Assessing Impacts of Natural Gas Development on Transboundary Freshwater Aquifers in the Liard Basin: Northwest Territories, Canada

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Summary

The Liard Basin, located in the northwest corner of the Western Canada Sedimentary Basin, spans the borders of British Columbia, Yukon and Northwest Territories (Figure 1). The region has been developed for conventional oil and gas since the 1960s (Government of Yukon, 2001). Recent discoveries have indicated that the basin contains one of Canada's largest natural gas reserves, which has led to interest in its future development through unconventional technologies (NEB et al., 2016). The potential development of this basin has spurred concerns regarding impacts of stray gas to shallow freshwater resources such as surface water and freshwater aquifers (VanGulck, 2016). High-resolution characterization of the fresh groundwater zone (upper 150 m) has been initiated. A drilling campaign was undertaken in August 2019, consisting of two test boreholes to assess geologic conditions and suitability of core drilling methods. Preliminary HQ3 drilling revealed variably unstable borehole conditions through the Dunvegan Formation, which may represent an important regional freshwater aquifer (Lowen, 2011; Riddell, 2012).

The Dunvegan Formation was deposited as part of a fluvial-deltaic system that existed during the mid-Cenomanian (~95 Ma), when the Cretaceous Western Interior Seaway covered a large portion of North America (Figure 2). The Dunvegan Delta drained portions of the Mackenzie and Rocky Mountains, depositing sediment over a ~2 million-year period. The Dunvegan Formation has been studied in detail towards its distal deltaic reaches in northeast British Columbia and northwest Alberta (Figure 1) (Bhattacharya, 1994; Plint, 2000), but little is known about the Dunvegan's more proximal fluvial source area in southwest Northwest Territories (Stott, 1982; Riddell, 2012). Despite these proximal and distal deposits both being part of the Dunvegan Formation, the depositional structure (channels vs. clinoforms) and dominant lithology (coarse conglomerate vs. fine sandstone) result in very different groundwater flow systems, which may have differing vulnerabilities and characteristics. This information has been distilled to create a geologically-informed conceptual site model for the Dunvegan Formation (Figure 3), improving upon the existing lithostratigraphic framework (Figure 4), which will be more relevant for studying the groundwater flow system in detail, as illustrated by Shultz et al. (2017).

Based on preliminary drilling and background research, a revised work plan was created, utilizing a combination of rotosonic, wireline coring and air rotary techniques to core and install a series of multi-level system (MLS) groundwater monitoring wells. This subsequent drilling campaign will consist of paired boreholes at three specific locations based on surface electrical resistivity measurements (Figure 4). Following the DFN-M methodology presented by Parker et al. (2012), at each site, a continuous core will be collected, logged and sampled; and this will be followed by downhole geophysical and hydrophysical logging. Continuous lithology logs and hydraulic

profiling information will be combined with borehole and surface geophysical measurements to design a series of grouted-in transducers and MLS. Hydrogeologic units (HGUs) will be defined using hydraulic characteristics and background hydrochemistry of the fresh groundwater zone (Meyer, 2008, 2014). Sequence stratigraphic descriptions and depositional environment reconstructions created based on data collected during August 2019 and from existing mapping surveys, geologic reports and well logs will be used to refine these HGUs and delineate important stratigraphic features that may impact and constrain the groundwater flow system (Meyer, 2016). Preliminary hydraulic monitoring and water quality data will assess vertical flow potential across confining shale units bounding and within the Dunvegan Formation. Natural gas migration from upgradient within the basin where shale gas development is currently occurring is a potential threat to water quality. This baseline groundwater quality study in the Liard Basin will support future assessments of upstream shale gas activity and/or future development of shale gas in this region. This study will establish a transferable framework for continuous long-term monitoring of groundwater quality and quantity at a regional scale for the purpose of evaluating past, current and future impacts to groundwater quality from natural and anthropogenic sources.

Figures

Figure 1: (below) Outline of the Liard Basin Watershed, with the Liard Oil and Gas Basin shown in red and the Dunvegan Formation (the focus of this study) in green. Previous Dunvegan Formation study localities shown by the orange polygon (modified from National Post, 2016).

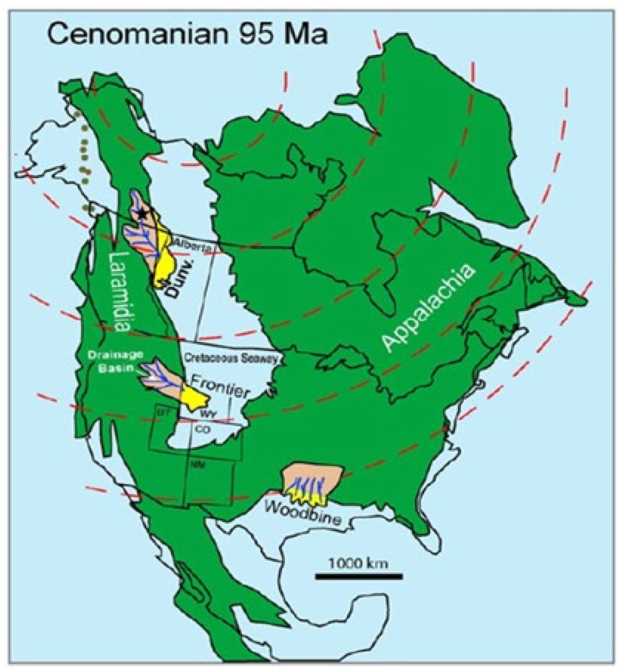

Figure 2: (above) Paleogeographic map during Dunvegan deposition. Study area shown by black star. Previous studies focused on the distal system (yellow deltaic deposits) (modified from Lin & Bhattacharya, 2017).

