

U.S. Geological Survey Water Resource Assessments in Areas of Energy Development in the Williston Basin

Lower Missouri River Basin Advisory Council Meeting
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Topics covered

- Historic assessments of water resources in the area
- Recent studies in areas of energy development
- Other energy-development related activities



Williston Structural Basin

- Large geographic area, covering nearly 300,000 square miles
- Leading oil and natural gas producing region since the 1950s
- Development from deep formations such as the Bakken and Three Forks Formations has been rapidly increasing due to advances in identification, exploration, and recovery techniques



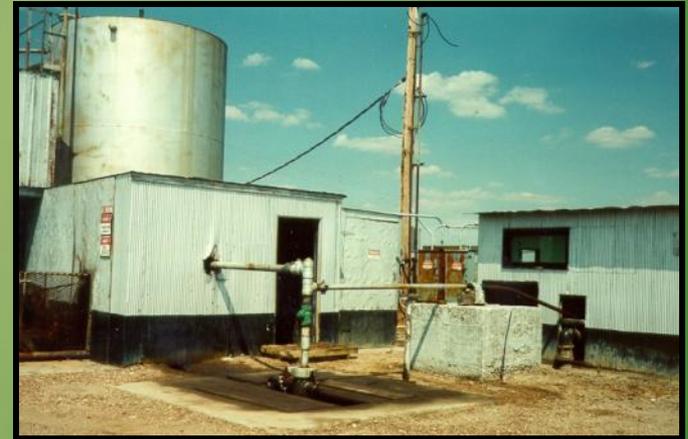
Potential issues related to water quality

- Potential for increased mobilization of naturally-occurring elements
- Accidents (vehicle, rail), spills or discharges of production water, product, or hydraulic fracturing fluid
- Infrastructure failure (production well or distribution system) resulting in release of product or produced water
- Increased population (disposal of waste water, change in land use)



East Poplar oil field/City of Poplar

- Study of brine impacts to groundwater
- History of activity
 - Oil production began in 1952
 - Field still in operation
- On going study with the Fort Peck Tribes Office of Environmental Protection (FPOEP)



Brine-injection well



Oil-producing well



Brine-disposal/evaporation
pit

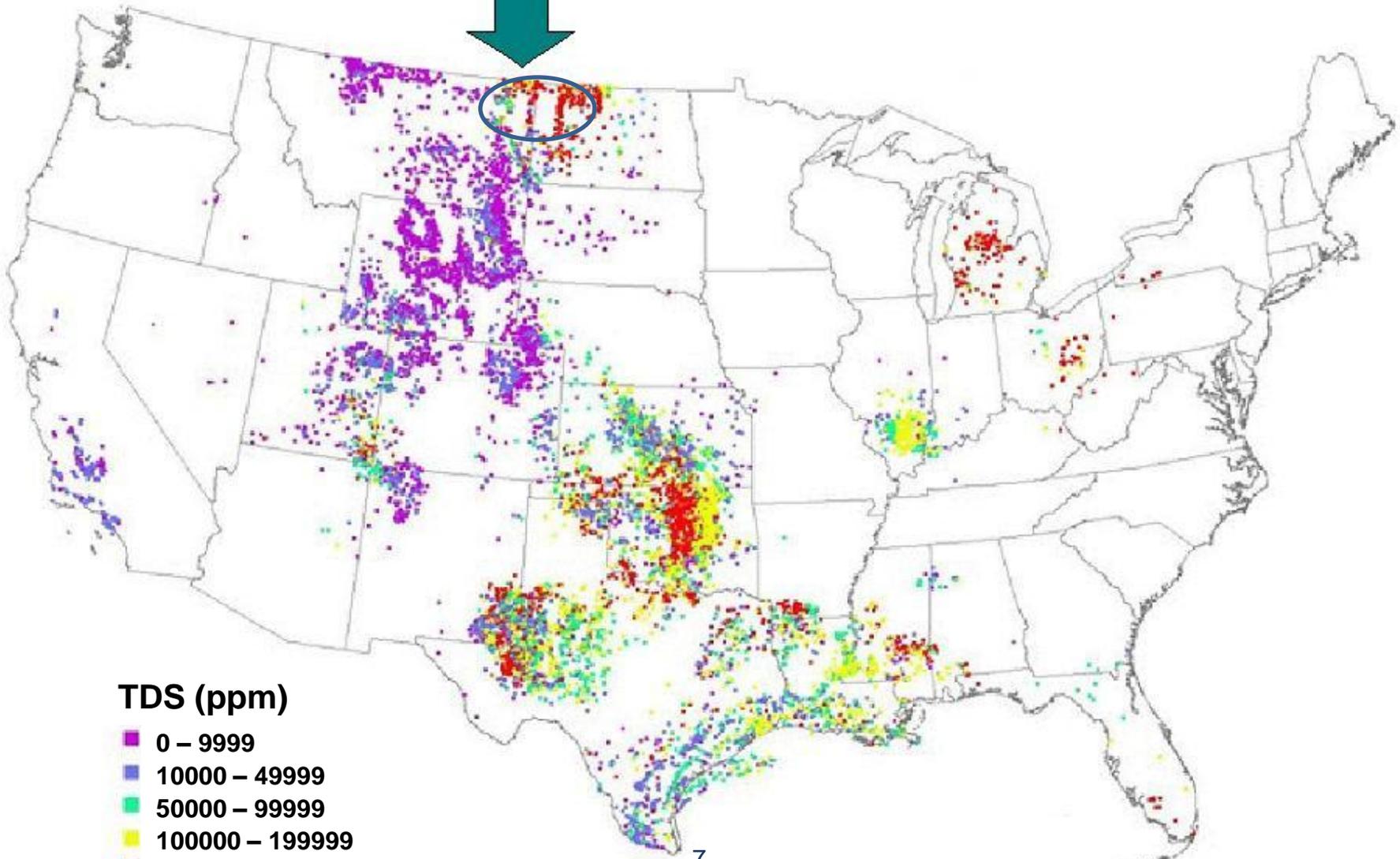
Documented sources of brine contamination

