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Chapter A of
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Scientific Investigations Report 2017–5070–A

U.S. Department of the Interior
U.S. Geological Survey

Front cover. An oil well pump jack in a grassland in Stark County, North Dakota. Photograph by Larry D. Igl, U.S. Geological Survey.

Back cover. An oil well pump jack in a grassland in Fallon County, Montana. Photograph by Larry D. Igl, U.S. Geological Survey.

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Potential Effects of Energy Development on Environmental Resources of the Williston Basin in Montana, North Dakota, and South Dakota—Executive Summary

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Executive Summary

The Williston Basin, which includes parts of Montana, North Dakota, and South Dakota in the United States and parts of Manitoba and Saskatchewan in Canada (see Vining and others, 2022 [chapter B of this report], fig. 1), has been explored as a potential source of energy resources since the early 20th century; however, commercially viable petroleum drilling and recovery began in earnest in the 1950s. When oil prices rose in the mid-1980s, the number of wells also increased and then subsequently declined (Peterson, 1995; Tangen and others, 2014). Interest in the Williston Basin increased again in the mid-2000s with the application of new drilling technology. Since then, development has increased rather quickly (Tangen and others, 2014). Most of this new development has been facilitated by advances in horizontal drilling and hydraulic fracturing technologies (Gaswirth and others, 2013). The North Dakota Department of Mineral Resources reported an increase of more than 10,000 producing wells between 2000 and the spring of 2016 (North Dakota Industrial Commission Oil and Gas Division, 2016). In total, 84 percent of those 10,000 wells target the Bakken Formation, which is now home to one of the Nation's largest energy booms. Current estimates suggest that exploration and drilling activities are expected to continue for the next 20 to 50 years (Mason, 2012); however, future activity will likely ebb and flow in response to energy prices.

Although most energy has been developed on non-Federal property, more than 2,000 wells were started on federally managed lands in the three States that contain the Williston Basin between 2004 and 2015 (Bureau of Land Management, 2016), though these numbers do not reflect whether or not these wells targeted the Bakken Formation. Executive Order no. 13604 (March 22, 2012) directs Federal agencies to improve the timeliness of the permitting process for extracting publically owned minerals, while minimizing negative environmental effects. This means that Federal agencies need information about how energy development may affect other resources they are tasked with managing. One example of where information about potential effects of development may be useful is the Bureau of Land Management's permitting process. Permits may include stipulations or special conditions that limit unforeseen negative consequences or ameliorate potential conflicts of future development. Federal agencies also need to coordinate permitting actions to ensure that development complies with existing regulations (for example, the Endangered Species Act [16 U.S.C. § 1531 et seq.] or the National Environmental Protection Act [42 U.S.C. § 4321 et seq.]) without unnecessarily restricting or delaying development. Part of this coordination entails agreeing on the information that will be used to assess the potential effects of energy development, which should also improve efficiency of the permitting process. Within the Williston Basin, a group of Federal agencies called the Bakken Federal Executive Group (Vining and others, 2022, table 1) is developing coordination strategies for numerous energy-related issues on Federal lands. This report was developed in cooperation with the Bureau of Land Management to provide them with the best available scientific information to support documentation of potential effects on resources that Federal agencies manage. This report summarizes information about the effects of energy development on air, water, and biological resources within the U.S. part of the Williston Basin.

The topics discussed in the report were based on a prioritized list of information needs elicited from the Bakken Federal Executive Group (app. A1). The list was developed using a process known as structured decision making or decision analysis (Gregory and others, 2012). This process began with an initial scoping workshop to determine the range of decisions made by those involved directly in managing energy development and resources on public land. U.S. Geological Survey staff then developed a simple quantitative ranking tool to assess which information needs were of greatest importance to those decisions (app. A1).

Principal Findings

Based on this ranking, the report was divided into four chapters (A–D). This chapter (chapter A) provides an executive summary of the report and principal findings from chapters B–D. Chapter B (Vining and others, 2022) provides a brief compilation of information regarding the history of energy development, physiography, climate, land use, demographics, and related studies in the Williston Basin. Chapter C (Bartos and others, 2022) synthesizes current information about water resources, identifies potential effects from energy development, and summarizes research and information needs in the Williston Basin. Chapter D (Post van der Burg and others, 2022) summarizes information about ecosystems, species of conservation concern, and potential effects to those species from energy development in the Williston Basin. Below are summaries (principal findings) of chapters B–D of this report.

