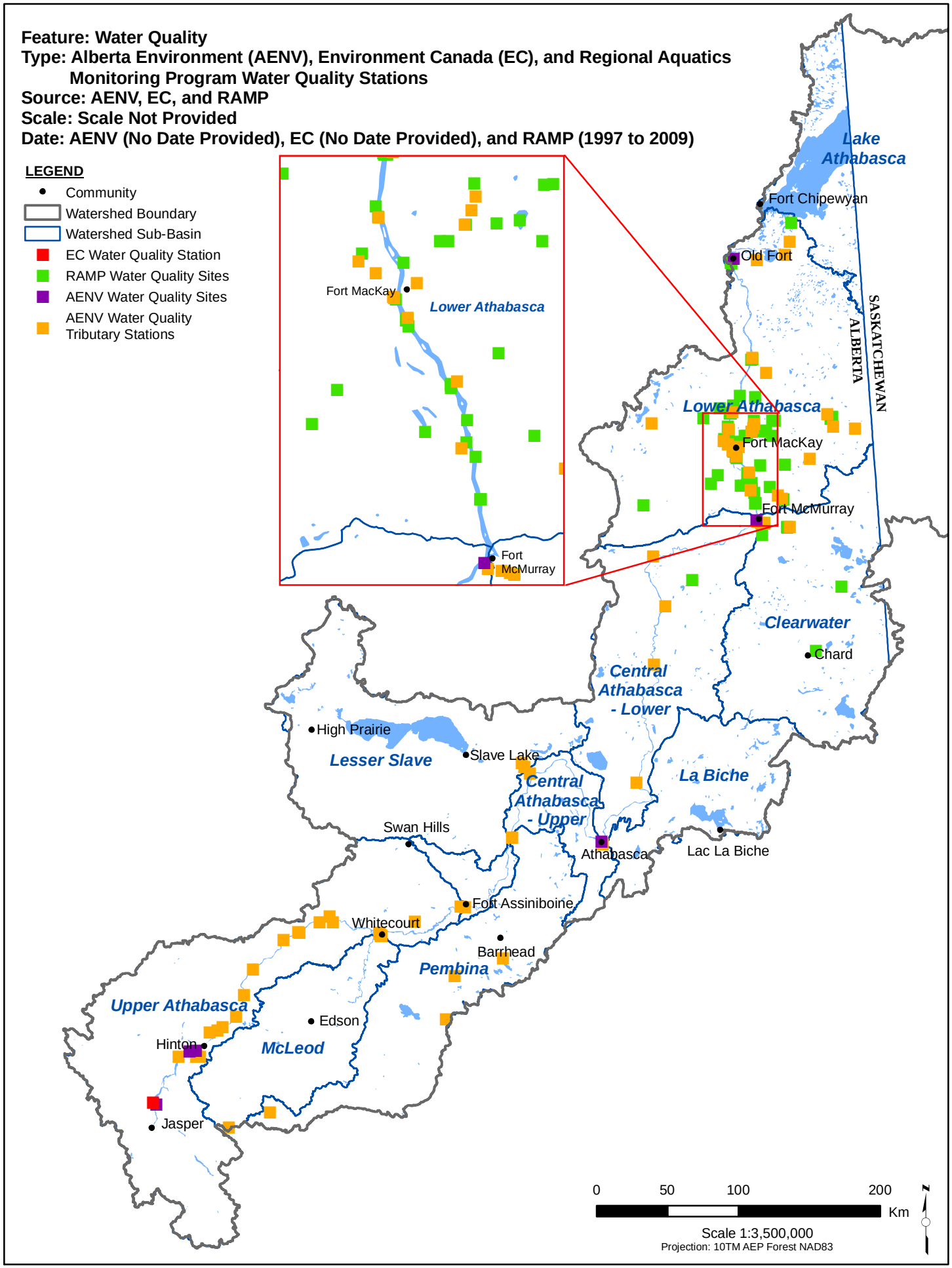
Feature: Water Quality
Type: Alberta Environment (AENV), Environment Canada (EC), and Regional Aquatics Monitoring Program Water Quality Stations
Source: AENV, EC, and RAMP
Scale: Scale Not Provided
Date: AENV (No Date Provided), EC (No Date Provided), and RAMP (1997 to 2009)



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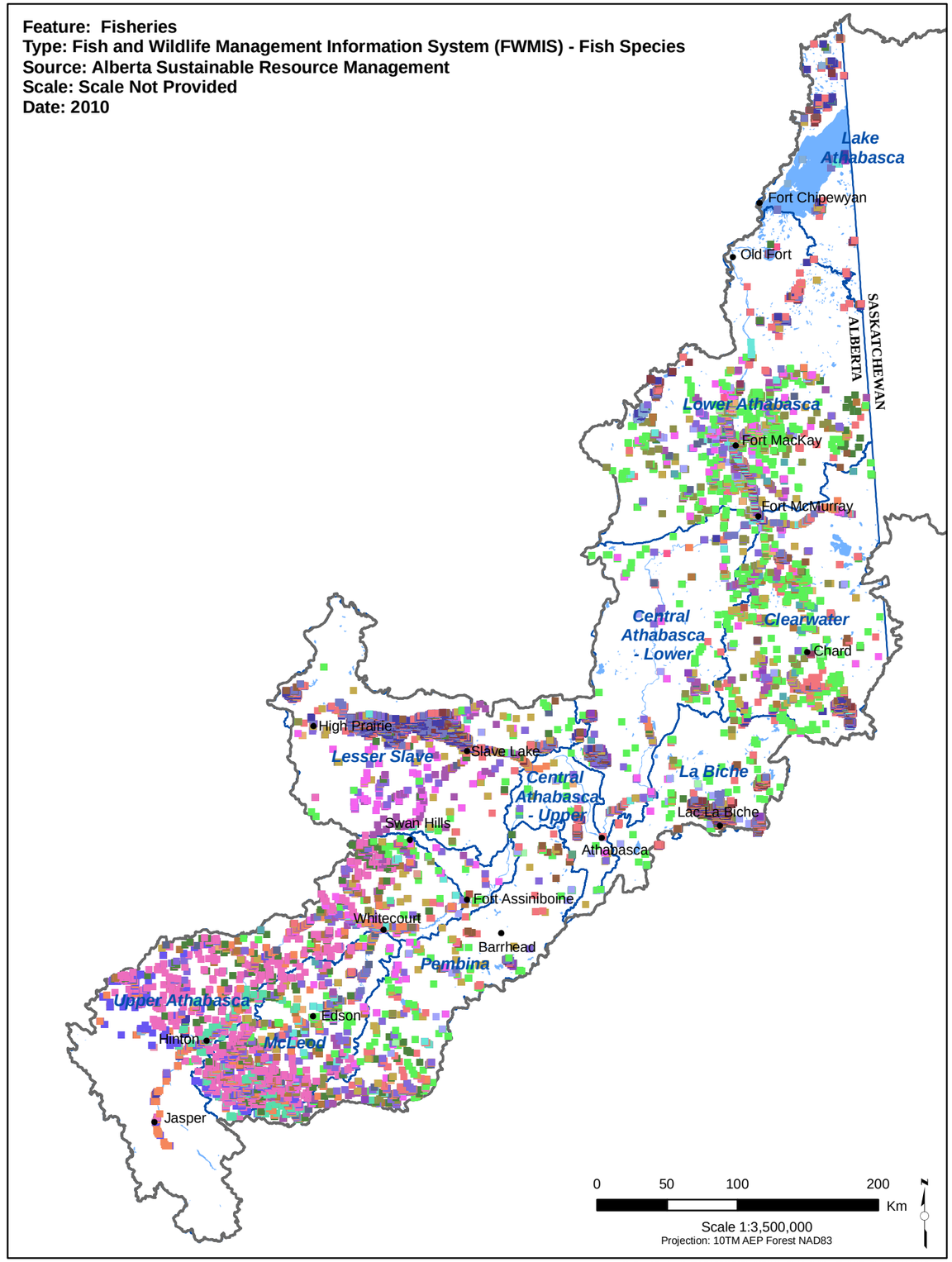
Feature: Fisheries
Type: Fish and Wildlife Management Information System (FWMIS) - Fish Species
Source: Alberta Sustainable Resource Management
Scale: Scale Not Provided
Date: 2010



K:\Data\Project\WPAC1650\GIS\MXD\H1_FishWildlife_FWMIS_Fish_20110218.mxd

LEGEND

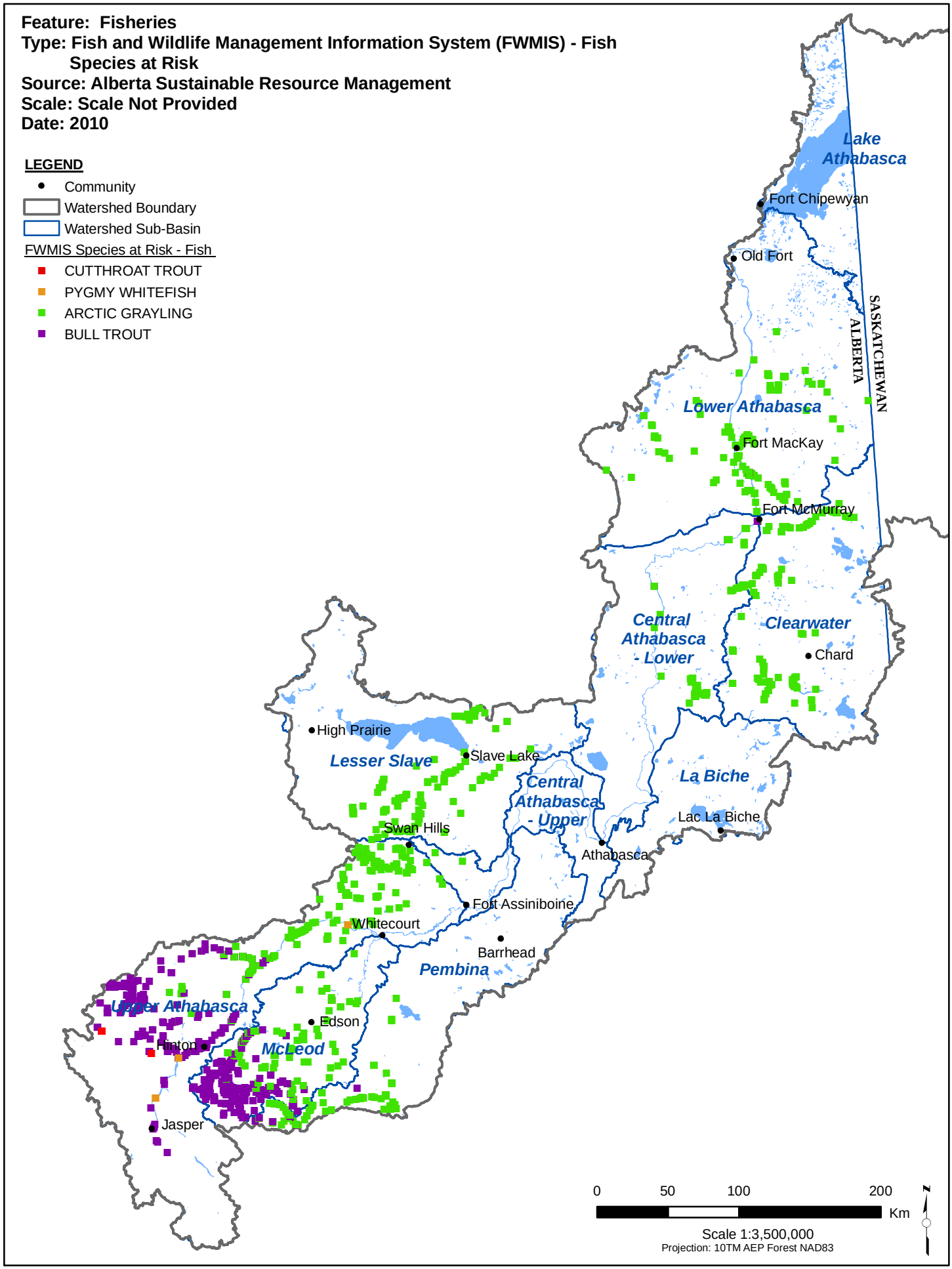
- Community
- Watershed Boundary
- Watershed Sub-Basin

FWMIS Fish Species

- ARCTIC GRAYLING
- ARCTIC GRAYLING (BELLY POPLN)
- BRASSY MINNOW
- BROOK STICKLEBACK
- BROOK TROUT
- BROWN TROUT
- BULL TROUT
- BULL TROUT X BROOK TROUT HYBRID
- BURBOT
- CUTTHROAT TROUT
- EMERALD SHINER
- FATHEAD MINNOW
- FINESCALE DACE
- FLATHEAD CHUB
- GOLDEYE
- IOWA DARTER
- KOKANEE
- LAKE CHUB
- LAKE TROUT
- LAKE WHITEFISH
- LOGPERCH
- LONGNOSE DACE
- LONGNOSE SUCKER
- MOUNTAIN WHITEFISH
- NINESPINE STICKLEBACK
- NORTHERN PIKE
- NORTHERN PIKEMINNOW
- NORTHERN REDBELLY DACE
- NORTHERN REDBELLY DACE X FINESCALE DACE
- PEARL DACE
- PYGMY WHITEFISH
- RAINBOW TROUT
- RIVER SHINER
- ROUND WHITEFISH
- SLIMY SCULPIN
- SPOONHEAD SCULPIN
- SPOTTAIL SHINER
- TROUT-PERCH
- TULLIBEE (CISCO)
- WALLEYE
- WHITE SUCKER
- YELLOW PERCH

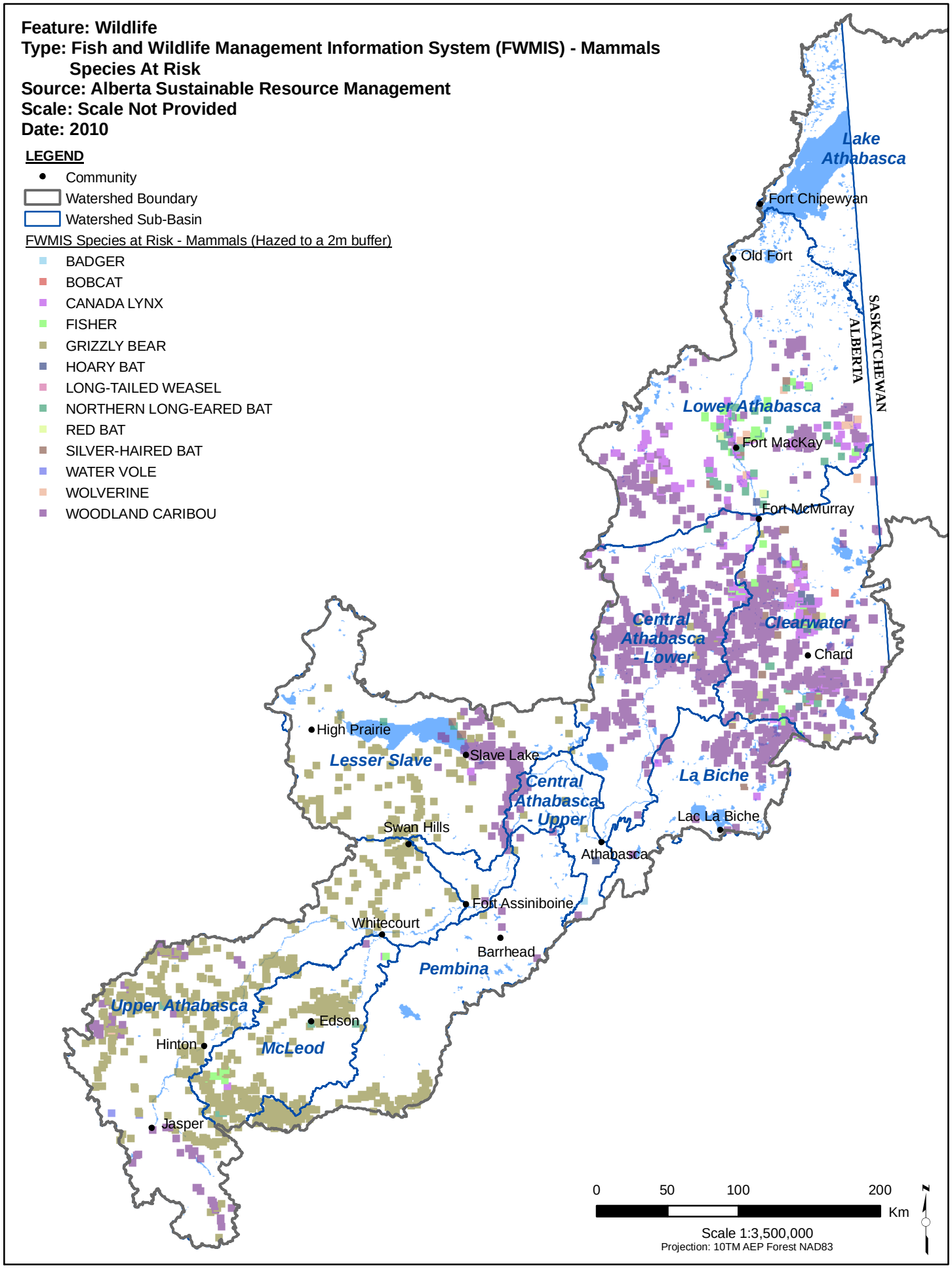
Note: "Unknown" and "n/a" data sets are not displayed.

