Wyoming-Montana Water Science Center
U.S. Department of the Interior
U.S. Geological Survey

Characterization of Water Quality in an Energy Development Area: Williston Basin of Montana, North Dakota, and South Dakota

Overview

The Williston Basin, a nearly 135,000 square-mile sedimentary basin in the north-central United States and south-central Canada is largely underlain by the Bakken Formation and is home to one of the Nation's largest energy booms (fig. 1) . The area includes aquifers of regional importance which are oftentimes the primary or sometimes only source of potable water. Although oil production has occurred for decades, advancements in unconventional drilling technologies and large-scale energy development have brought forth the need to more fully characterize the region's water resources.

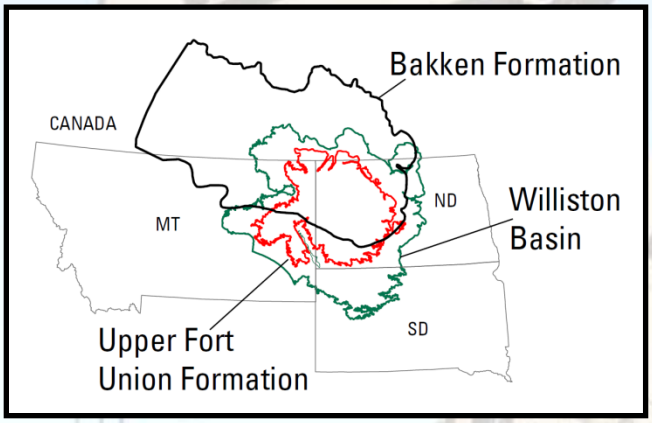

Figure 1: Map of the Williston Basin, extent of the Bakken Formation, and the upper Fort Union Formation (a principal aquifer).

A team of USGS scientists from the Colorado, North Dakota, South Dakota, and Wyoming-Montana Water Science Centers (WSCs) and the Energy Resources Program (ERP) has been formed to improve understanding of the interface between produced waters from unconventional oil resources and the ambient water resources in this area. The ongoing and proposed studies are designed to characterize the chemistry (major ions, trace metals, radiogenic, volatile organic, isotopic) of waters throughout the life cycle of tight oil production. These waters include: source waters (ambient groundwater and (or) surface water); hydraulic fracturing fluids, formation waters (waters which co-exist with rock/oil/gas), produced waters, and waste waters (a combination of recovered fluids). The term "produced water" represents water generated from an oil or gas well (including water produced immediately after hydraulic fracturing as well as water produced after months or years of production).

Project Accomplishments

A baseline groundwater-quality study was conducted within the Williston Basin in 2013. Most of the 34 sampled wells were completed in the upper Fort Union Formation and underlain by the Bakken Formation (figure 2). Samples were analyzed for constituents of concern in energy-development areas. Results give no indication of groundwater contamination from energy -development activities, however , flow path and age-dating analysis indicated that potential chemical effects related to energy development may still be less than 0.5 km from their source (McMahon and others, 2014). Slow groundwater velocities support the need for a long-term commitment to groundwater monitoring.

Produced waters were sampled in 2012 from 9 oil wells that were in production for at least one year to ascertain the "end-member" composition of the Bakken formation water. Initially, the Bakken Formation waters appear chemically distinct from other area waters (Peterman and others, 2014). Although produced waters have been sampled for years using "modified" methods of Lico and others (1982), it was recognized during this sampling that future produced water sampling efforts require well-documented, safe, and consistent methodologies.

A team of WSC and ERP scientists and safety specialists conducted a field exercise at 19 Bakken/Three Forks Formation oil wells in August 2014. Work included safety assessments, produced water sample collection, and a sample-strategy evaluation. Chemical results will be evaluated to identify sampling and processing methods that ensure safety and nationally consistent, defensible data. Key water-quality constituents will be identified for future investigations in areas of energy development.

Collection of produced water from a Bakken Formation oil well (August 2014).

