Section 1
Introduction

1.1 Background

Agriculture is an important industry to Alberta's economy and a major land use activity in the province. Livestock production is a large component of Alberta's agriculture, with beef cattle production predominating. There are about 2.2 million breeding cattle in Alberta, representing 39% of the total number of cattle in Canada (Alberta Beef Producers 2011). Of the province's confined feeding operations (CFOs), which include feedlots, dairies, piggeries, and poultry operations, approximately 4,000 are feedlots, making Alberta the fifth largest confined cattle-feeding area in North America (Alberta Beef Producers 2011). An important management activity at these CFOs is manure storage and utilization, which usually involves the application of manure on adjacent cropland.

The agricultural industry is under increasing pressure to improve environmental stewardship. The impacts of livestock production and associated manure/nutrient management on water quality are among the issues of current concern. In particular, manure from CFOs has the potential to affect groundwater quality, which is an important source of water in many parts of the province. Manure storage and spreading are sources of nitrogen (N), phosphorus (P), and pathogens, and these contaminants may enter groundwater (Liebhardt *et al.* 1979, Chang *et al*. 1991, Chang and Entz, 1996, Chang and Janzen 1996, Whalen and Chang 2001, Rodvang *et al.* 2002, Rodvang *et al*. 2004, Olson *et al.* 2009).

Recently, the impact of manure storage facilities and manure spreading on groundwater quality in Alberta was reviewed (Hendry *et al.* 2007, Hendry Groundwater Sciences 2009). Key findings of these reviews included:

- Soil and groundwater contamination can occur from CFOs.
- Most land applications of manure occur near CFOs. Areas with concentrated CFOs in Alberta (i.e., near Lethbridge, between Calgary and Edmonton, and north of Edmonton; Figure 1.1) were identified as areas where groundwater is most vulnerable to impacts from manure application.
- Consistent annual manure applications in excess of crop uptake requirements lead to the accumulation of nitrogen within the soil profile and greater potential to impact groundwater quality. In Alberta, potential exists for groundwater contamination under current manure application rates.
- The dominant contaminant in soil and soil pore-water regimes associated with CFOs is ammonium (NH_4^+), while the dominant contaminant to groundwater from manure spreading activities is nitrate (NO_3^-). Ammonium migration can be retarded along the groundwater flow system, while NO_3^- can readily leach through the soil and into the groundwater.

- In Alberta, relatively thick clay-till aquitards (fine-grained soils) are prevalent throughout much of the landscape. Furthermore, shallow aquifer systems are typically not extensive. This suggests that many sites within the province are hydrogeologically stable. However, deep fractures are common in clay-rich sediments in Alberta. These fractures may increase rapid migration of contaminants to greater depths and into underlying aquifers.
- Alberta's regulatory program was considered neither the most stringent nor the most lenient for CFOs and manure spreading requirements compared to other jurisdictions in North America.

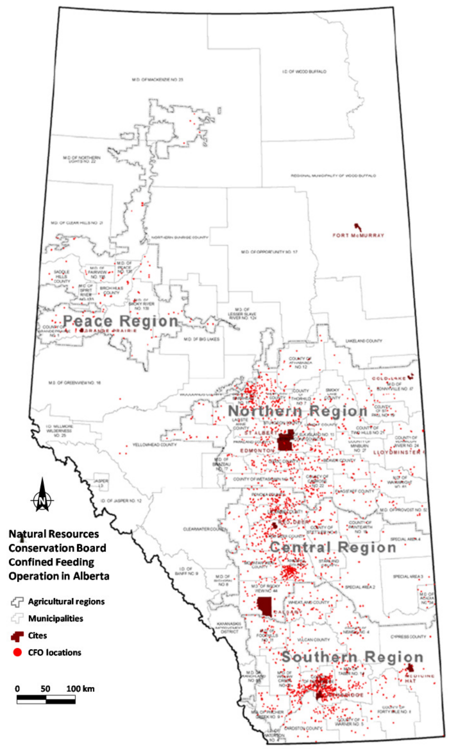

Figure 1.1. Distribution of confined feeding operations in Alberta (ARD 2007).

Based on the recommendations made by Hendry *et al.* (2007) and Hendry Groundwater Sciences (2009) along with the continued concerns of agricultural impacts on groundwater, Alberta Agriculture and Rural Development initiated a 6-yr field project to examine and better understand the impact of earthen manure storages (EMSs) , CFOs, and manure spreading on groundwater under Alberta conditions.

1.2 Objectives

The overall objective of this project is to improve the understanding of the fate and transport of manure constituents in groundwater in Alberta. Specific objectives include:

1) Determine groundwater quality changes with time in the Battersea area; which has extensive irrigation, a high density of CFOs, and historical groundwater data.

2) Determine risks to groundwater quality from manure field application and earthen manure storages.

3) Compare relative impacts between manure field application and storage facilities on groundwater quality.