Feature: Fisheries
Type: Fish and Wildlife Management Information System (FWMIS) - Fish Species at Risk
Source: Alberta Sustainable Resource Management
Scale: Scale Not Provided
Date: 2010



K:\Data\Project\WPAC1650\GIS\MXD\H2_FishWildlife_FWMIS_FishSAR_20110218.mxd

Feature: Wildlife
Type: Fish and Wildlife Management Information System (FWMIS) - Mammals Species At Risk
Source: Alberta Sustainable Resource Management
Scale: Scale Not Provided
Date: 2010



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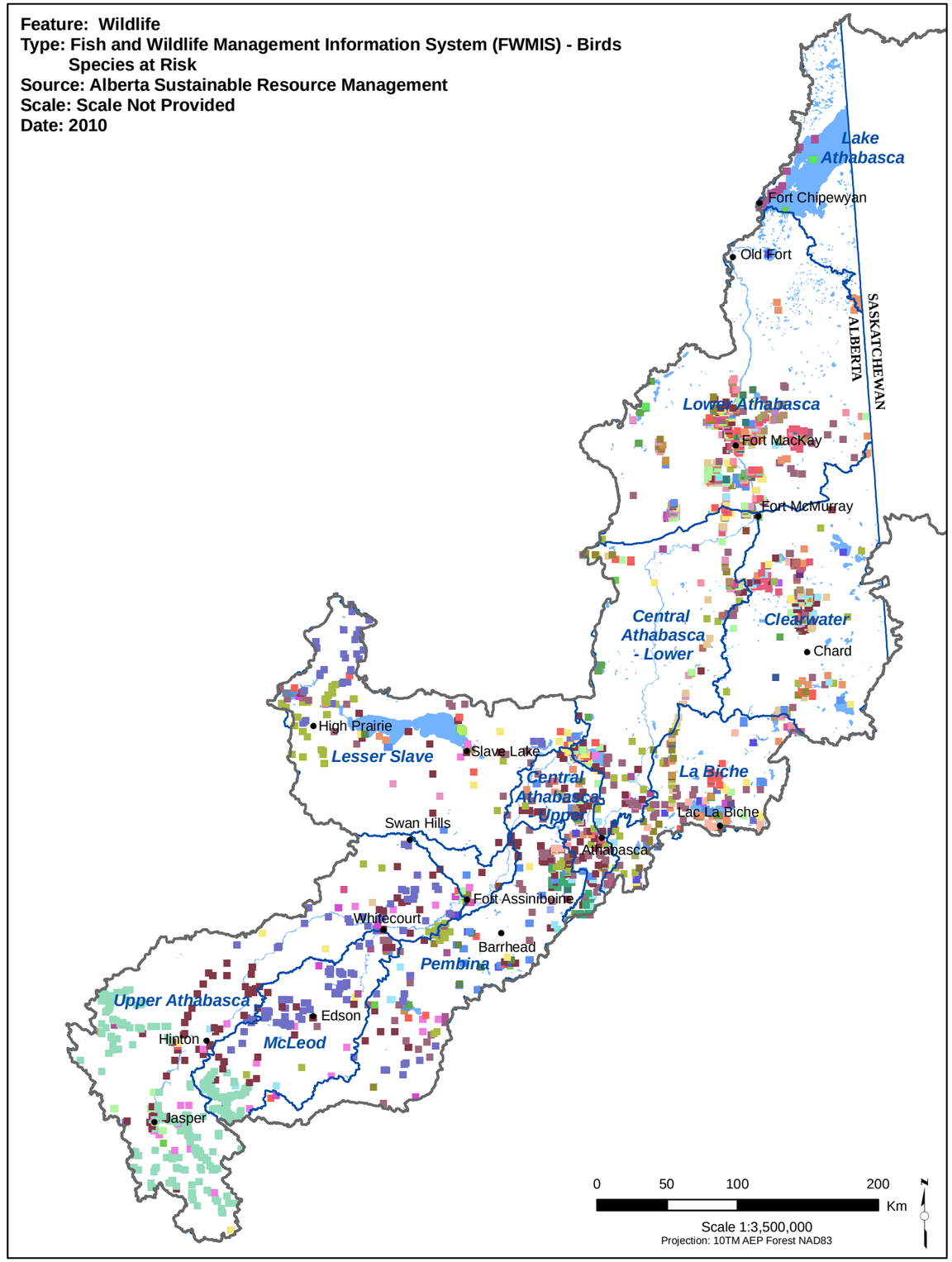
Feature: Wildlife
Type: Fish and Wildlife Management Information System (FWMIS) - Birds Species at Risk
Source: Alberta Sustainable Resource Management
Scale: Scale Not Provided
Date: 2010



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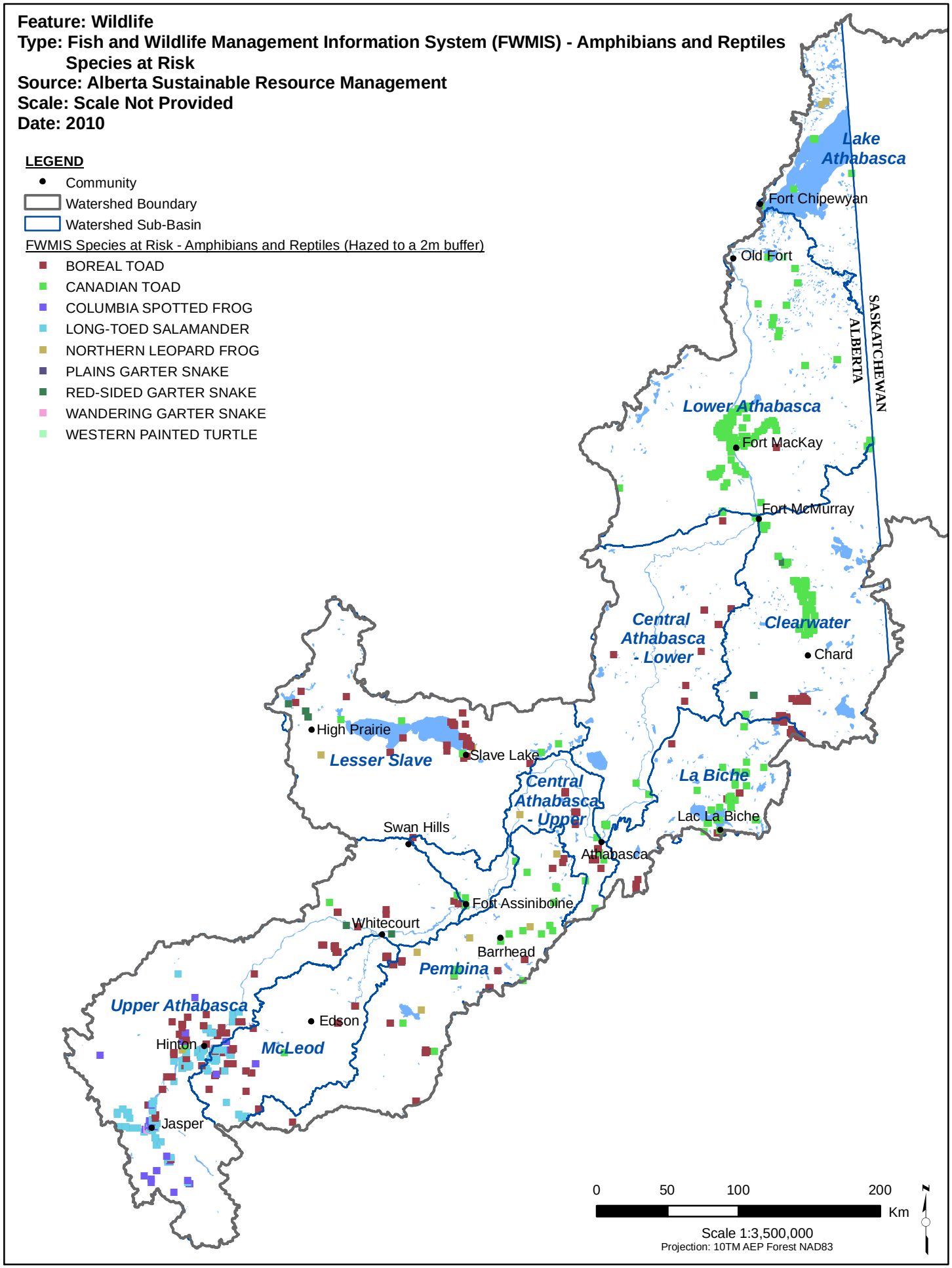
LEGEND

- Community
- Watershed Boundary
- Watershed Sub-Basin

FWMIS Speciesat Risk - Birds (Hazed to a 2m buffer)

- AMERICAN BITTERN
- AMERICAN WHITE PELICAN
- BALD EAGLE
- BARN SWALLOW
- BARRED OWL
- BAY-BREASTED WARBLER
- BLACK TERN
- BLACK-BACKED WOODPECKER
- BLACK-THROATED GREEN WARBLER
- BLACKBURNIAN WARBLER
- BOBOLINK
- BROAD-WINGED HAWK
- BROWN CREEPER
- CANADA WARBLER
- CAPE MAY WARBLER
- CASPIAN TERN
- COMMON NIGHTHAWK
- COMMON YELLOWTHROAT
- EASTERN PHOEBE
- FORSTER'S TERN
- GOLDEN EAGLE
- GREAT BLUE HERON
- GREAT GRAY OWL
- GREEN-WINGED TEAL
- HARLEQUIN DUCK
- HORNED GREBE
- LEAST FLYCATCHER
- LESSER SCAUP
- NORTHERN GOSHAWK
- NORTHERN HARRIER
- NORTHERN PINTAIL
- NORTHERN PYGMY-OWL
- OSPREY
- PEREGRINE FALCON
- PIED-BILLED GREBE
- PILEATED WOODPECKER
- PIPING PLOVER
- PURPLE MARTIN
- RUSTY BLACKBIRD
- SANDHILL CRANE
- SEDGE WREN
- SHARP-TAILED GROUSE
- SHORT-EARED OWL
- SORA
- SWAINSON'S HAWK
- TRUMPETER SWAN
- UPLAND SANDPIPER
- WESTERN GREBE
- WESTERN TANAGER
- WHITE-WINGED SCOTER
- WHOOPING CRANE

Feature: Wildlife
Type: Fish and Wildlife Management Information System (FWMIS) - Amphibians and Reptiles Species at Risk
Source: Alberta Sustainable Resource Management
Scale: Scale Not Provided
Date: 2010



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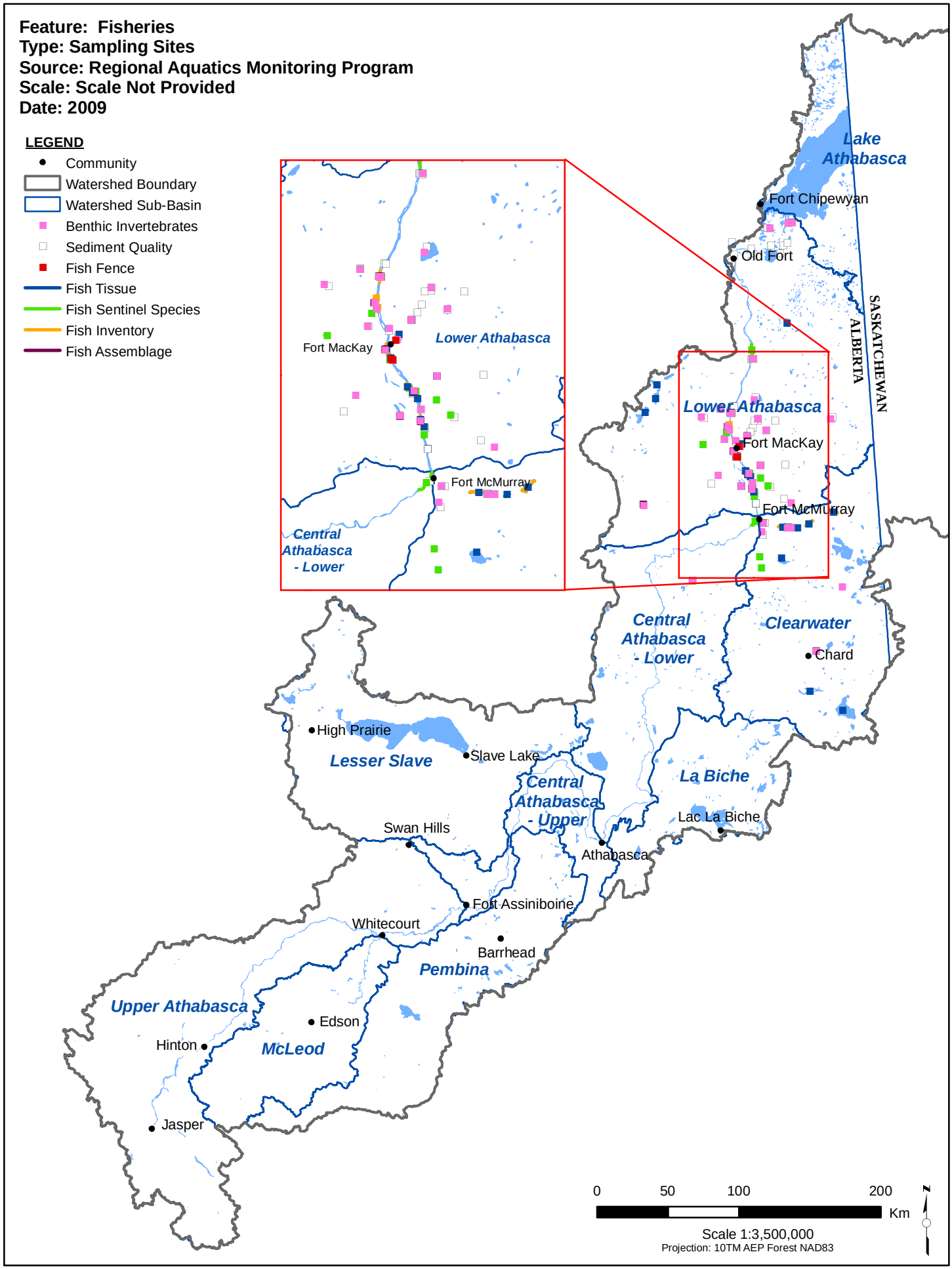
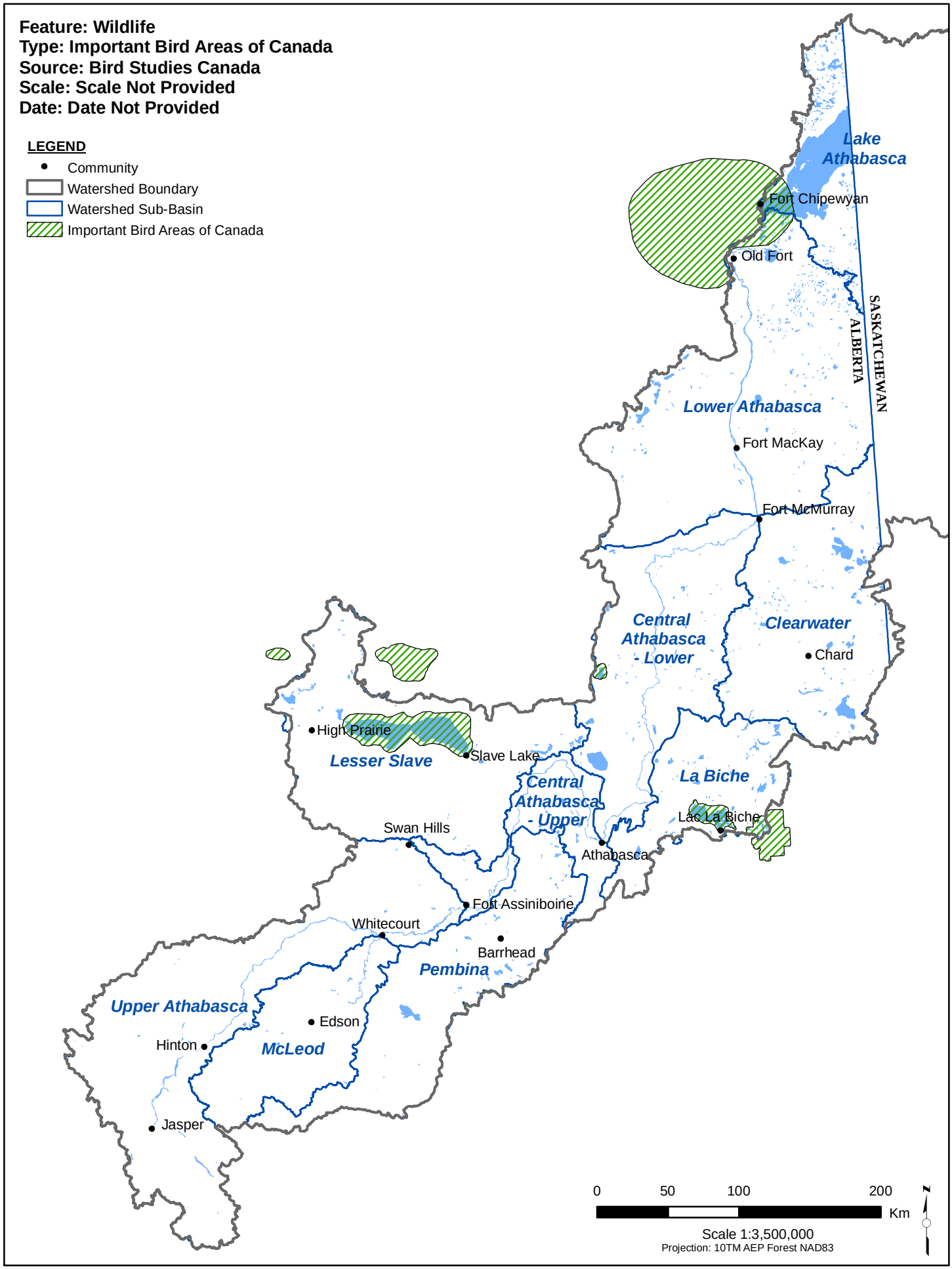
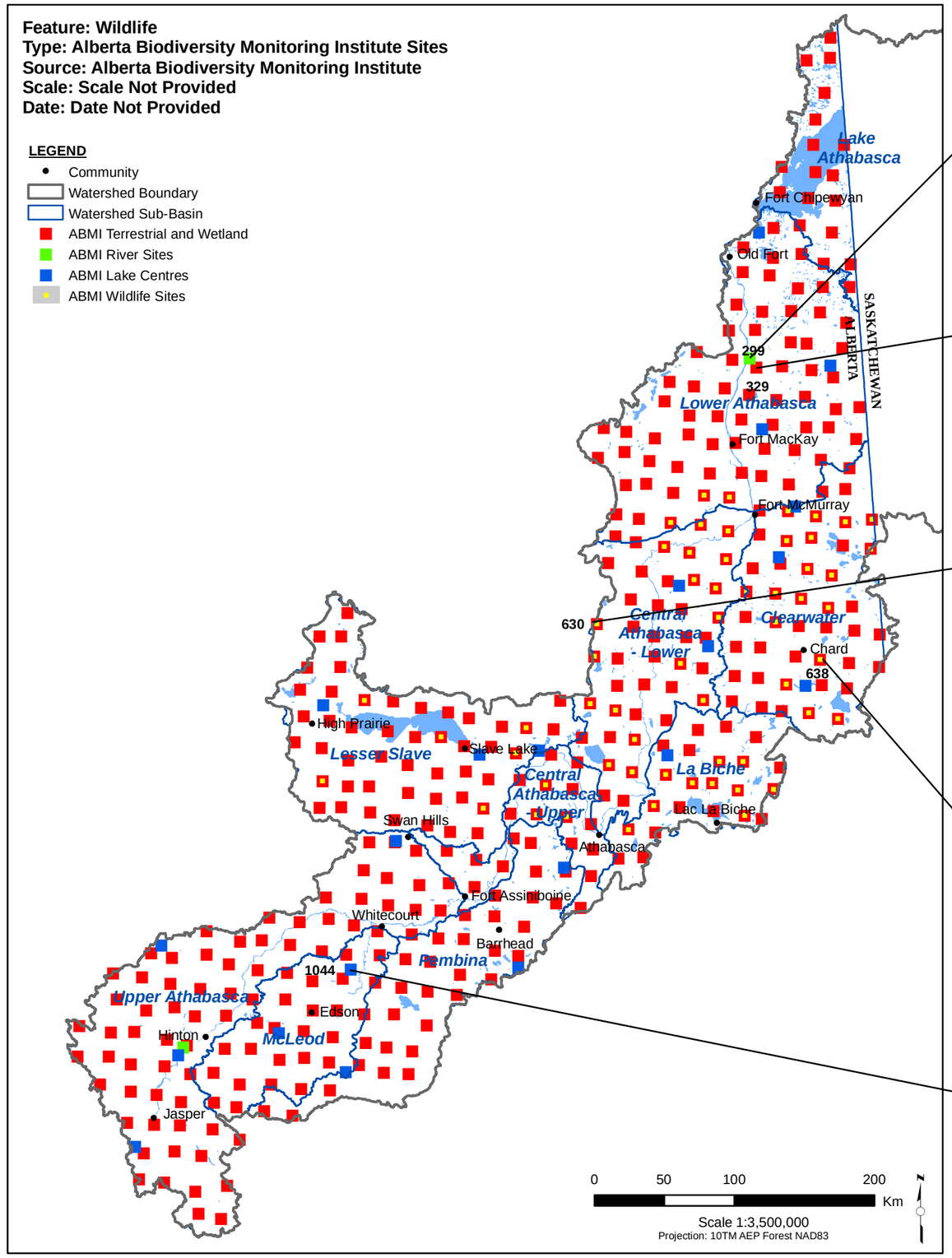

