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Methodology to assess groundwater quality during CO_2 injection at the Quest CCS project

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Summary

Demonstrating to stakeholders that injected CO_2 is safely contained within a storage complex is a key aspect of any Carbon Capture and Storage (CCS) project. At the Quest CCS project, a comprehensive study (pre-injection) was undertaken to develop hydro(geo)logical and hydrogeochemical models of the Quest Sequestration Lease Area from ground surface to base of groundwater protection. These models form an essential framework for assessing groundwater quality during the CO_2 injection phase. A number of key analytes were identified to be included in on-going monitoring for containment assessment and assurance monitoring purposes during CO_2 injection. Descriptive statistics were used to assess the data and to establish baseline ranges for parameters of interest. This allowed to define and to establish project specific triggers being applicable to either aquifers or individual wells. In order to optimize evaluation of groundwater data collected during the injection phase a semi-automated ArcGIS workflow will be implemented.

Introduction

In 2015, CO_2 injection will start at the Quest Carbon Capture and Storage (CCS) located in Alberta, north of Fort Saskatchewan. Shell on behalf of the Athabasca Oil Sands Project venture (Shell Canada Energy, Chevron Canada Limited, Marathon Oil Canada Corporation) operates the Quest CCS project. Quest will capture more than one million tonnes of CO_2 per year from the Scotford oil sands bitumen Upgrader, reducing the direct CO_2 emissions from the Upgrader by up to 35%. The CO_2 captured from the Upgrader will be transported by a 60-km underground pipeline to three injection wells where it will be injected into the Basal Cambrian Sandstone (BCS), a saline aquifer located at a depth of about 2 km below ground surface, over a potential time period of 25 years. Demonstrating to stakeholders that injected CO_2 is safely contained within a storage complex is a key aspect of any Carbon Capture and Storage (CCS) project. In a recent report by the International Energy Agency (IEA), it was stated that: "*Integrity and safety of a CO2 storage can only be proven through appropriate monitoring.*". Hence, a key component of the Quest Project is a Measurement, Monitoring and Verification (MMV) plan, which covers various domains including Atmosphere, Biosphere, Hydrosphere and Geosphere (Shell, 2012). With regards to the Hydrosphere domain, a comprehensive study (pre-injection) was undertaken to develop hydrological and hydrogeochemical models of the Quest Sequestration Lease Area from ground surface to base of groundwater protection.

The aim of this paper is to present and to discuss the methodology used and developed to assess groundwater quality during CO_2 injection at the Quest CCS project.

Methods & Materials

A prerequisite to establish a methodology for assessing groundwater quality during CO_2 injection at the Quest project, is a thorough understanding of the hydrogeology and hydrogeochemistry within the aquifers located between ground surface and base of groundwater protection zone. Hence, the following approach was used:

- Review and collation of all existing and relevant data / information (pre-2012).
- Installation of project specific groundwater wells.
- Integration of pre-injection monitoring data (Q4-2012 to Q4-2014) from project specific groundwater wells and private landowner wells.
- Development of internally consistent hydrogeological and hydrogeochemical models.
- Identification of key parameters to be included in on-going monitoring for containment assessment and assurance monitoring purposes during CO_2 injection.
- Use of descriptive statistics to define and to establish project specific triggers.
- Design of a semi-automated ArcGIS workflow for groundwater data interpretation during the CO_2 injection phase.

Findings - Outcome

In this study, the hydrosphere was defined as the zone from ground surface to the base of the groundwater protection zone, stratigraphically coincident with the top of the regionally extensive Lea Park Aquitard. Based upon previous potable water aquifer classifications across the Quest Study Area, four distinct aquifers were defined which included, from structurally and stratigraphically lowest to highest, the Basal Belly River Sandstone (BBRS), Foremost, Oldman, and Surficial (Fig. 1). The BBRS is formally considered to be a component of the Foremost aquifer, but for the purposes of this study, it is treated as a separate aquifer. Except for the BBRS aquifer, all other overlying aquifers are considered to be in hydraulic communication. Over 3000 chemistry records were gathered, processed, and evaluated. Groundwater types vary across the Quest SLA from Ca-Mg-HCO_3 to NaCl and Na-SO_4 with a quite range in TDS (58 to 18,300 mg/L). Descriptive statistics (e.g. min, max, average) were calculated for the various aquifers above the base of the groundwater protection zone, as well as for individual wells (1510 wells were processed). The descriptive statistics formed the basis for setting thresholds/triggers post baseline monitoring. A number of key analytes (e.g. pH, DIC, TDS, $\delta^{13}C$) were identified as being important for ongoing monitoring for containment assessment and assurance monitoring purposes.