Physiography, Climate, Land Use, and Demographics

Topographically, the Williston Basin is a large, roughly circular depression that covers several hundred thousand square miles across parts of the Great Plains of North Dakota, South Dakota, Montana, and parts of the Canadian provinces of Manitoba and Saskatchewan (North Dakota Geological Survey, n.d.; Vining and others, 2022, fig. 1*A*). The basin lies almost entirely within the glaciated and unglaciated areas of the Missouri Plateau of the Great Plains physiographic region (Fenneman, 1931; Keefer, 1974), and is a major source of coal, oil, and natural gas. Major rivers in the area include the Missouri, Yellowstone, Little Missouri, and Souris Rivers (Vining and others, 2022, fig. 2).

The climate of the Williston Basin is characterized by large temperature variations and light to moderate irregular precipitation (Enz, 2003; Potts, 2011; Todey, 2011). Its location at the geographic center of North America results in a strong semiarid to continental climate controlled by the mountains to the west (Enz, 2003). Climate and wildfires have been essential in shaping natural grassland and wetland communities (Kantrud, 1986; Anderson, 1990). More recent land-use practices in the Williston Basin have also developed in response to climate and other natural processes, as well as changes in lifestyles and technological advancements; for example, hydrological processes have been altered because many wetlands and soils were drained for agricultural purposes. Activities associated with energy development affect only a small percentage of the land in the Williston Basin, but these activities can affect alternate uses for the land. The usability of small parts of land for agriculture or other activities also can be quickly altered by spills of oil, brine, and other chemicals (North Dakota Department of Health, 2015). Aside from effects on land use, concerns about the effects of energy development on other resources also have been raised. For instance, air-quality awareness has increased in the Williston Basin as a result of energy exploration. Emissions during well drilling and completion activities may be intensive and continue for weeks or months, whereas emissions during production activities may be less intense but could continue for years. Energy development activities also have been recognized as affecting local communities. Human populations in parts of the Williston Basin have increased because of new economic opportunities (U.S. Census Bureau, 2015). The population of four North Dakota counties near the center of energy development activities (Dunn, McKenzie, Mountrail, and Williams Counties; Vining and others, 2022, fig. 1) has increased about 43 percent from 2010 to 2014. The population changed less dramatically in counties in Montana and South Dakota. The cities of Williston and Watford City, North Dakota, have had population increases of about 67 and 128 percent, respectively, from 2000 to 2013 (Census Viewer, 2012; City-Data, 2015).

In response to questions about the potential effects of energy development on natural resources within the Williston Basin, the U.S. Geological Survey has been coordinating numerous studies since 2008 (Vining and others, 2022). Investigations have included unconventional oil and gas assessments, water quality, water availability, air quality, effects on human health, and ecological effects. Vining and others (2022) summarizes these studies, as well as many others. In chapter B (Vining and others, 2022), read more about these studies, physiography, climate, land use, and demographics of the Williston Basin.

Water Resources

Water resources in the Williston Basin include groundwater; streams and rivers; and lakes, reservoirs, and wetlands. This chapter characterizes and describes these water resources in terms of physical occurrence, flow characteristics, recharge, water quality, and water use. The first part of this chapter describes groundwater and surface-water (rivers and streams) resources. Groundwater resources are described in terms of hydrogeologic units, and a generalized groundwater budget and flow system for each unit is presented (Bartos and others, 2022 [chapter C of this report], tables 1 and 2, figs. 3–10 and 12–14). For surface-water resources, a subset of rivers and streams are characterized in terms of daily, monthly, and annual mean flow. The extreme flow values provide information on short term or extreme events that are relevant to infrastructure design and evaluating spills, leaks, or accidental discharges of water or products. The spatial distribution of the surface-water features and their proximity to energy development infrastructure also are presented. The proximity of the surface-water features to energy development infrastructure (specifically oil well pads) was evaluated. It was determined, that while oil wells are often located near a surface-water feature, the majority of surface-water features do not have wells in close proximity, with the exception being in the Prairie Pothole Region (Bartos and others, 2022, table 6).