Feature: Fisheries
Type: Sampling Sites
Source: Regional Aquatics Monitoring Program
Scale: Scale Not Provided
Date: 2009
LEGEND
Community
Watershed Boundary
Watershed Sub-Basin
Benthic Invertebrates
Sediment Quality
Fish Fence
Fish Tissue
Fish Sentinel Species
Fish Inventory
Fish Assemblage
Lake Athabasca
Fort Chipewyan
Old Fort
SASKATCHEWAN
ALBERTA
Lower Athabasca
Fort MacKay
Fort McMurray
Central Athabasca - Lower
Clearwater
Chard
High Prairie
Lesser Slave
Slave Lake
Central Athabasca - Upper
La Biche
Lac La Biche
Swan Hills
Athabasca
Fort Assiniboine
Whitecourt
Barrhead
Pembina
Upper Athabasca
Edson
Hinton
McLeod
Jasper
0
50
100
200
Km
Scale 1:3,500,000
Projection: 10TM AEP Forest NAD83
K:\Data\Project\WPAC1650\GIS\MXD\H6_FishWildlife_Sites_RAMP_20110221.mxd


Feature: Wildlife
Type: Important Bird Areas of Canada
Source: Bird Studies Canada
Scale: Scale Not Provided
Date: Date Not Provided
LEGEND
Community
Watershed Boundary
Watershed Sub-Basin
Important Bird Areas of Canada
Lake Athabasca
Fort Chipewyan
Old Fort
ALBERTA
SASKATCHEWAN
Lower Athabasca
Fort MacKay
Fort McMurray
Central Athabasca - Lower
Clearwater
Chard
High Prairie
Lesser Slave
Slave Lake
Central Athabasca - Upper
La Biche
Lac La Biche
Swan Hills
Athabasca
Fort Assiniboine
Whitecourt
Barrhead
Pembina
Upper Athabasca
Edson
Hinton
McLeod
Jasper
0
50
100
200
Km
Scale 1:3,500,000
Projection: 10TM AEP Forest NAD83
K:\Data\Project\WPAC1650\GIS\MXD\H7_FishWildlife_ImportantBirdAreas_20110221.mxd

Feature: Wildlife
Type: Alberta Biodiversity Monitoring Institute Sites
Source: Alberta Biodiversity Monitoring Institute
Scale: Scale Not Provided
Date: Date Not Provided



Example Datasets

River Species - Fish Tally

ABMI Site	Year	Field Date	Field Crew Member(s)	Common Name	Scientific Name	Taxonomic Resolution	Unique Taxonomic Identification Number	Transect 1-2	Transect 2-3	Transect 3-4	Transect 4-5	Transect 5-6	Total	Released	Died	Voucher Specimen
299	2008	18-Jul-08	CJ/CL/KM	Northern Pike	Esox lucius	Species	162139	0	3	0	4	2	9	8	1	1
299	2008	18-Jul-08	CJ/CL/KM	Walleye	Sander vitreus	Species	650173	1	0	0	2	1	4	3	0	1
299	2008	18-Jul-08	CJ/CL/KM	Burbot	Lota lota	Species	164725	0	0	0	0	2	2	1	0	1
299	2008	18-Jul-08	CJ/CL/KM	Emerald Shiner	Notropis atherinoides	Species	163412	0	0	0	3	0	3	2	2	1
299	2008	18-Jul-08	CJ/CL/KM	Pearl Dace	Margariscus margarita	Species	163873	0	3	0	0	5	8	7	0	1
299	2008	18-Jul-08	CJ/CL/KM	Goldeye	Hiodon alosoides	Species	161905	0	0	0	2	0	2	1	0	1
299	2008	18-Jul-08	CJ/CL/KM	Longnose Sucker	Catostomus catostomus	Species	163894	1	0	0	1	0	2	1	0	1
299	2008	18-Jul-08	CJ/CL/KM	White Sucker	Catostomus commersonii	Species	553273	1	3	1	3	1	9	8	0	1
299	2008	18-Jul-08	CJ/CL/KM	Spottail Shiner	Notropis hudsonius	Species	163404	0	0	0	7	0	7	6	5	1
299	2008	18-Jul-08	CJ/CL/KM	Trout-perch	Percopsis omiscomaycus	Species	164409	2	5	3	22	4	36	35	5	1
299	2008	18-Jul-08	CJ/CL/KM	Lake Whitefish	Coregonus clupeaformis	Species	161941	0	1	6	0	0	7	5	5	2

Wetland Species - Vascular Plants

ABMI Site	Field Date	Field Crew Member(s)	Zone	Transect	Common Name	Scientific Name	Unique Taxonomic Identification Number
329	20-Jul-07	ENO	Emergent	Transect 1	Water Parsnip	Sium suave	29558
329	20-Jul-07	ENO	Emergent	Transect 1	VNA	Utricularia macrorhiza	34456
329	20-Jul-07	ENO	Emergent	Transect 1	Broad-leaved Water-plantain	Alisma plantago-aquatica	38894
329	20-Jul-07	ENO	Emergent	Transect 1	Creeping Spike-rush	Eleocharis palustris	40019
329	20-Jul-07	ENO	Emergent	Transect 1	Bluejoint	Calamagrostis canadensis	40544
329	20-Jul-07	ENO	Emergent	Transect 1	Giant Bur-reed	Sparganium eurycarpum	42316
329	20-Jul-07	ENO	Emergent	Transect 1	Common Cattail	Typha latifolia	42326
329	20-Jul-07	ENO	Emergent	Transect 1	Common Duckweed	Lemna minor	42590
329	20-Jul-07	ENO	Emergent	Transect 1	Larger Duckweed	Spirodela polyrhiza	42599
329	20-Jul-07	ENO	Emergent	Transect 1	VNA	Callitriche palustris	501143
329	20-Jul-07	ENO	Emergent	Transect 1	VNA	Polygonum amphibium var. emersum	529773

Terrestrial Species - Other Vertebrates

ABMI Site	Year	Observer Effort (Time/site/person)	1 hectare / 36 hectares	Common Name	Scientific Name	Unique Taxonomic Identification Number	Type of Observation
630	2003	05:10-10:00	1	Moose	Alces alces	180703	Scat
630	2003	05:10-10:00	1	Great Gray Owl	Strix nebulosa	177929	Nest
630	2003	10:00-14:30	1	Black Bear	Ursus americanus	180544	Scat
630	2003	05:15-10:00	36	Black Bear	Ursus americanus	180544	Other
630	2003	05:15-10:00	36	Deer	Odocoileus	180697	Scat
630	2003	05:15-10:00	36	Grouse, Pheasants and Allies	Phasianidae	175861	Scat
630	2003	05:15-10:00	36	Marten	Martes americana	180559	Scat
630	2003	05:15-10:00	36	Red Squirrel	Tamiasciurus hudsonicus	180166	Other
630	2003	05:15-10:00	36	Pileated Woodpecker	Dryocopus pileatus	178166	Other
630	2003	05:15-10:00	36	Moose	Alces alces	180703	Scat
630	2003	10:00-14:00	1	Wood Frog	Rana sylvatica	173440	Observed
630	2003	05:15-10:00	36	Porcupine	Erethizon dorsatum	180393	Other
630	2003	05:10-10:00	1	Red Squirrel	Tamiasciurus hudsonicus	180166	Other

Terrestrial Species - Breeding Birds

ABMI Site	Year	Common Name	Scientific Name	Unique Taxonomic Identification Number	Average Number of Detections per Point Count Station
638	2003	Greater Yellowlegs	Tringa melanoleuca	176619	0.22
638	2003	Hermit Thrush	Catharus guttatus	179779	0.67
638	2003	Red-eyed Vireo	Vireo olivaceus	179021	0.11
638	2003	Black-capped Chickadee	Poecile atricapillus	554382	0.22
638	2003	Swainson's Thrush	Catharus ustulatus	179788	0.11
638	2003	Olive-sided Flycatcher	Contopus cooperi	554221	0.11
638	2003	Gray Jay	Perisoreus canadensis	179667	0.33
638	2003	Magnolia Warbler	Dendroica magnolia	178886	0.11
638	2003	American Redstart	Setophaga ruticilla	178979	0.11
638	2003	Alder Flycatcher	Empidonax alnorum	178340	2.22

Lake Species - Minnow Seine Fish

ABMI Site	Year	Field Date	Field Crew Member(s)	Common Name	Scientific Name	Unique Taxonomic Identification Number	Fork Length (millimetres)	Weight (gram)	Sex	Maturity	Injuries or Deformities
1044	2007	16-Aug-07	JM/NC	Yellow Perch	Perca flavescens	168469	122	16	Unknown	Unknown	none
1044	2007	16-Aug-07	JM/NC	Yellow Perch	Perca flavescens	168469	123	27	Unknown	Unknown	none
1044	2007	16-Aug-07	JM/NC	Spottail Shiner	Notropis hudsonius	163404	25	DNC	Unknown	Unknown	none
1044	2007	16-Aug-07	JM/NC	Spottail Shiner	Notropis hudsonius	163404	33	DNC	Unknown	Unknown	none
1044	2007	16-Aug-07	JM/NC	Spottail Shiner	Notropis hudsonius	163404	26	DNC	Unknown	Unknown	none
1044	2007	16-Aug-07	JM/NC	Spottail Shiner	Notropis hudsonius	163404	34	DNC	Unknown	Unknown	none
1044	2007	16-Aug-07	JM/NC	White Sucker	Catostomus commersonii	553273	509	DNC	Female	Mature	none
1044	2007	16-Aug-07	JM/NC	Spottail Shiner	Notropis hudsonius	163404	37	DNC	Unknown	Unknown	none
1044	2007	16-Aug-07	JM/NC	Spottail Shiner	Notropis hudsonius	163404	40	DNC	Unknown	Unknown	none
1044	2007	16-Aug-07	JM/NC	Spottail Shiner	Notropis hudsonius	163404	34	DNC	Unknown	Unknown	none
1044	2007	16-Aug-07	JM/NC	Spottail Shiner	Notropis hudsonius	163404	34	DNC	Unknown	Unknown	none
1044	2007	16-Aug-07	JM/NC	Spottail Shiner	Notropis hudsonius	163404	35	DNC	Unknown	Unknown	none
1044	2007	16-Aug-07	JM/NC	Spottail Shiner	Notropis hudsonius	163404	34	DNC	Unknown	Unknown	none

Feature: Wildlife
Type: Alberta Biodiversity Monitoring Institute - Datasets Available
Source: Alberta Biodiversity Monitoring Institute
Scale: Scale Not Provided
Date: Date Not Provided

Terrestrial Species Data	☐ All	☐ All
Breeding Birds	☐ Raw	☐ Compiled
Vascular Plants	☐ Raw	☐ Compiled
Bryophytes	☐ Raw	☐ Compiled
Lichens	☐ Raw	☐ Compiled
Soil Arthropods	☐ Raw	☐ Compiled
Winter Animal Tracking	☐ Raw	☐ Compiled
Other Vertebrates	☐ Raw	☐ Compiled

Wetland Species Data	☐ All	
Fish	☐ Raw	☐ Compiled
Invertebrates	☐ Raw	☐ Compiled
Other Vertebrates	☐ Raw	☐ Compiled
Vascular Plants	☐ Raw	☐ Compiled

River Species Data	☐ All	
Benthic Macroinvertebrate	☐ Raw	☐ Compiled
Benthic Algae	☐ Raw	☐ Compiled
Fish	☐ Raw	☐ Compiled
Other Vertebrates	☐ Raw	☐ Compiled

Lake Species Data	☐ All	
Fish	☐ Raw	☐ Compiled
Vertebrate Survey	☐ Raw	☐ Compiled
Phytoplankton	☐ Raw	☐ Compiled
Zooplankton	☐ Raw	☐ Compiled

Terrestrial Habitat Data	☐ All	☐ All
Trees & Snags	☐ Raw	☐ Compiled
Downed Woody Material	☐ Raw	☐ Compiled
Ground Cover	☐ Raw	☐ Compiled
Soil	☐ Raw	☐ Compiled
Site Disturbance	☐ Raw	☐ Compiled

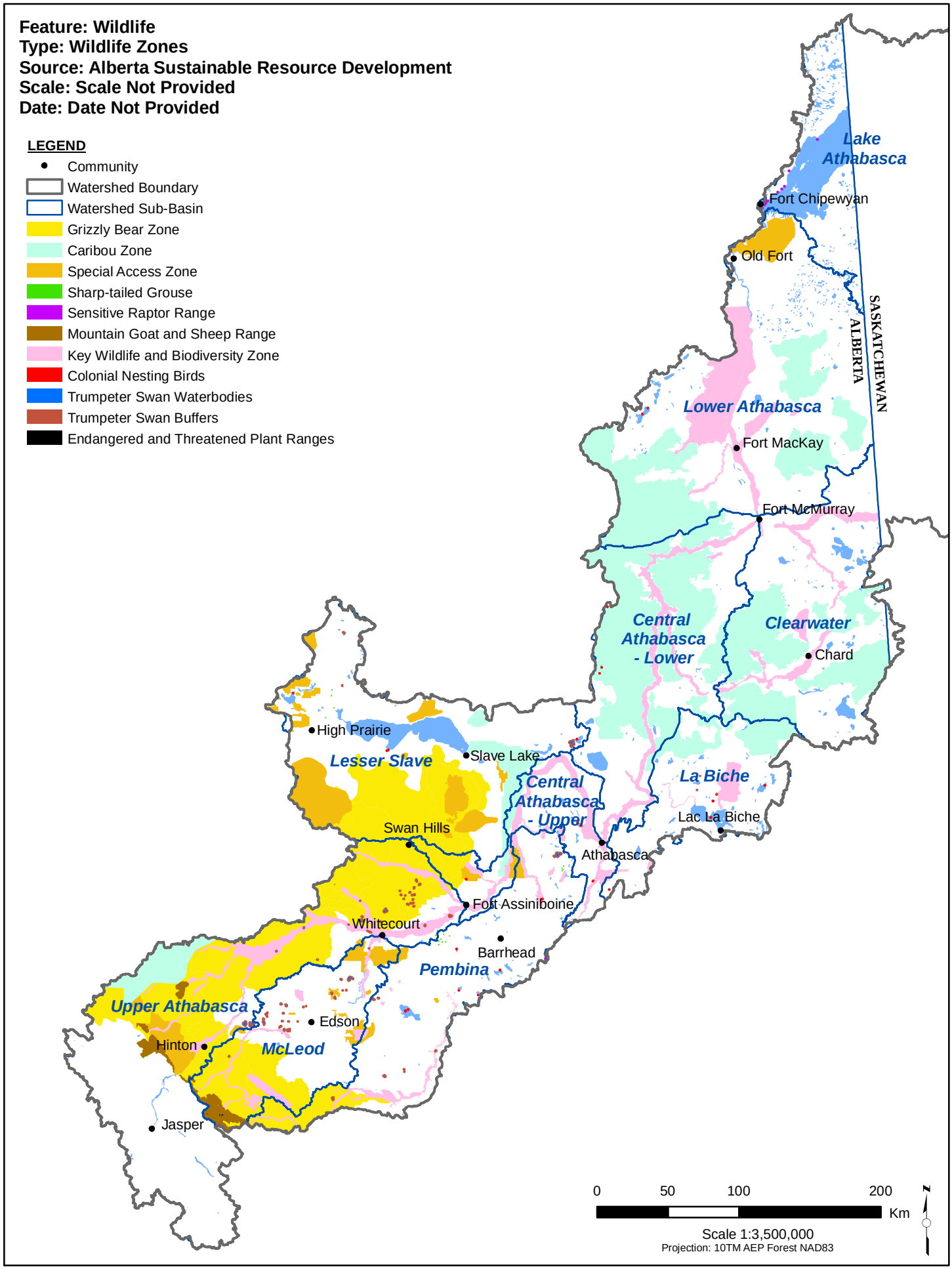
Wetland Habitat Data	☐ All	
Physical Characteristics	☐ Raw	☐ Compiled
Water Physiochemistry	☐ Raw	☐ Compiled
Site Disturbance	☐ Raw	☐ Compiled
Bank Characteristics	☐ Raw	☐ Compiled

River Habitat Data	☐ All	
Physical Characteristics	☐ Raw	☐ Compiled
Bank Characteristics	☐ Raw	☐ Compiled
Site Disturbance	☐ Raw	☐ Compiled
Water Physiochemistry	☐ Raw	☐ Compiled

Lake Habitat Data	☐ All	
Physical Characteristics	☐ Raw	☐ Compiled
Site Disturbance	☐ Raw	☐ Compiled
Water Physiochemistry	☐ Raw	☐ Compiled

Remote Sensing Habitat Data	☐ All	
Human Footprint	☐ Raw	☐ Compiled

Feature: Wildlife
Type: Wildlife Zones
Source: Alberta Sustainable Resource Development
Scale: Scale Not Provided
Date: Date Not Provided