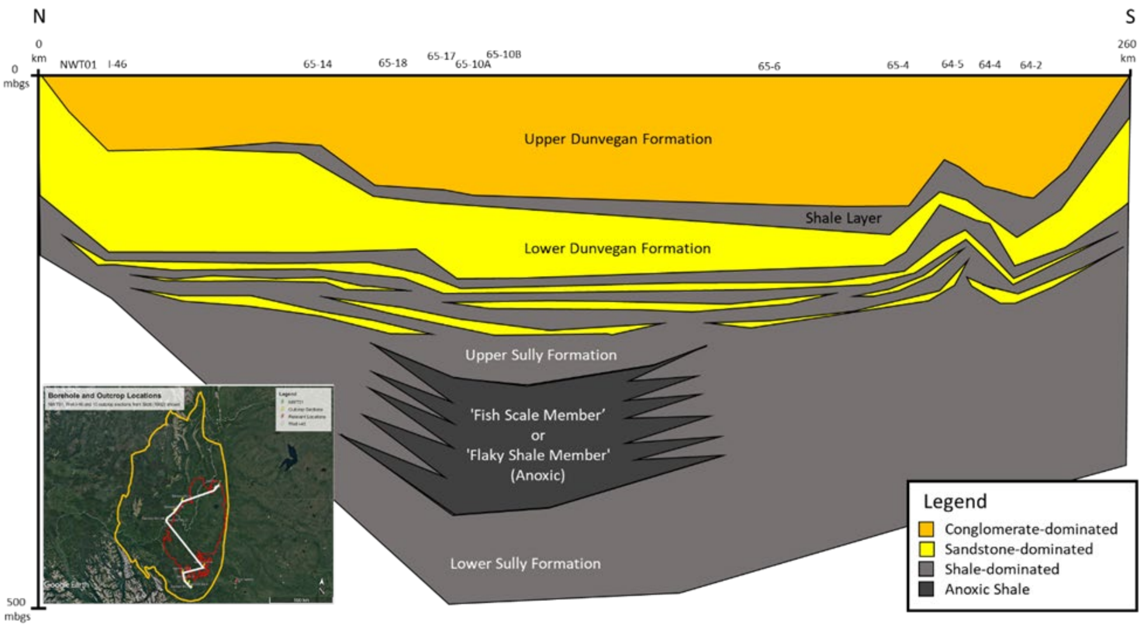

Figure 3: Geologically informed cross section, showing a more detailed breakdown of the internal heterogeneity within the Dunvegan and underlying Sully Formations. This conceptual model will be compared to the more simplistic lithostratigraphic model (Figure 4) and a more complex sequence stratigraphic model (in prep.) to better understand how the resolution of geologic information incorporated into a conceptual model impacts the ability to understand flow system conditions. Outcrop and well log locations shown along the top and within inset map.

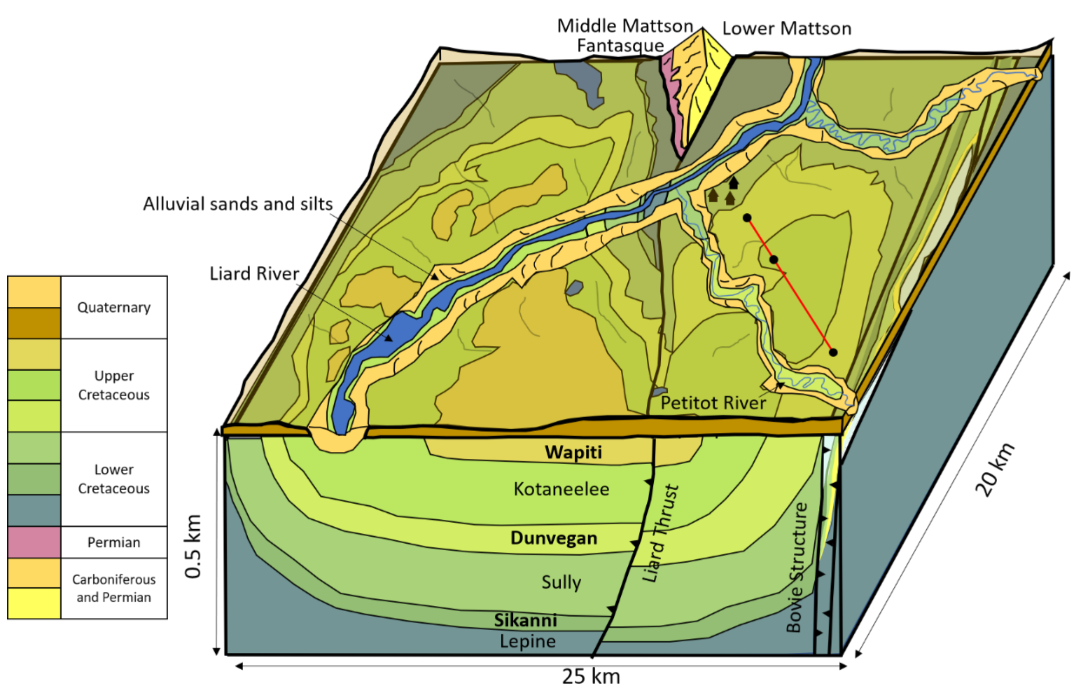

Figure 4: Conceptual lithostratigraphic block model of the Northwest Territories portion of the Liard Basin (the study area) showing the subsurface formations and surface water bodies. The red line represents the cross-section created by this study, with black circles representing study sites and black houses representing the Hamlet of Fort Liard.

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