Evaluated aquifers are situated above the base of ground water protection as defined in Alberta, and their water compositions ranged from dilute fresh waters to saline brines. Concentrations of some analytes within the brines were above Drinking Water Quality guidelines. Hence, the concept of Water Quality Limits cannot be applied to the evaluated aquifers for establishing triggers. For this reason, triggers are considered as Quest Project-specific triggers and do not imply meeting a regulatory condition, but rather exceeding a limit defined by the historically observed concentrations, which may include samples taken up to the time of initial CO_2 injection.

Project triggers are based upon comparing analytical results with parameter and analyte concentration statistics calculated from the baseline survey data for aquifers and individual wells; hence aquifer-specific and well-specific triggers were developed. The results of the trigger calculation are a numerical value which is either greater than 1 or less than or equal to 0. If the calculated value is less than or equal to 1, it should be stored as a null value. As such, when the trigger values are exceeded, trigger locations can be displayed on the various aquifer base maps using symbology proportional to the magnitude of the trigger event. In order to efficiently assess any changes in groundwater quality above the base of groundwater protection zone during CO_2 injection, a semi-automated ArcGIS workflow will be implemented to optimize data interpretation.

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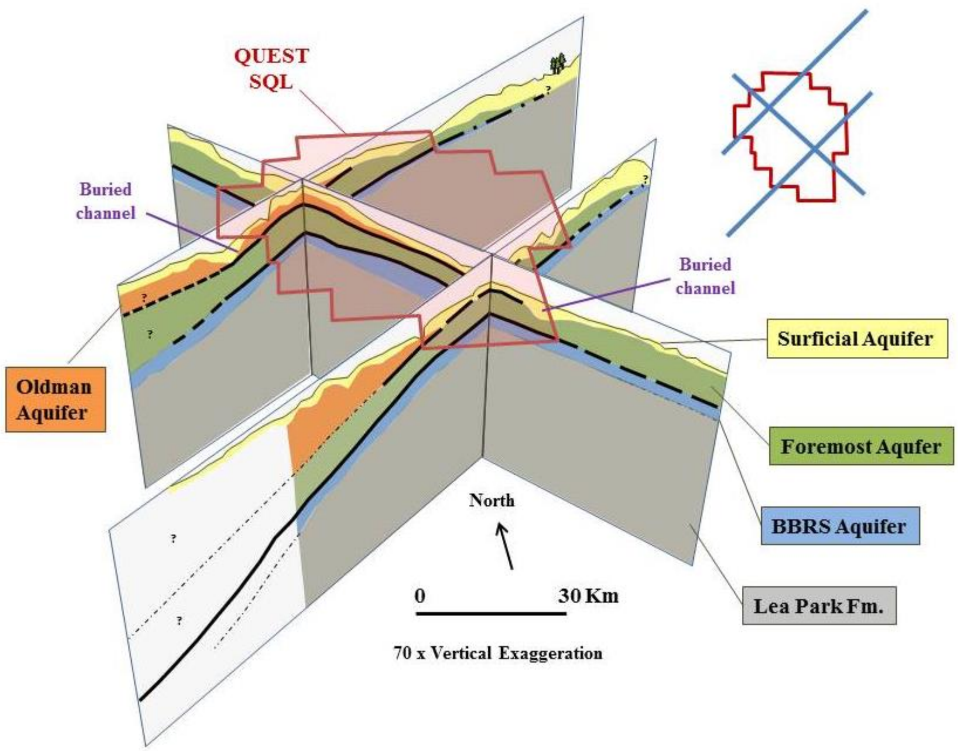

Figure 1: Conceptual geological model for the Quest Project Sequestration Lease Area (Brydie et al., 2014)