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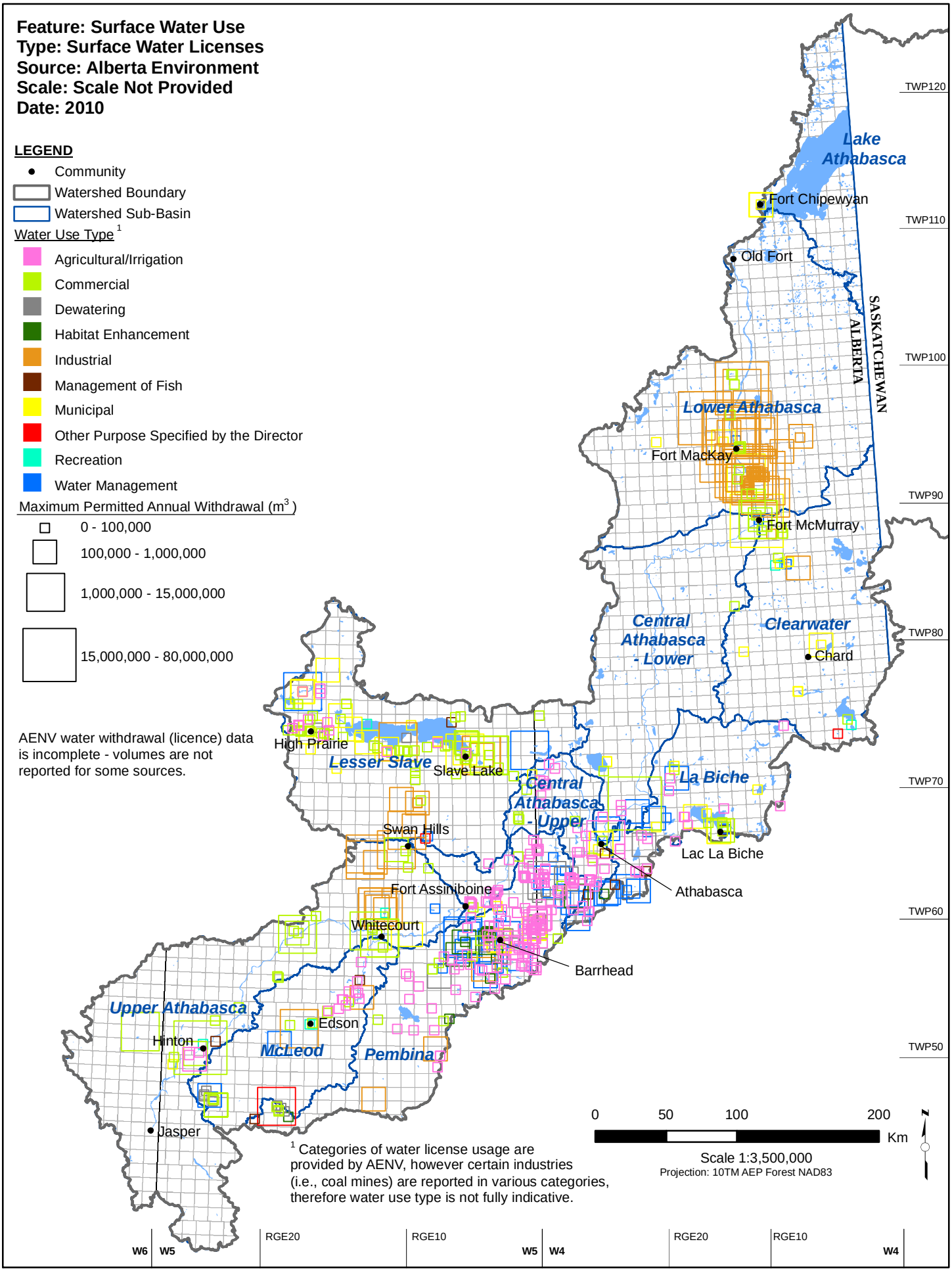
Feature: Surface Water Use
Type: Surface Water Licenses
Source: Alberta Environment
Scale: Scale Not Provided
Date: 2010



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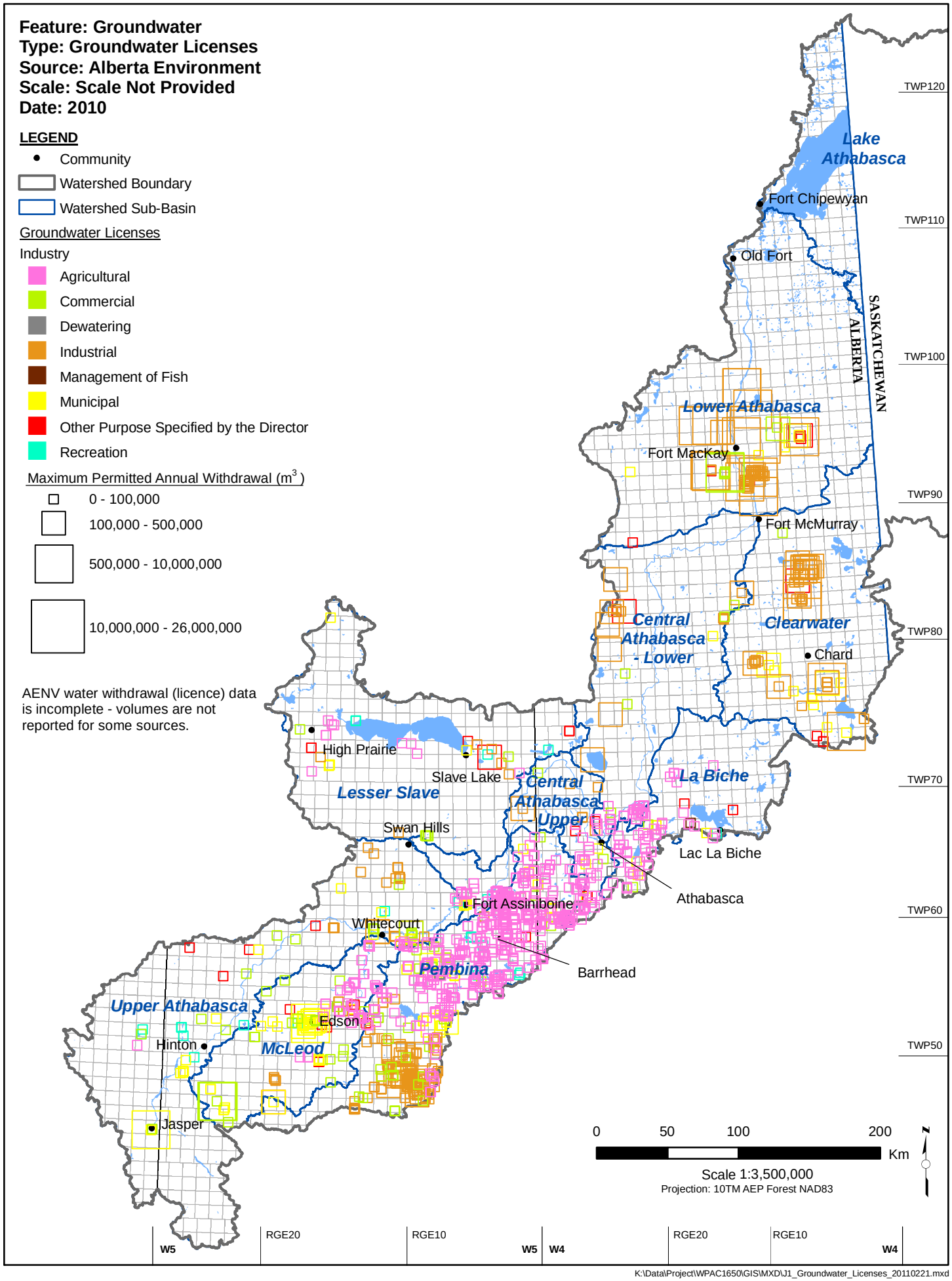
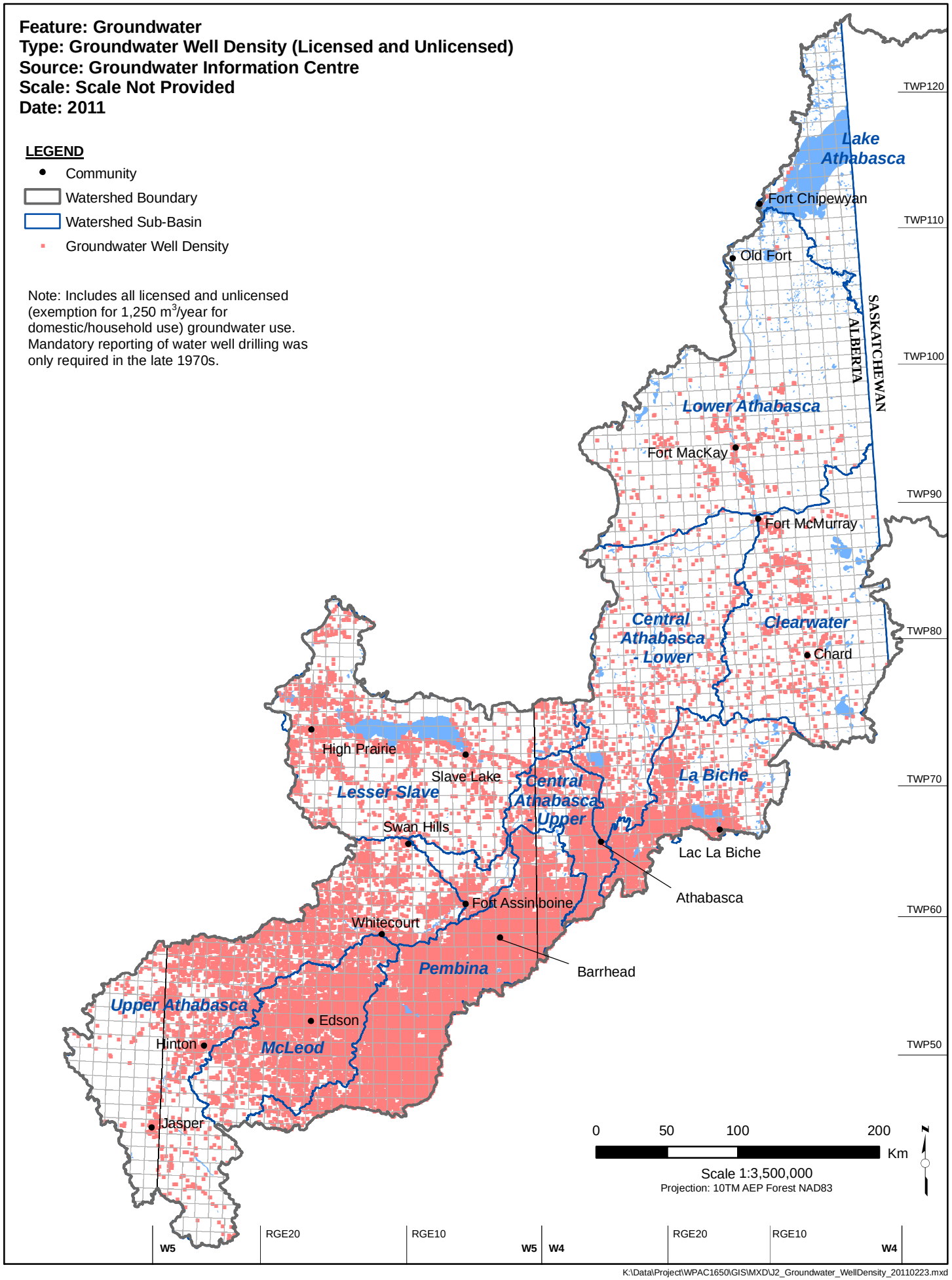

Feature: Groundwater
Type: Groundwater Licenses
Source: Alberta Environment
Scale: Scale Not Provided
Date: 2010
LEGEND
Community
Watershed Boundary
Watershed Sub-Basin
Groundwater Licenses
Industry
Agricultural
Commercial
Dewatering
Industrial
Management of Fish
Municipal
Other Purpose Specified by the Director
Recreation
Maximum Permitted Annual Withdrawal (m3)
0 - 100,000
100,000 - 500,000
500,000 - 10,000,000
10,000,000 - 26,000,000
AENV water withdrawal (licence) data is incomplete - volumes are not reported for some sources.
TWP120
TWP110
TWP100
TWP90
TWP80
TWP70
TWP60
TWP50
Lake Athabasca
Fort Chipewyan
Old Fort
ALBERTA
SASKATCHEWAN
Lower Athabasca
Fort MacKay
Fort McMurray
Central Athabasca - Lower
Clearwater
Chard
La Biche
High Prairie
Slave Lake
Lesser Slave
Central Athabasca - Upper
Swan Hills
Lac La Biche
Athabasca
Fort Assiniboine
Whitecourt
Barrhead
Pembina
Upper Athabasca
Edson
Hinton
McLeod
Jasper
0 50 100 200 Km
Scale 1:3,500,000
Projection: 10TM AEP Forest NAD83
W5 RGE20 RGE10 W5 W4 RGE20 RGE10 W4
K:\Data\Project\WPAC1650\GIS\MXD\J1_Groundwater_Licenses_20110221.mxd

Feature: Groundwater
Type: Groundwater Well Density (Licensed and Unlicensed)
Source: Groundwater Information Centre
Scale: Scale Not Provided
Date: 2011



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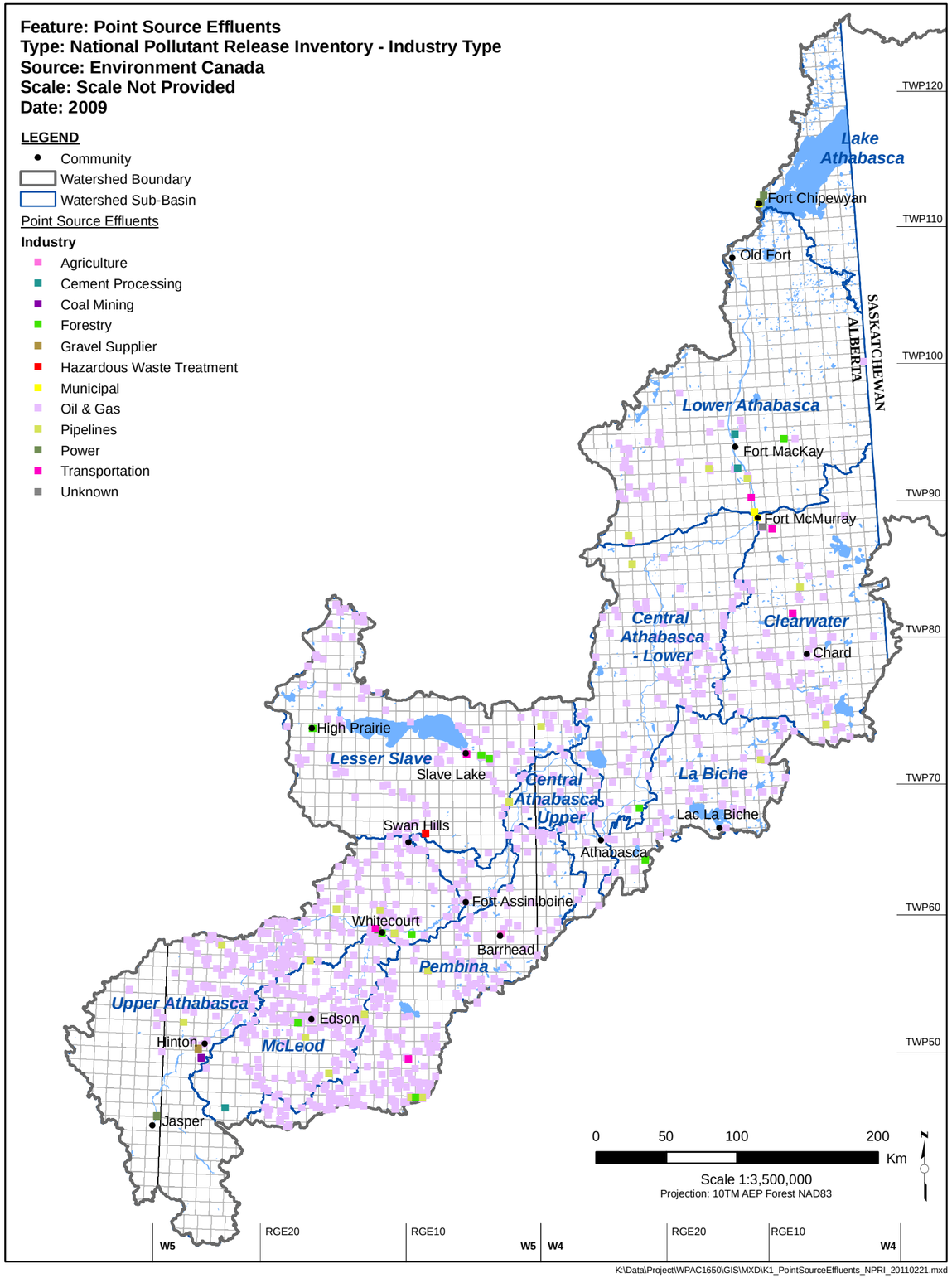
Feature: Point Source Effluents
Type: National Pollutant Release Inventory - Industry Type
Source: Environment Canada
Scale: Scale Not Provided
Date: 2009