Information is summarized about the quality of surface water and groundwater resources. Using aggregated water-quality data, the spatial distribution of constituents, the temporal variability of constituents, and comparisons of the constituent concentrations measured to U.S. Environmental Protection Agency drinking-water standards are presented (Bartos and others, 2022, tables 8–10, figs. 28, 35–36, and 44–47). Available data regarding produced waters were aggregated, which determined that produced waters are characterized by extreme salinity and contain elevated concentrations of other constituents that could negatively affect water and aquatic resources if released (Bartos and others, 2022, tables 14–15). Water-use data for energy production also was aggregated within the Williston Basin for coal, thermoelectric power, oil and gas, hydropower, biomass and biofuels, wind, geothermal, and solar data. Concerning oil and gas, a large amount of water is used for oil and gas well development and postprocessing. It was determined that an increased population in the Williston Basin area also led to increased public-water demand.

There is a need for improved potentiometric surface maps for glacial units, a uniform stream network coverage that spans the international boundary with Canada, and enhanced surface-water use information. Gaps in information were identified on ice-jam flooding and an understanding of the cumulative effects of largely undocumented stock and diversion dams. Although this study resulted in the aggregation of a large quantity of water-quality data, the availability of consistently collected, systematically processed and reported data over large parts of the Williston Basin are limited. Few samples have been analyzed for constituents that may indicate the effect of energy development on water resources. Collaboration between Tribal, Federal, State, and local entities to identify common study designs, common monitoring constituents, and consistent sampling locations could generate datasets with broad utility for long-term monitoring. Additional characterization of produced water properties and the collection of time series to document the changes in produced waters during and after well development would also be useful. Likewise, water-use estimates could be improved through the implementation of comprehensive studies of water use from groundwater and surface-water sources using consistent methodologies across the basin. Consistent implementation of regulations and monitoring controls across political boundaries could further improve the consistency of data available for the estimates of water use. In chapter C (Bartos and others, 2022), read more about these research and information needs and the water resources of the Williston Basin.

Species of Conservation Concern

The ecosystems of the Williston Basin provide direct and indirect benefits to society (see Post van der Burg, 2022 [chapter D of this report], “Ecosystems of the Williston Basin” section). These benefits include carbon sequestration, flood control, nutrient rich soils for agricultural productivity, and habitat for wildlife. The main focus of Post van der Burg (2022) is on the potential effects of energy development on species of conservation concern that occupy the ecosystems in the Williston Basin. A list of documented species of conservation concern was compiled that are of most interest to Federal regulators and resource managers (Post van der Burg, 2022, app. D1). Species of conservation concern were either listed as endangered or threatened under the Endangered Species Act or listed by States as species of concern in Natural Heritage Program checklists or State Wildlife Action Plans. In total, 361 species of conservation concern (including 67 species of nonnative plant) likely occupy the Williston Basin area. These species represented seven different taxonomic groups: plants (native and nonnative), terrestrial invertebrates, birds, mammals, reptiles and amphibians, and fish and mussels (Post van der Burg, 2022, “Species of Conservation Concern in the Williston Basin” section).

Existing scientific information was reviewed pertaining to potential effects of energy development on these taxonomic groups (Post van der Burg, 2022, “Potential Effects of Energy Development on Species of Concern” section). Currently, little is known about the abundance and distribution of many of these species. Some information exists that may be useful in predicting the potential effects of energy development on certain taxonomic groups. Most of this information has been developed through scientific research focused on effects to mammal and bird populations. Effects to other taxonomic groups seems to be understudied. In general, it seems that disturbances and modifications associated with energy development have the potential to negatively affect a wide range of species; however, many studies produce uncertain results because they are not designed to compare populations before and after energy development takes place. Most of these studies also did not monitor resources over multiple years and thus cannot detect population trends. Likewise, there are few examples of landscape-scale assessments of the cumulative effects of energy development that could be used for species or habitat management purposes. More research may be needed to measure potential effects on a broad range of species in multiple taxonomic groups. This may require also developing some understanding about the basic ecology of many of the species covered in this report. In concert with this more basic research, more comprehensive assessments of potential negative cumulative effects across the Williston Basin could be developed in an effort to guide more strategic management of biological resources in the basin. In chapter D (Post van der Burg, 2022, read more about these information needs, ecosystems, species of conservation concern, and potential effects of energy development on these species of the Williston Basin.

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Appendix A1. Administrative Report—Summary of Scoping Process for Bakken Environmental Status and Trends (BEST) Report

The administrative report for this study is available for download at https://doi.org/10.3133/sir20175070A.

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