1.3 General Project Description

The project involves the study of groundwater impacts associated with:

1) Manure spreading
   - Battersea Regional Transect Study (Section 2)
   - Field-scale Manure Spreading Study (Section 3)
2) Earthen manure storages and CFOs (Section 4)

The study sites were located in the Battersea area and at three CFOs in central Alberta (Figure 1.2). The Battersea area is near Picture Butte and is in the eastern portion of the Lethbridge Northern Irrigation District (LNID). This area contains the highest density of CFOs in Alberta (Figure 1.1). The majority of the land in the area is used for irrigated crop production, which supports the local CFO industry. The Battersea Drain, an irrigation return flow in the LNID, collects excess irrigation water and field runoff before discharging to the Oldman River on the east side of the Battersea area. Shallow groundwater in the area has the potential to be influenced by surface water and vice versa. Historical studies in the Battersea area provide a background context with respect to hydrogeological properties and groundwater quality in the area (Rodvang *et al.* 1998, 2002). As a result of these factors, the Battersea area was selected to study the fate and transport of manure constituents in groundwater.

A previously established regional transect of 23 wells in the Battersea area, east of Picture Butte, Alberta (Figure 1.2), was re-activated and monitored. Results from these wells were compared to historical findings (Rodvang *et al.* 2002) to determine changes in Cl^- and NO_3^--N concentrations with time. In addition, to better understand the risk of groundwater contamination from manure spreading in southern Alberta, four field sites, with a history of heavy solid beef manure application in the Battersea area, were instrumented with groundwater monitoring wells and monitored.

Five CFOs were selected to investigate the impacts of manure storage on groundwater quality: three in central Alberta, in the Lacombe-Ponoka region, and two in southern Alberta near Picture Butte (Figure 1.2). The three sites in central Alberta are dairies each with an EMS. One of the sites in southern Alberta is a combined dairy and feedlot operation, while the second site is a beef feedlot. Earthen manure storages for liquid dairy manure are the only type of manure storage facility being investigated at the dairies. Facilities associated with the feedlots include outside pens and catch basins. Seventy-two water table wells and piezometers have been installed at the five CFOs.

Nitrate, NH_4^+, and chloride (Cl^-) will be used as the main contaminant indicators in this project. Nitrate and Cl^-, in particular, are highly mobile and can be indicators of manure contamination in groundwater. Nitrate generally occurs naturally at low concentrations in groundwater, and levels above 3 mg L^{-1} are considered to be from anthropogenic sources (Madison and Brunett 1985), with the exception of geologic nitrate (Hendry *et al.* 1984, Rodvang and Simpkins 2001, Rodvang *et al.* 2002). Chloride does not undergo biological transformations or adsorb to soil and is considered to travel at the same rate as groundwater (i.e., conservatively). It can therefore be used as a tracer and an indicator of manure contamination (Olson *et al.* 2005, Rodvang *et al.* 2004). Shallow groundwater with Cl^- concentrations greater than 10 to 20 mg L^{-1} is generally regarded as being impacted by anthropogenic sources (Forrest *et al.* 2006).

Data collected from 2009 to 2011 included groundwater elevations, groundwater chemistry and isotopes, manure chemistry, soil chemistry, and vertical and horizontal groundwater flow velocities. Isotopes were analyzed by the University for Saskatchewan and these data are not presented in this progress report.

1.4 Current Report and Project Timelines

This project was initiated in November 2008 and is anticipated to be completed in December 2015. This current report is the first progress report of the project, and focuses on field work and data collected from 2008 to 2011.

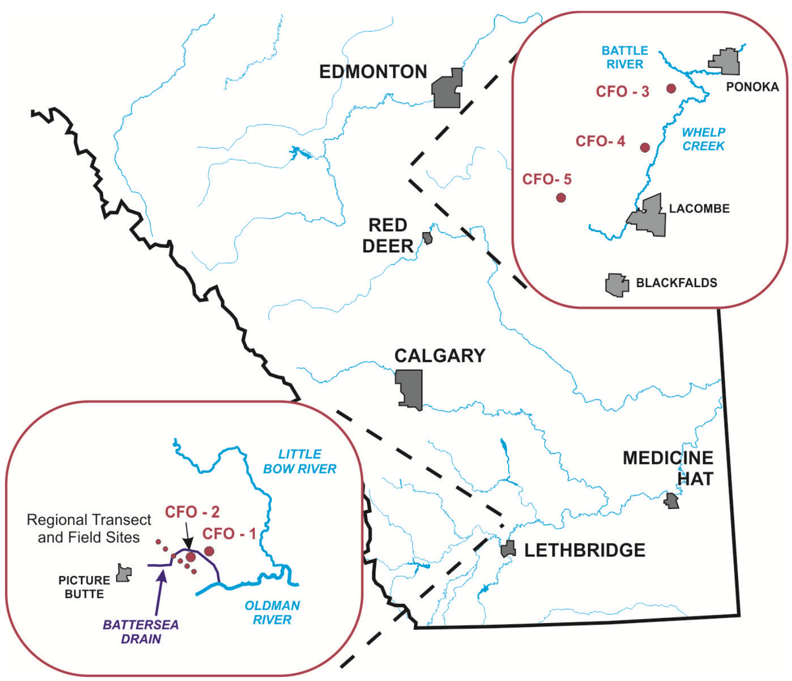

Figure 1.2. Location of main study areas.