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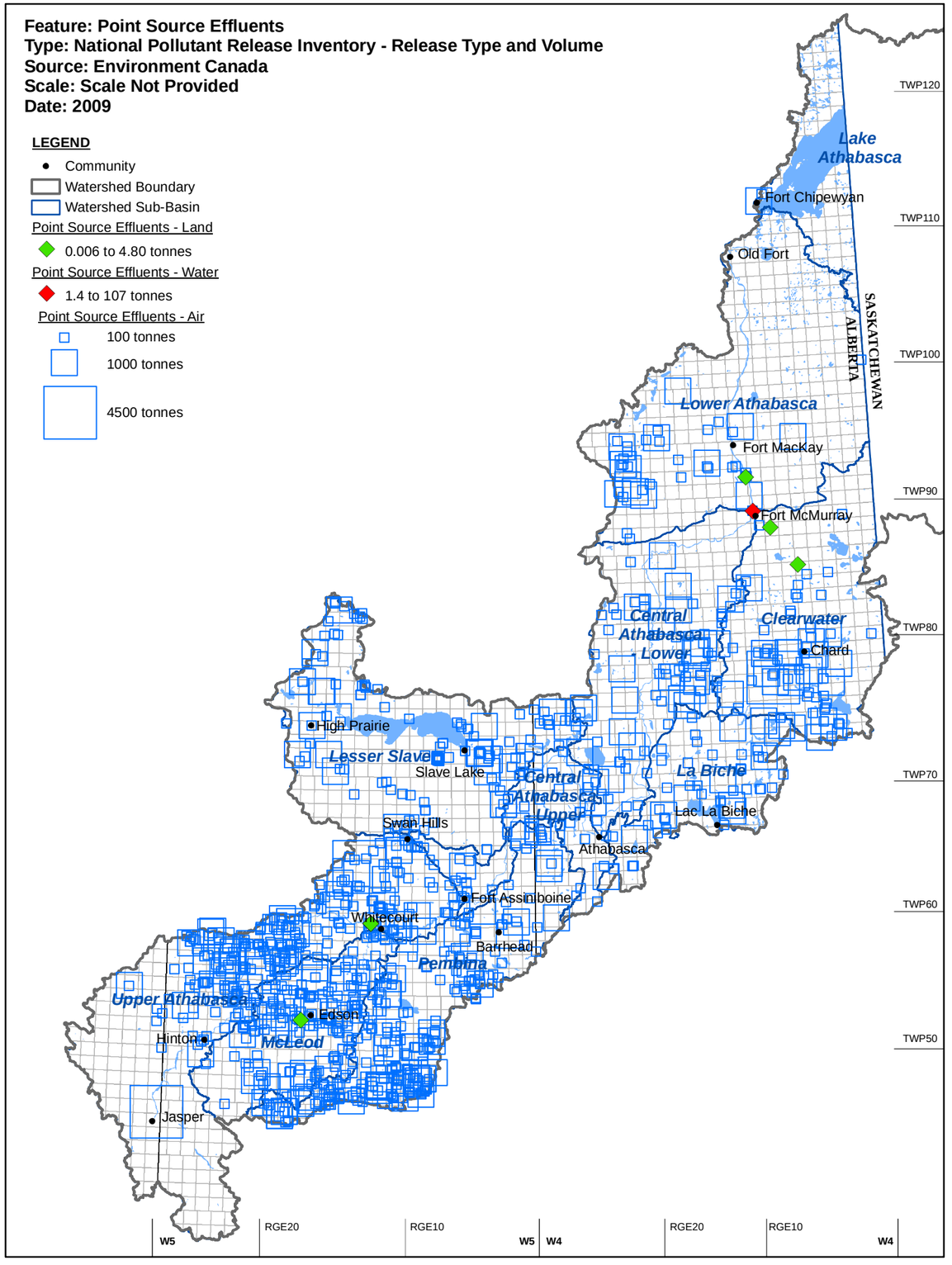
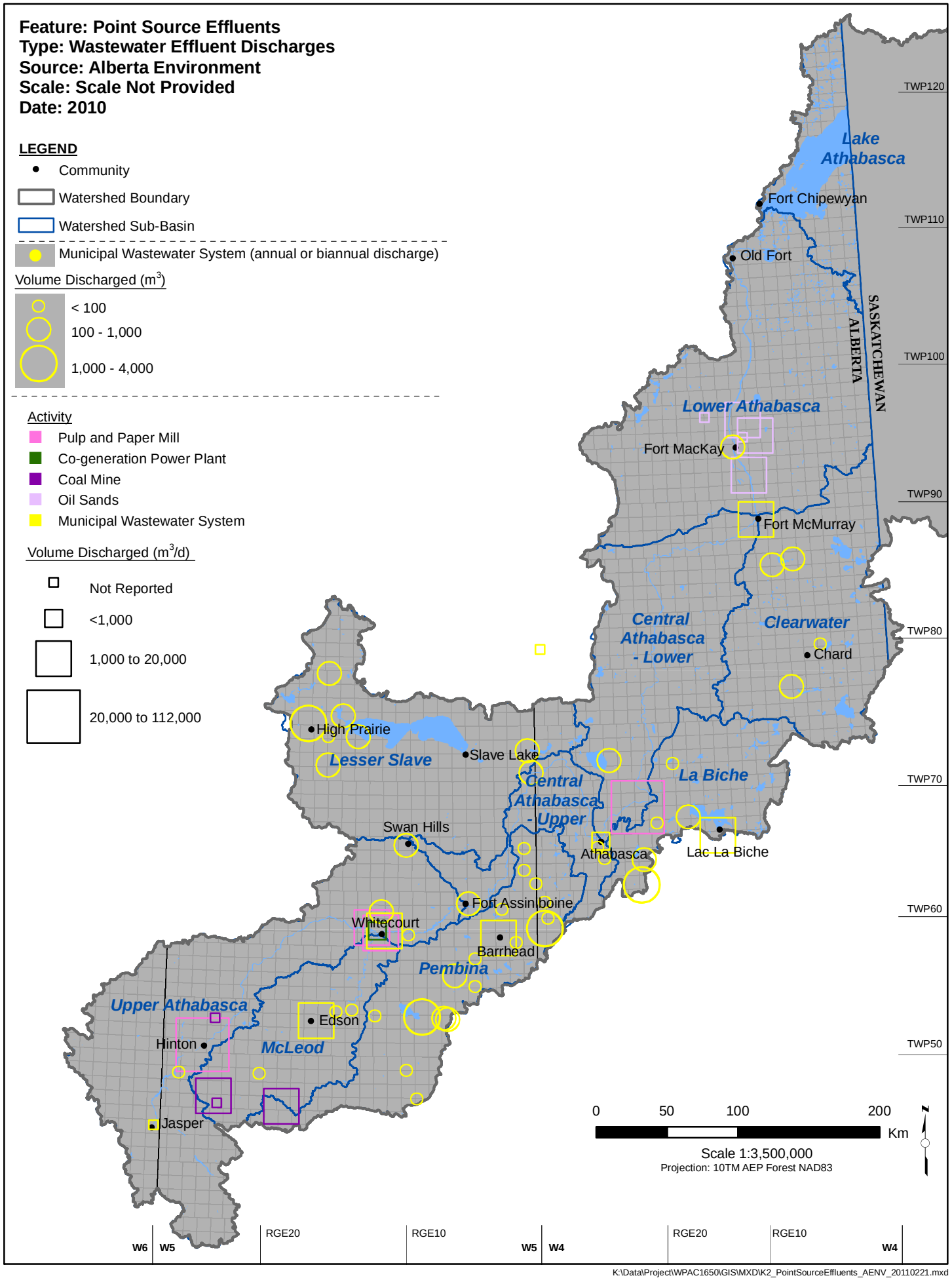
Feature: Point Source Effluents
Type: National Pollutant Release Inventory - Release Type and Volume
Source: Environment Canada
Scale: Scale Not Provided
Date: 2009



Feature: Point Source Effluents
Type: Wastewater Effluent Discharges
Source: Alberta Environment
Scale: Scale Not Provided
Date: 2010



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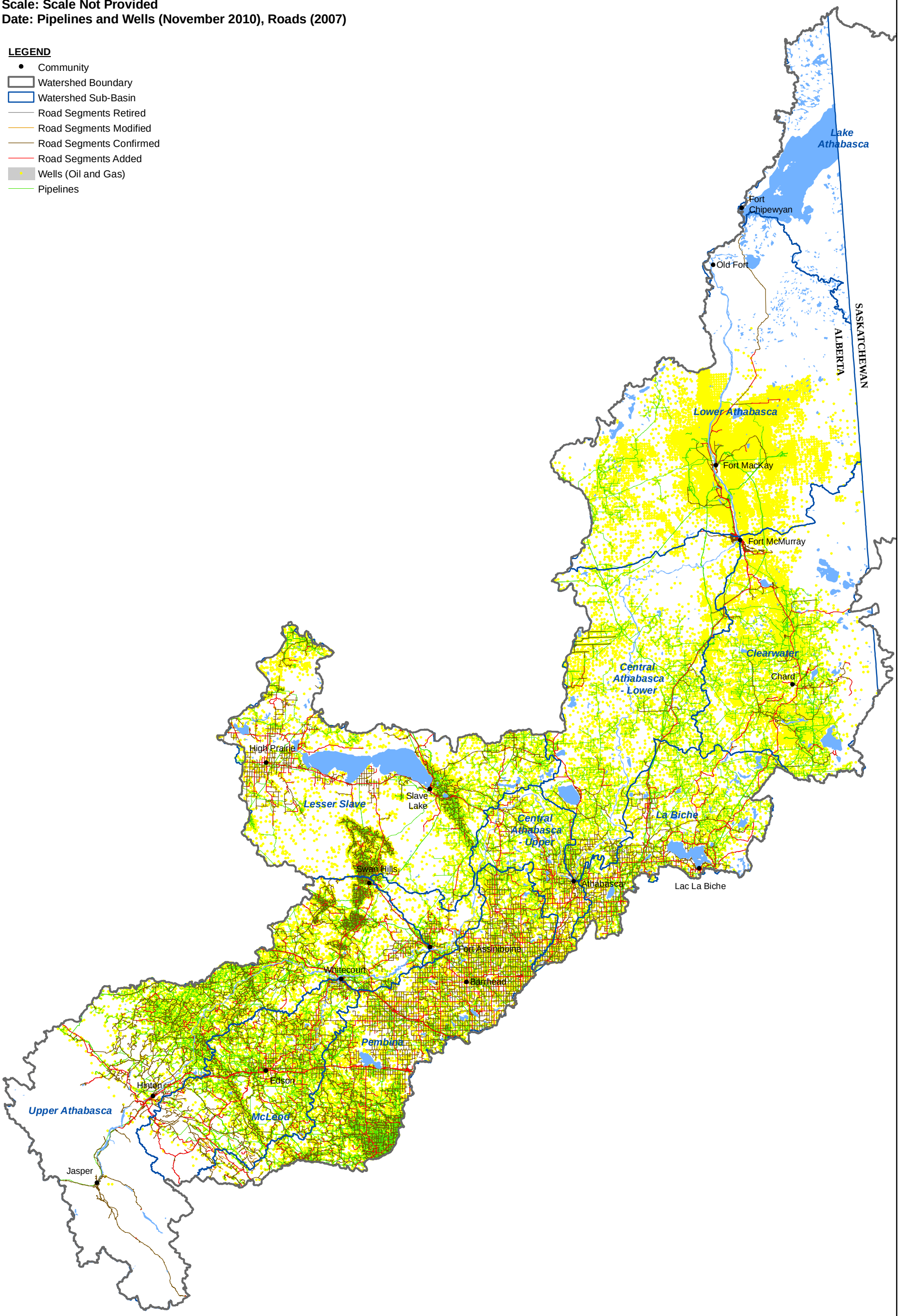
Feature: Land Use Indices - Linear
Type: Pipelines, Wells, and Roads
Source: Energy Resources Conservation Board and Natural Resources Canada
Scale: Scale Not Provided
Date: Pipelines and Wells (November 2010), Roads (2007)

LEGEND

- Community
- Watershed Boundary
- Watershed Sub-Basin
- Road Segments Retired
- Road Segments Modified
- Road Segments Confirmed
- Road Segments Added
- Wells (Oil and Gas)
- Pipelines



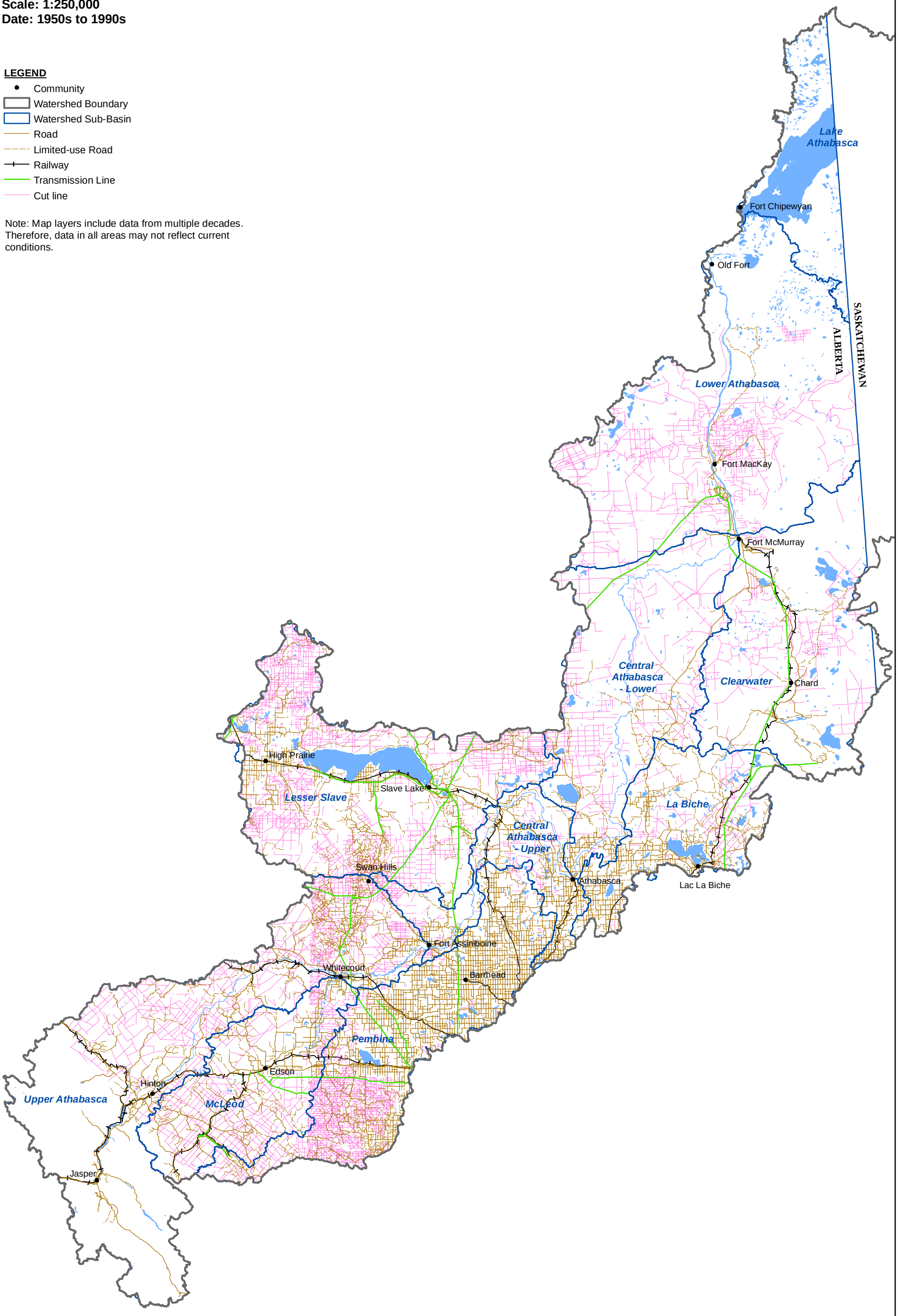
K:\Data\Project\WPAC1650\GIS\MXD\L1_LandUseIndicesLinear_PipelinesWellsRoads_ERCBNRCan_20110121.mxd

Feature: Land Use Indices - Linear
Type: National Topographic Database - Road, Limited-use Road, Transmission Line, Cut line, and Railway
Source:Natural Resources Canada
Scale: 1:250,000
Date: 1950s to 1990s

LEGEND

- Community
- Watershed Boundary
- Watershed Sub-Basin
- Road
- Limited-use Road
- Railway
- Transmission Line
- Cut line

Note: Map layers include data from multiple decades. Therefore, data in all areas may not reflect current conditions.