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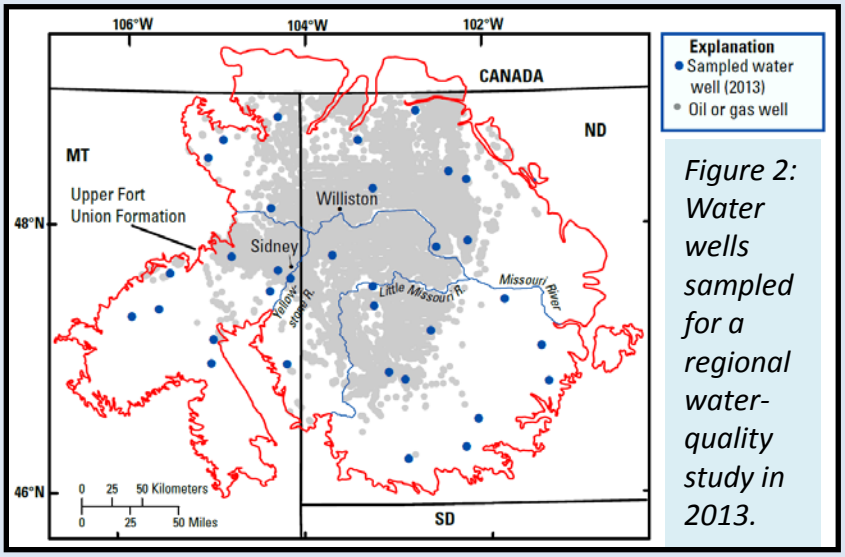

Figure 2: Water wells sampled for a regional water-quality study in 2013.

Water-quality sample collection from a domestic well completed in the Fort Union Formation (September 2013)

Proposed Work

The objective of this study is to more broadly characterize the quality of water resources related to the life cycle of production of tight oils of the Williston Basin. There is a need to complete the baseline evaluation of ambient surface and ground waters because these are the basic sources of hydraulic fracturing fluid and also the waters potentially vulnerable to produced water releases. There is also a need to distinguish between water generated from the development and production in the Bakken and the Three Forks Formations. The following activities address information gaps needed to complete the project goals:

- Baseline water-quality assessments of surface-water and groundwater.
- Water-quality assessment of produced waters from the Bakken and Three Forks Formations using methods defined from prior work. Sample additional oil wells to characterize the range of chemical and isotopic compositions and quantities (volumes) of "end-member" produced water.
- Sample and characterize hydraulic fracturing fluids and early produced water (flowback water) consisting of formation water mixed with hydraulic fracturing fluids over a "time series" (i.e. day 10, 30, 60, 90, 180, 365 after hydraulic fracturing).
- Baseline water-quality assessments of waste water resulting from energy production activities.

Collaborators/Stakeholders

This work has included the extensive collaboration between personnel at the USGS Water Science Centers (Greg Delzer, Joel Galloway, Rod Caldwell, Peter Wright, and Bill Damschen), the Energy Resource Program (Tanya Gallegos and Colin Doolan), the Crustal Geophysics and Geochemistry Center (Zell Peterman and Tom Oliver), and safety specialists (Paul Callao and Bill Simonds). Stakeholders include private citizens, industry, the Montana Bureau of Mines and Geology, and the Montana Department of Environmental Quality.

References

Lico, M.S., Kharaka, Y.K., Carothers, W.W., and Wright, V.A., 1988, Methods for collection and analysis of geopressured geothermal and oil field waters: U.S. Geological Survey Water Supply Paper 2194, 21 p.

McMahon, P.B, Caldwell, R.R., Galloway, J.M., Valder, J.F., and Hunt, A.G., 2014, Use of Geochemical Tracers to Improve Understanding of Groundwater Dynamics in the Williston Basin, Montana and North Dakota: [abs] : Geological Society of America, Rocky Mountain and Cordilleran Joint Meeting (19–21 May 2014).

Peterman, Z.E., Thamke, J., Neymark, L.A., Oliver, T.A., and Futa, K., 2014, Bakken Formation water salinity and the role of ion filtration, Williston Basin, [abs] : Geological Society of America, Rocky Mountain and Cordilleran Joint Meeting (19–21 May 2014).

Sample collected from the well head of a Bakken Formation oil well including highly saline produced water with a layer of oil.

Sample collected from an oil/water separator – water chemistry will be compared to samples collected at the well head.

The Wyoming-Montana Water Science Center is headquartered in Helena, Montana and includes four hydrologic field stations in Montana and two field stations and a project office in Wyoming (Center Director: John Kilpatrick, 406-457-5902, jmkilpat@usgs.gov).