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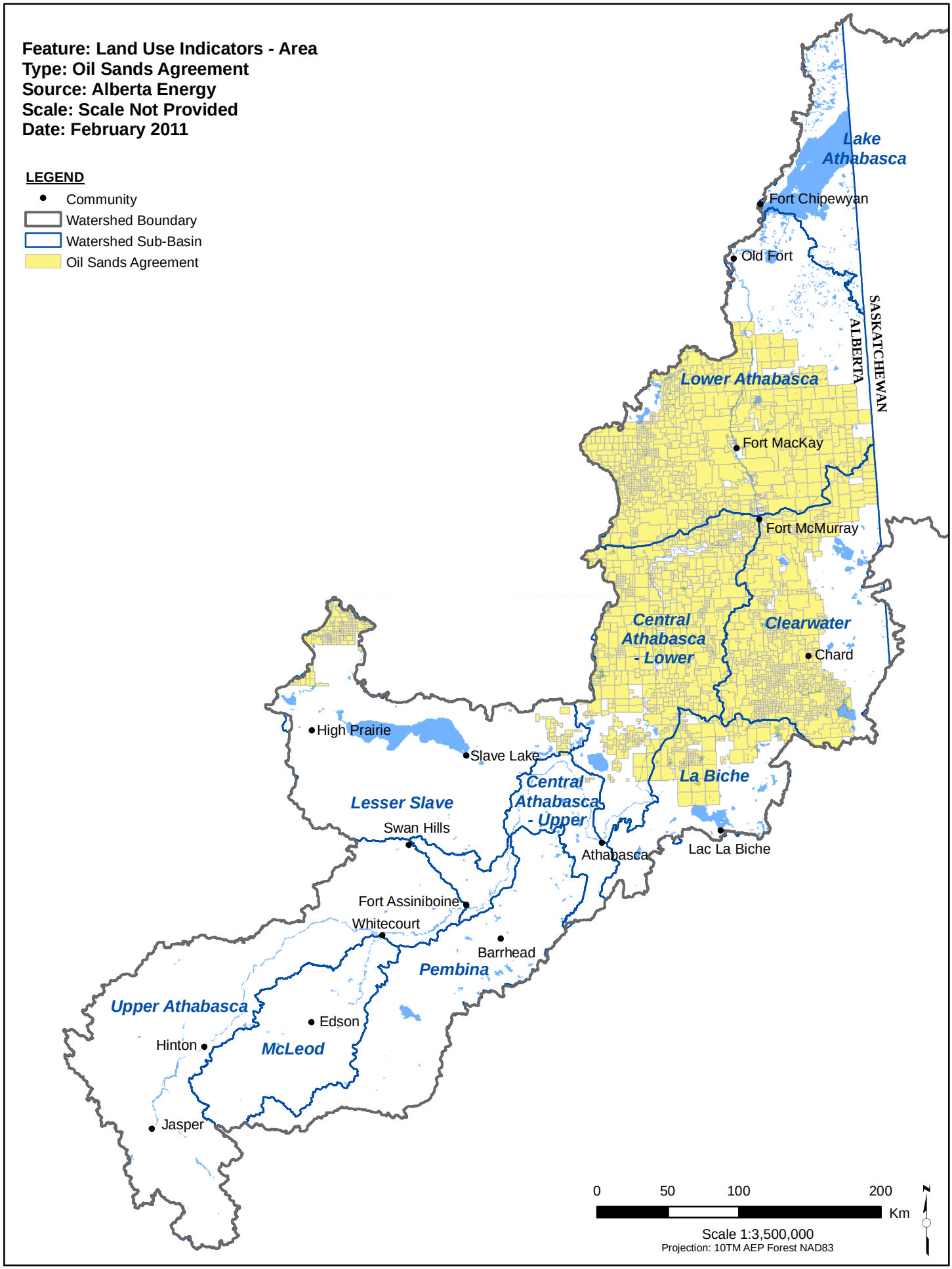
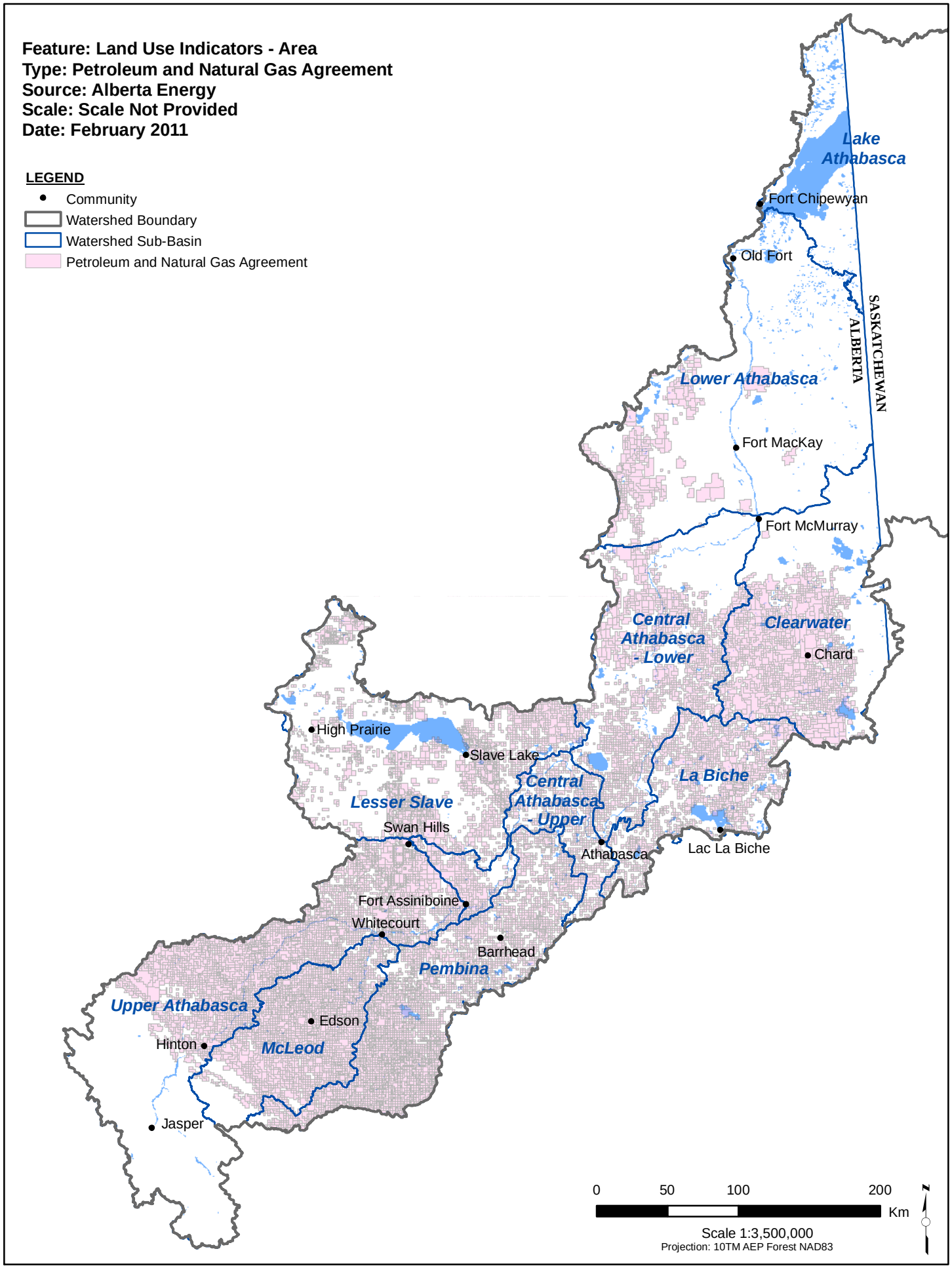
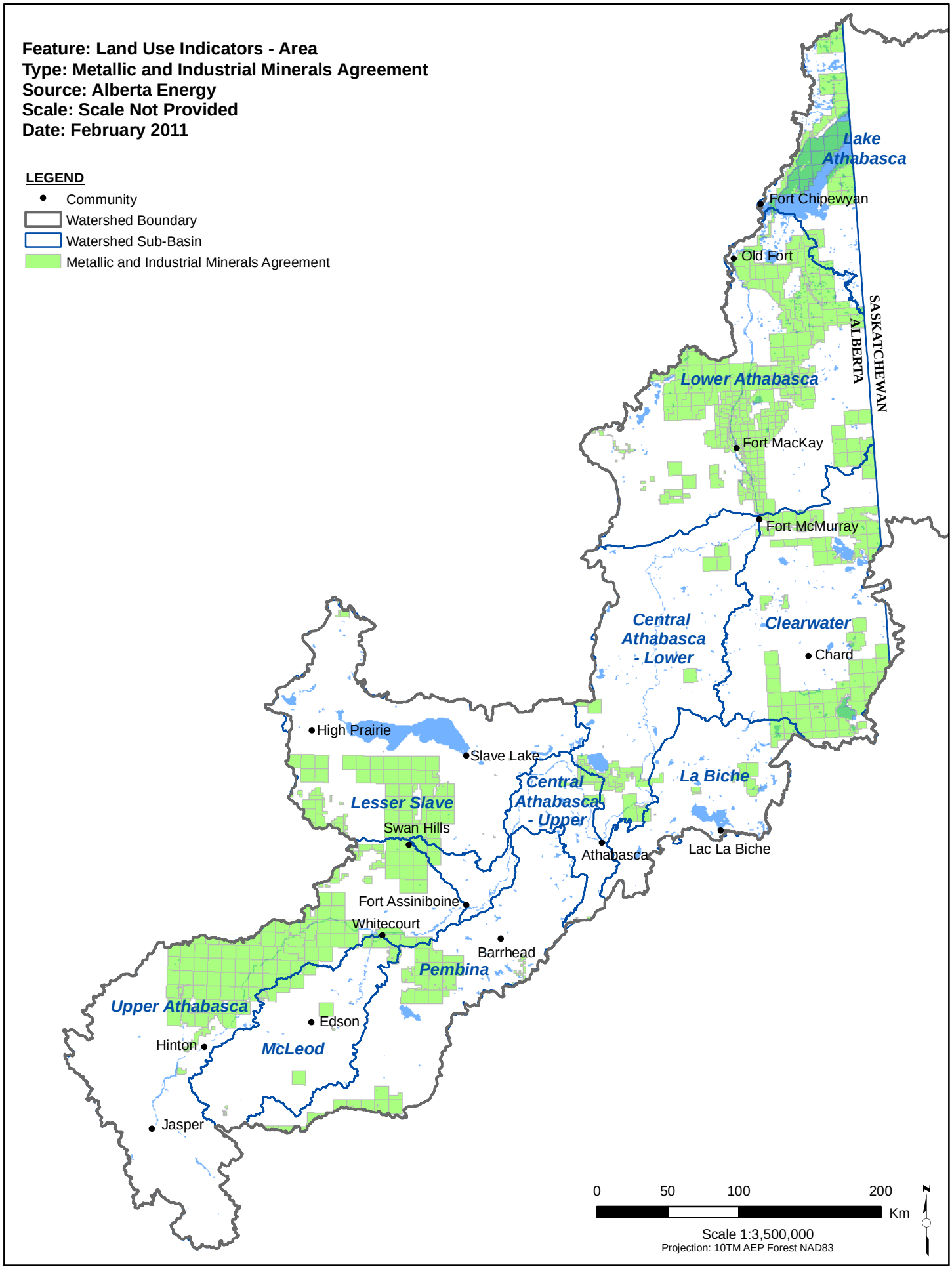

Feature: Land Use Indicators - Area
Type: Oil Sands Agreement
Source: Alberta Energy
Scale: Scale Not Provided
Date: February 2011
LEGEND
Community
Watershed Boundary
Watershed Sub-Basin
Oil Sands Agreement
Lake Athabasca
Fort Chipewyan
Old Fort
SASKATCHEWAN
ALBERTA
Lower Athabasca
Fort MacKay
Fort McMurray
Central Athabasca - Lower
Clearwater
Chard
High Prairie
Slave Lake
La Biche
Central Athabasca - Upper
Lesser Slave
Swan Hills
Athabasca
Lac La Biche
Fort Assiniboine
Whitecourt
Barrhead
Pembina
Upper Athabasca
Edson
Hinton
McLeod
Jasper
0
50
100
200
Km
Scale 1:3,500,000
Projection: 10TM AEP Forest NAD83
K:\Data\Project\WPAC1650\GIS\MXD\M1a_LandUseIndicesArea_OS_20110221.mxd

Feature: Land Use Indicators - Area
Type: Petroleum and Natural Gas Agreement
Source: Alberta Energy
Scale: Scale Not Provided
Date: February 2011



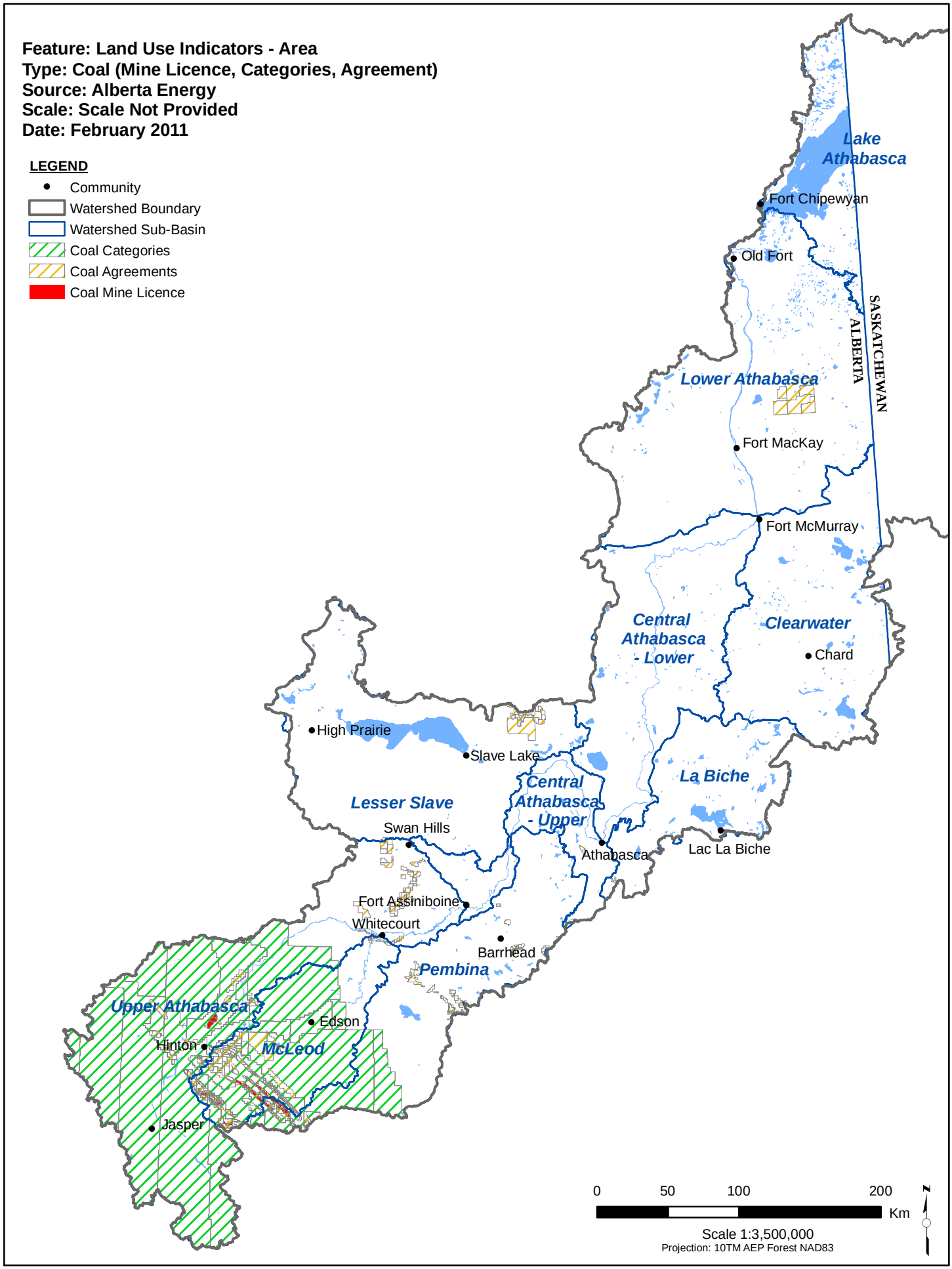
K:\Data\Project\WPAC1650\GIS\MXD\M1b_LandUseIndicesArea_PNG_20110221.mxd

Feature: Land Use Indicators - Area
Type: Metallic and Industrial Minerals Agreement
Source: Alberta Energy
Scale: Scale Not Provided
Date: February 2011



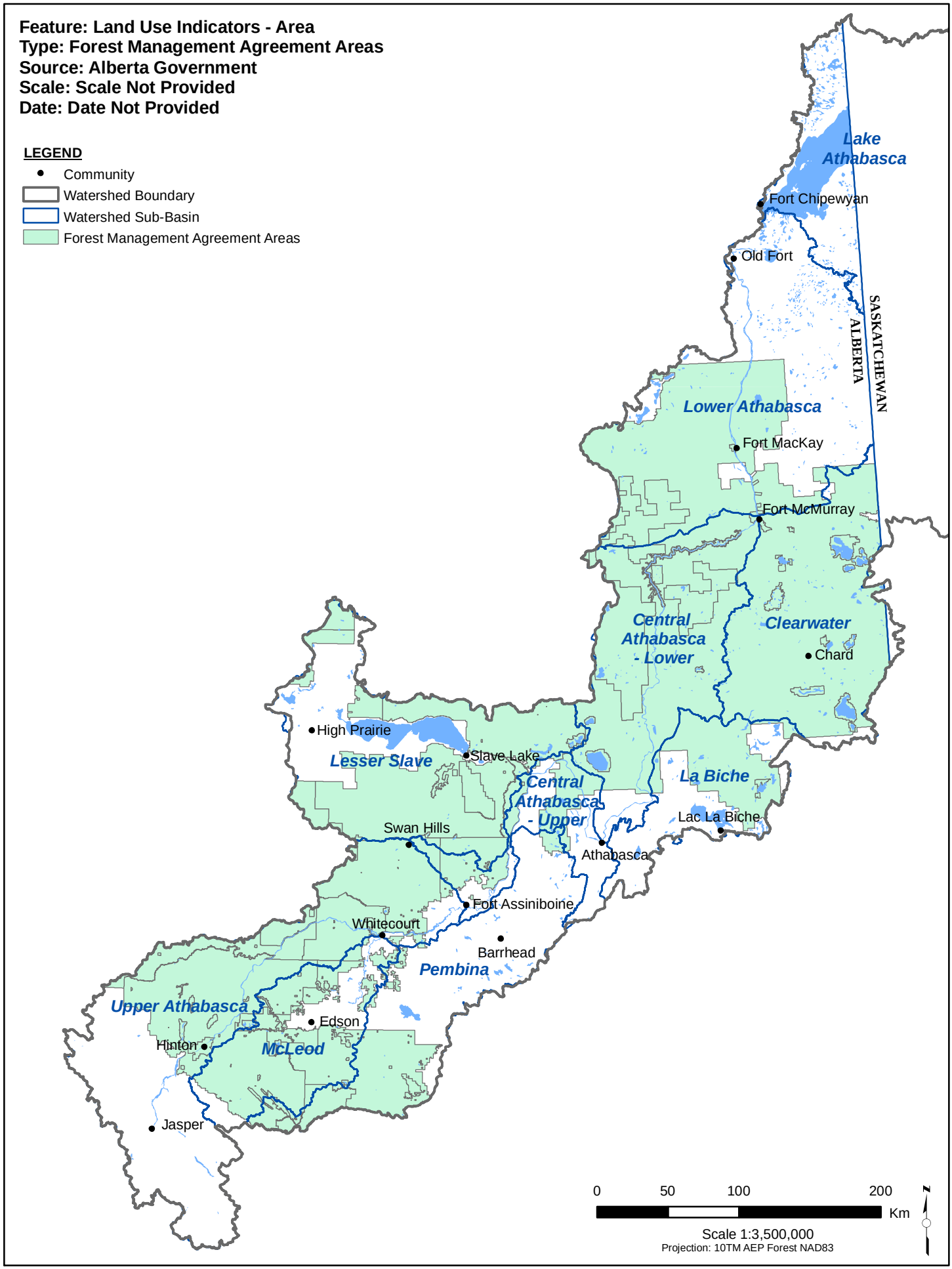
K:\Data\Project\WPAC1650\GIS\MXD\M1c_LandUseIndicesArea_MET_20110221.mxd

Feature: Land Use Indicators - Area
Type: Coal (Mine Licence, Categories, Agreement)
Source: Alberta Energy
Scale: Scale Not Provided
Date: February 2011



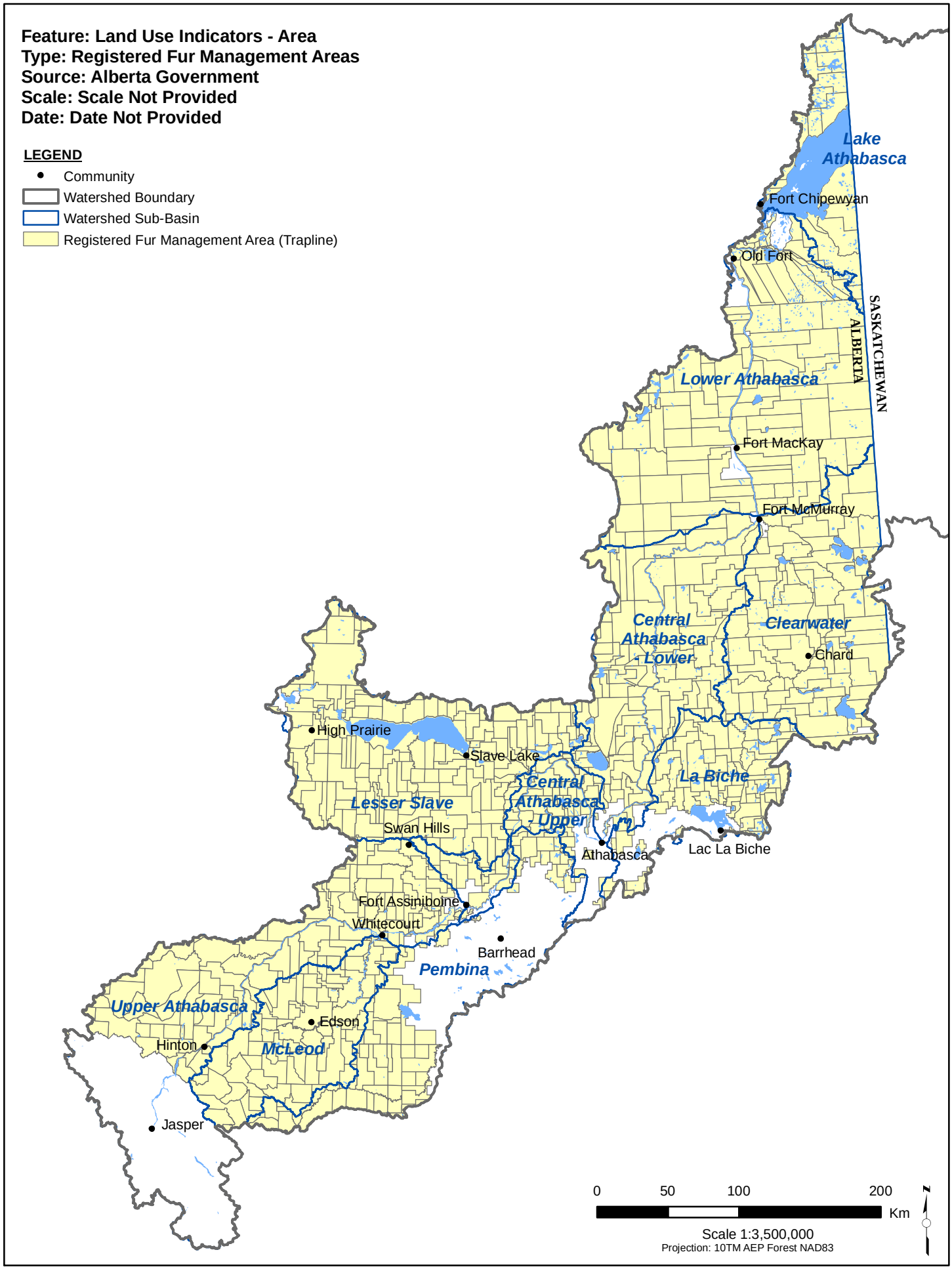
K:\Data\Project\WPAC1650\GIS\MXD\M1d_LandUseIndicesArea_Coal_20110221.mxd

Feature: Land Use Indicators - Area
Type: Forest Management Agreement Areas
Source: Alberta Government
Scale: Scale Not Provided
Date: Date Not Provided



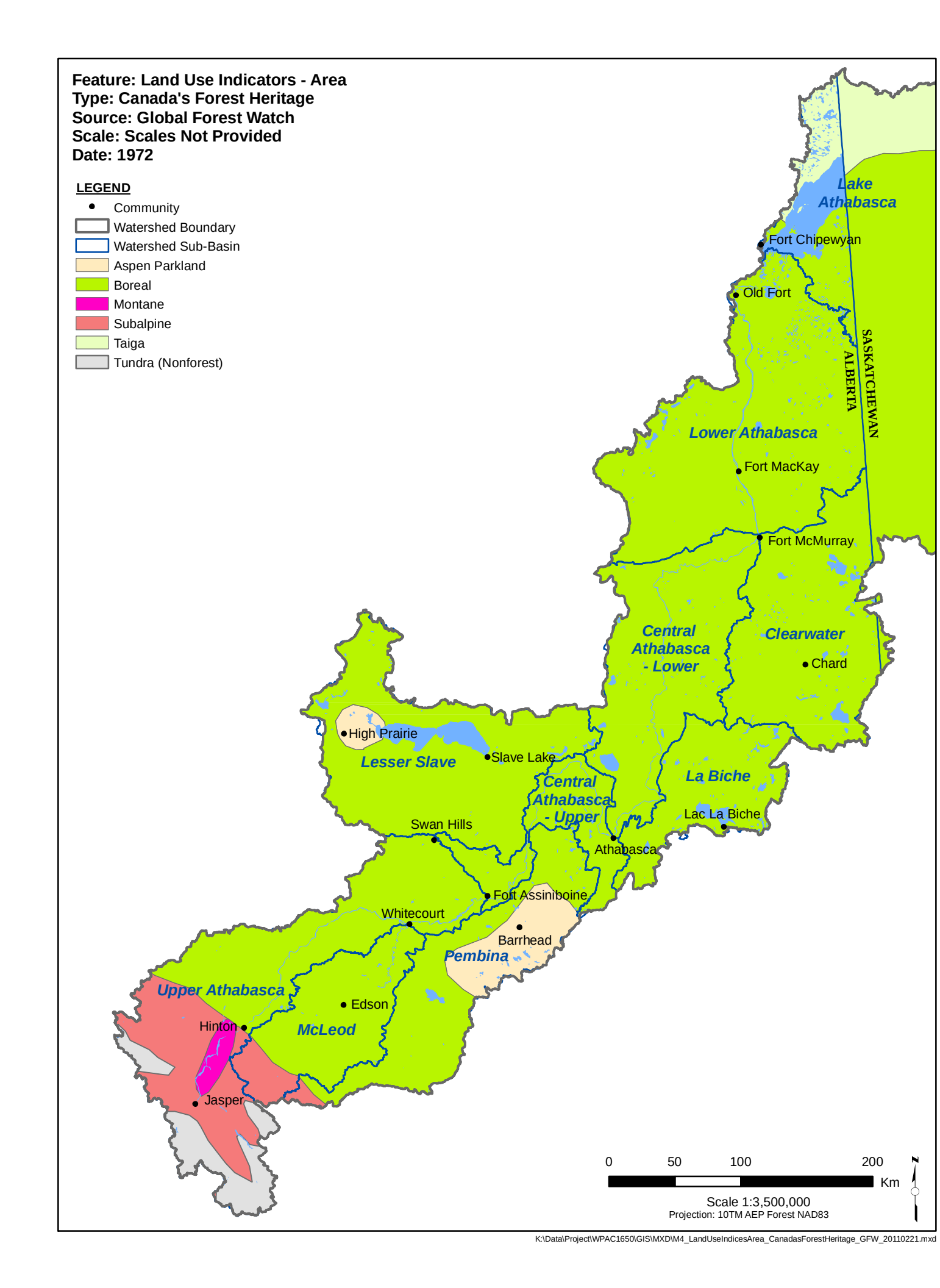
K:\Data\Project\WPAC1650\GIS\MXD\M2_LandUseIndicesArea_ForestManagementAgreementAreas_GofA_20110221.mxd

Feature: Land Use Indicators - Area
Type: Registered Fur Management Areas
Source: Alberta Government
Scale: Scale Not Provided
Date: Date Not Provided



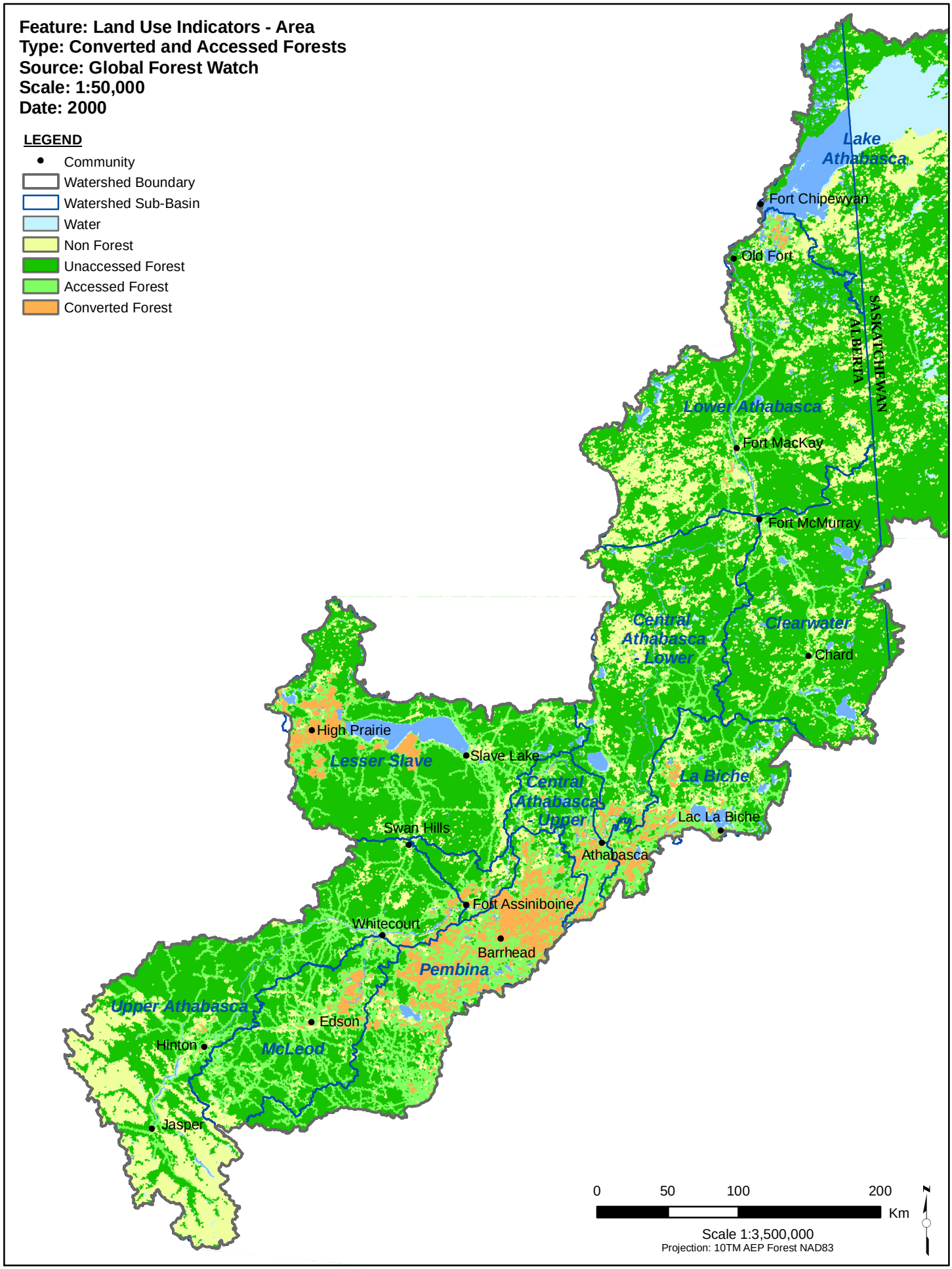
K:\Data\Project\WPAC1650\GIS\MXD\M3_LandUseIndicesArea_RegisteredFurManagementAreas_20110221.mxd

Feature: Land Use Indicators - Area
Type: Canada's Forest Heritage
Source: Global Forest Watch
Scale: Scales Not Provided
Date: 1972



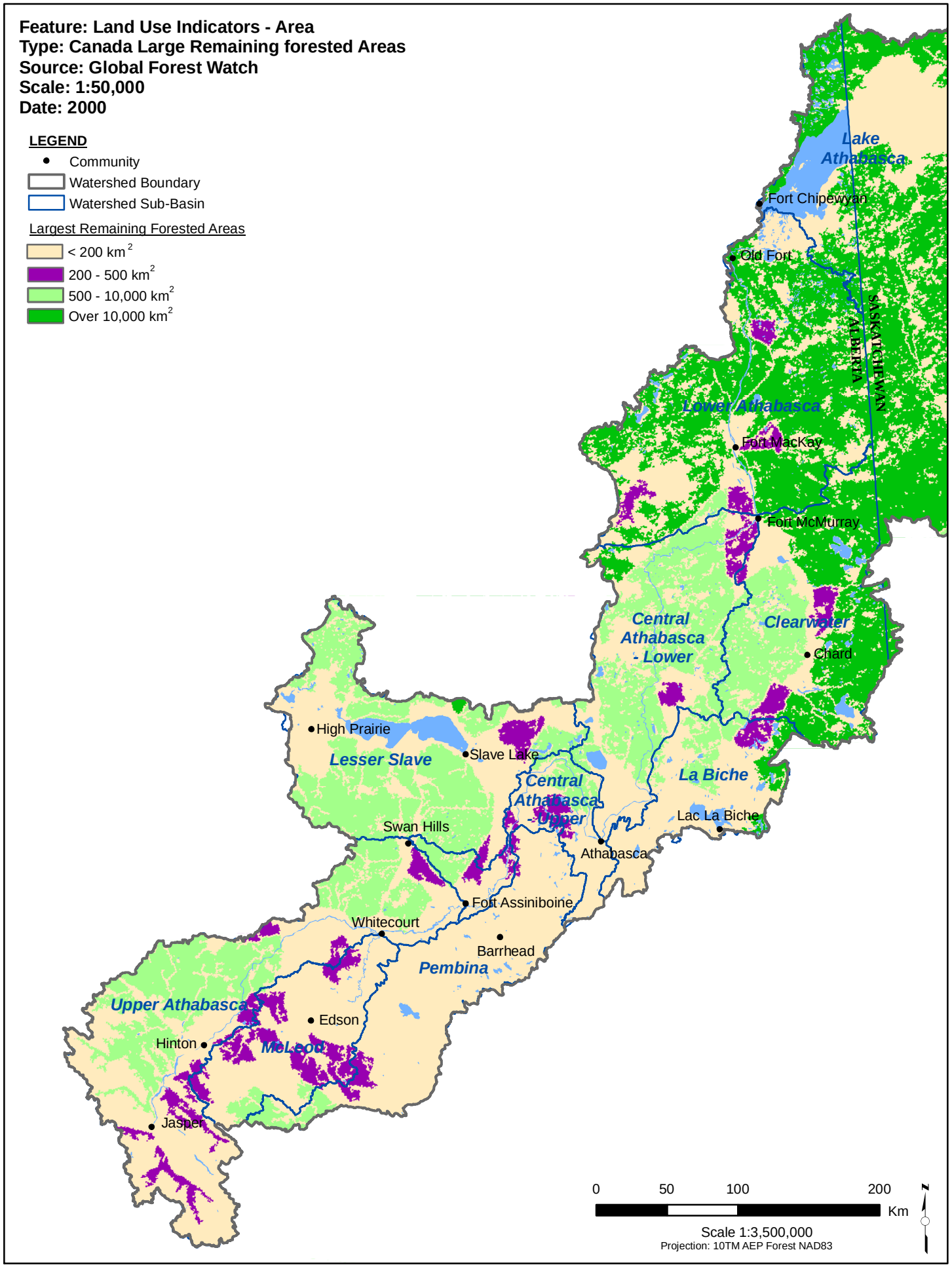
K:\Data\Project\WPAC1650\GIS\MXD\M4_LandUseIndicesArea_CanadasForestHeritage_GFW_20110221.mxd

Feature: Land Use Indicators - Area
Type: Converted and Accessed Forests
Source: Global Forest Watch
Scale: 1:50,000
Date: 2000



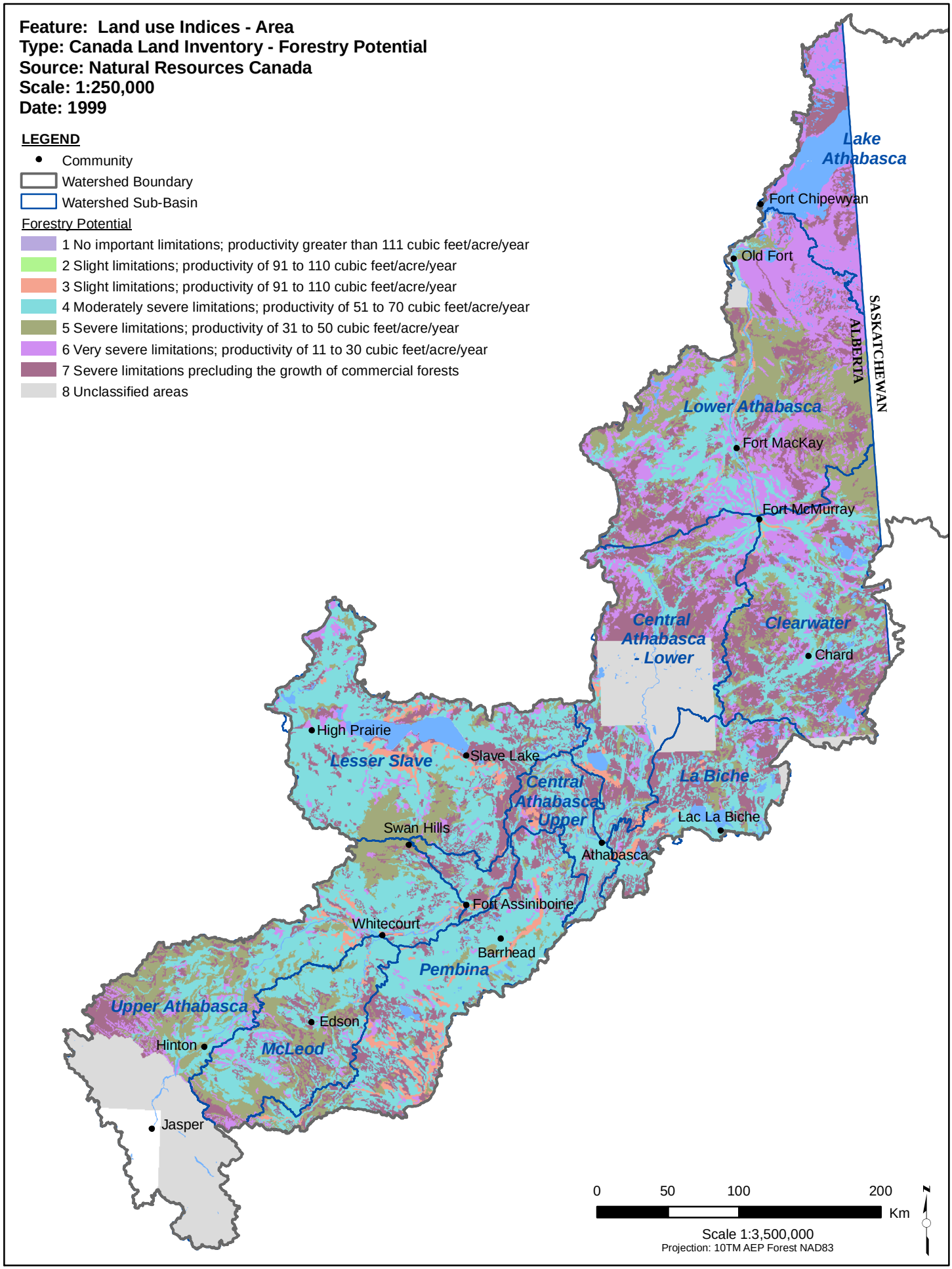
K:\Data\Project\WPAC1650\GIS\MXD\M5_LandUseIndicesArea_ConvertedAccessedForests_GFW_20110221.mxd

Feature: Land Use Indicators - Area
Type: Canada Large Remaining forested Areas
Source: Global Forest Watch
Scale: 1:50,000
Date: 2000



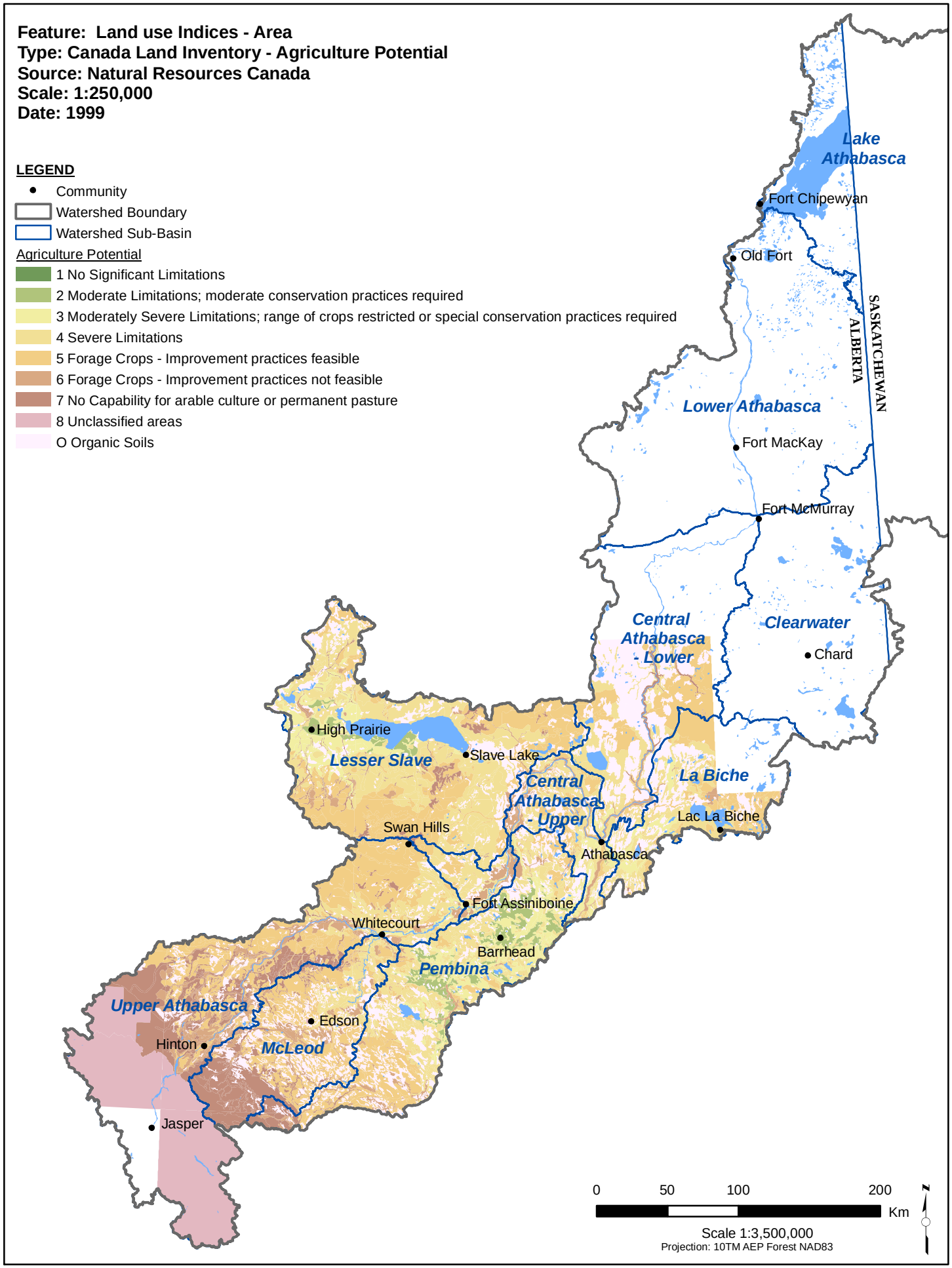
K:\Data\Project\WPAC1650\GIS\MXD\M6_LandUseIndicesArea_LargeRemainingForestedAreas_GFW_20110221.mxd

Feature: Land use Indices - Area
Type: Canada Land Inventory - Forestry Potential
Source: Natural Resources Canada
Scale: 1:250,000
Date: 1999



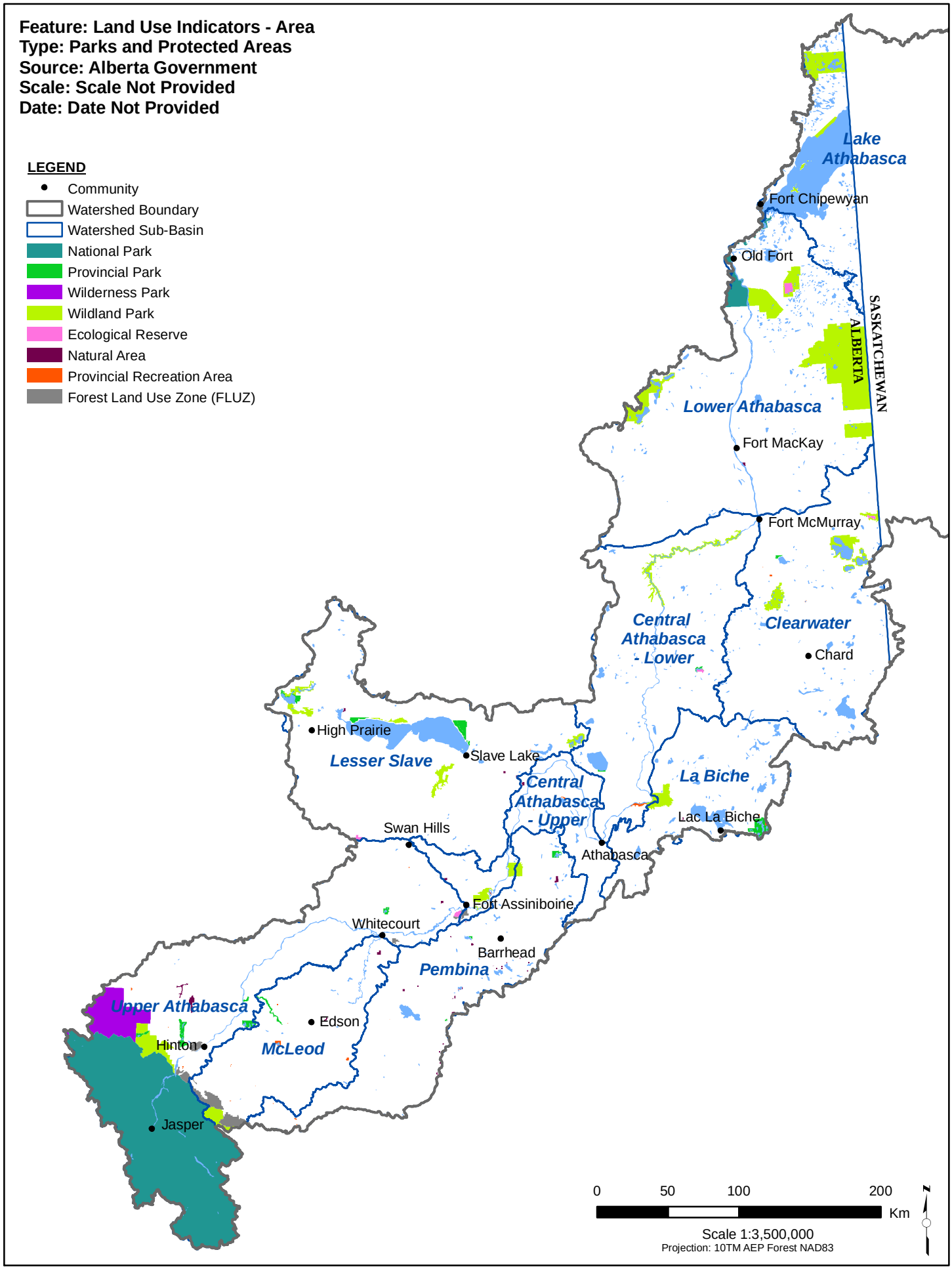
K:\Data\Project\WPAC1650\GIS\MXD\M7_LandUseIndicesArea_ForestryPotential_AAFC_20110221.mxd

Feature: Land use Indices - Area
Type: Canada Land Inventory - Agriculture Potential
Source: Natural Resources Canada
Scale: 1:250,000
Date: 1999



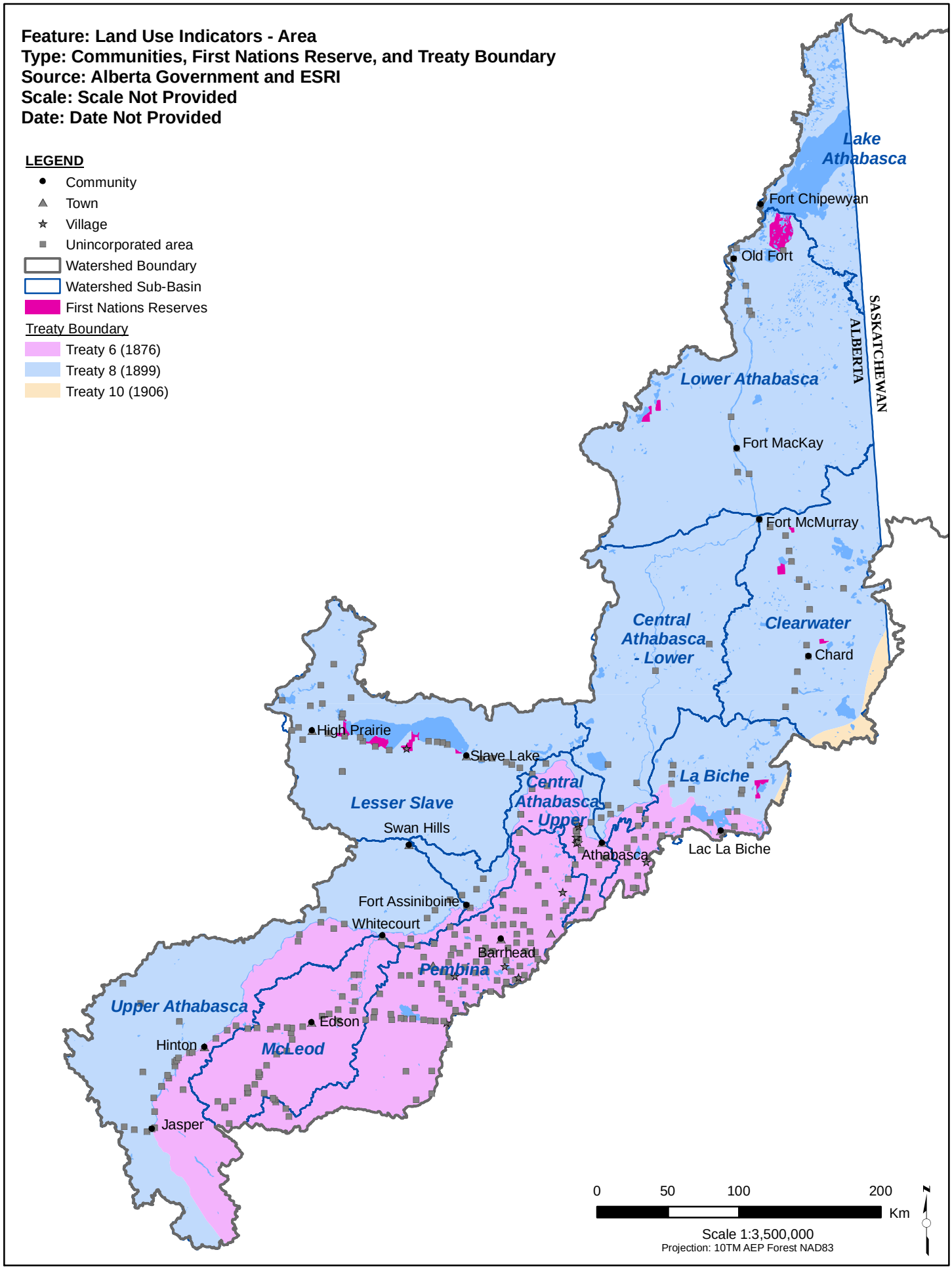
K:\Data\Project\WPAC1650\GIS\MXD\M8_LandUseIndicesArea_AgriculturePotential_AAFC_20110221.mxd

Feature: Land Use Indicators - Area
Type: Parks and Protected Areas
Source: Alberta Government
Scale: Scale Not Provided
Date: Date Not Provided



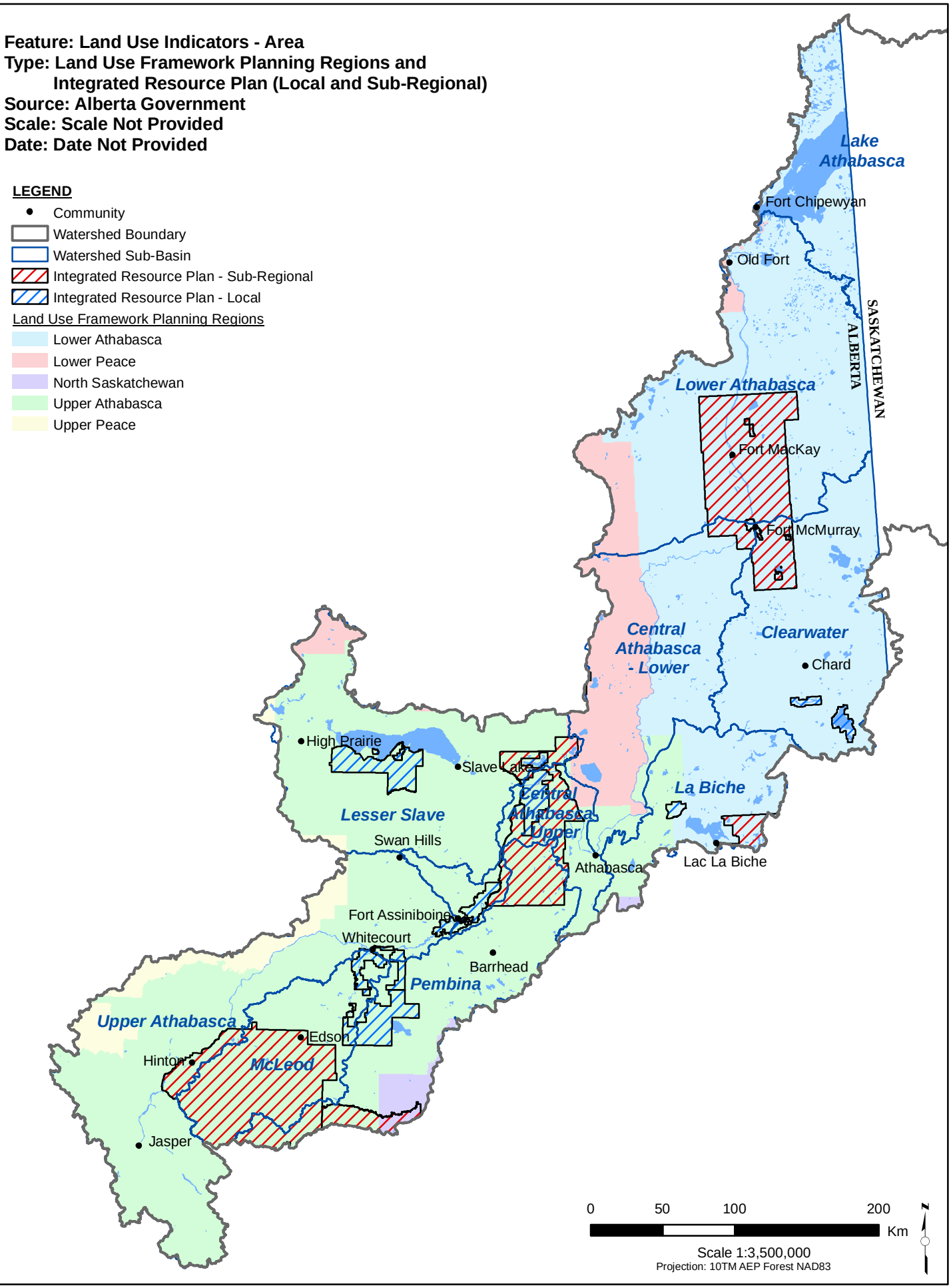
K:\Data\Project\WPAC1650\GIS\MXD\M9_LandUseIndicesArea_ParksProectedAreas_GofA_20110222.mxd

Feature: Land Use Indicators - Area
Type: Communities, First Nations Reserve, and Treaty Boundary
Source: Alberta Government and ESRI
Scale: Scale Not Provided
Date: Date Not Provided



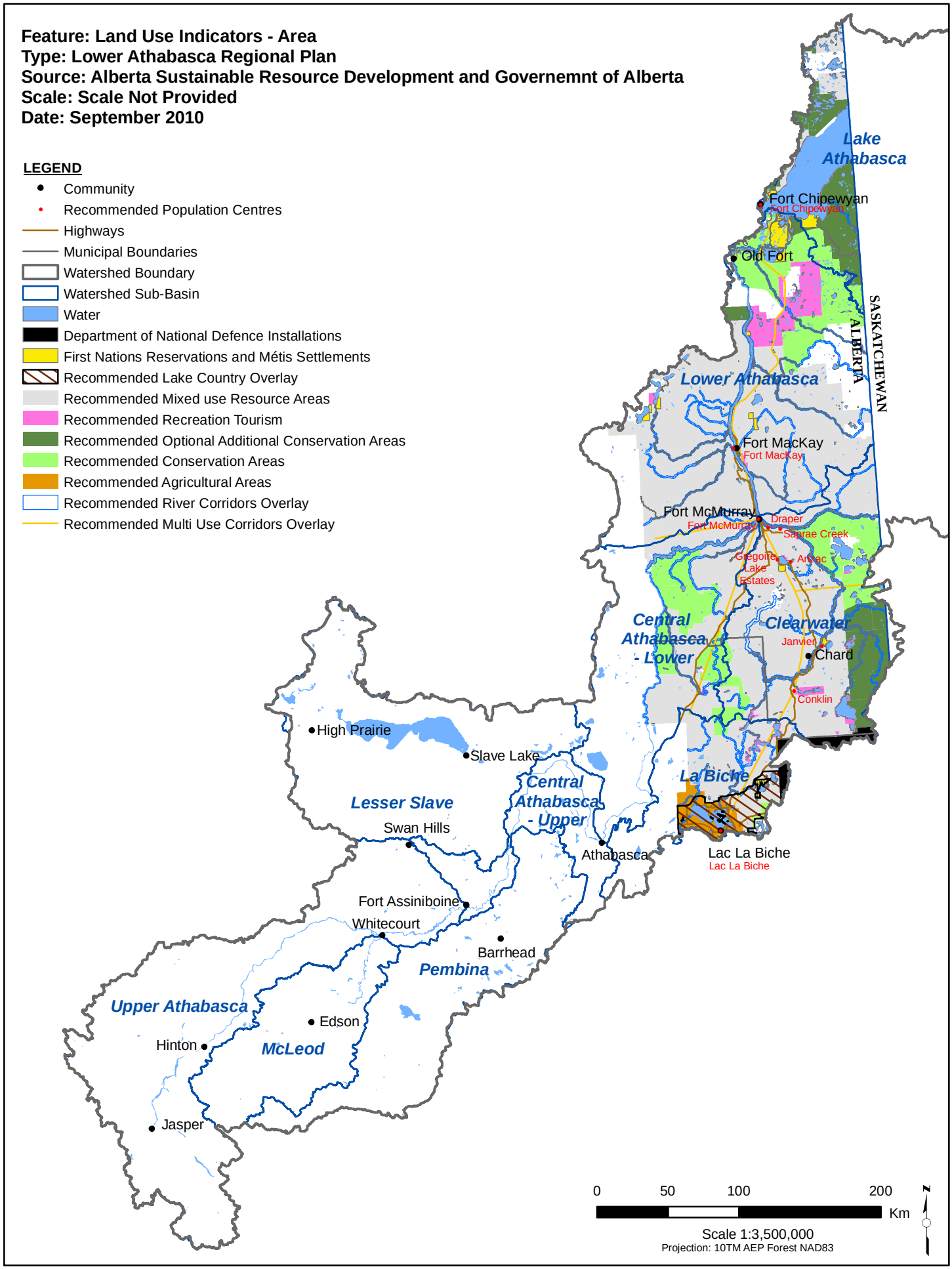
K:\Data\Project\WPAC1650\GIS\MXD\M10_LandUseIndicesArea_Communities_20110221.mxd

Feature: Land Use Indicators - Area
Type: Land Use Framework Planning Regions and Integrated Resource Plan (Local and Sub-Regional)
Source: Alberta Government
Scale: Scale Not Provided
Date: Date Not Provided



K:\Data\Project\WPAC1650\GIS\MXD\M11_LandUseIndicesArea_LandUse_IntegratedResourcePlan_20110221.mxd

Feature: Land Use Indicators - Area
Type: Lower Athabasca Regional Plan
Source: Alberta Sustainable Resource Development and Governemnt of Alberta
Scale: Scale Not Provided
Date: September 2010



K:\Data\Project\WPAC1650\GIS\MXD\M12_LandUseIndicesArea_LowerAthabascaRegionalPlan_20110222.mxd