- Reserve/evaporation pits
 - Used to store drilling fluids and co-produced water
 - Unlined prior to the early-1980's and “spider-legged” until the early-1990s
- Well casing failures/corrosion
- Pipeline leaks and failures



Chemistry of oil-field brine in the United States

Approximate location of study area

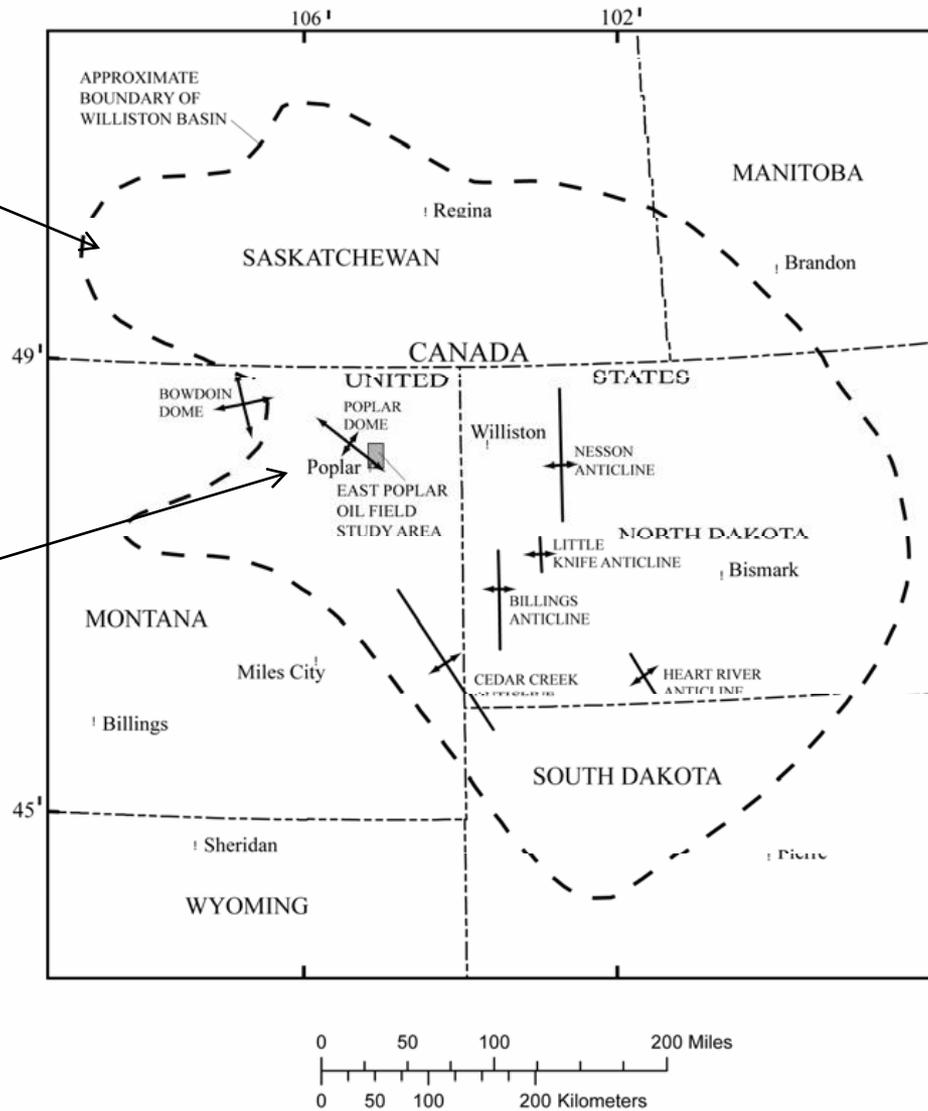


TDS (ppm)

- 0 – 9999
- 10000 – 49999
- 50000 – 99999
- 100000 – 199999
- 200000 – 460000

Williston Basin

City of Poplar



Use of multiple hydrologic and geophysical methods



Water-quality samples



Helicopter-borne
Electromagnetic
survey (HEM)



Borehole
geophysics

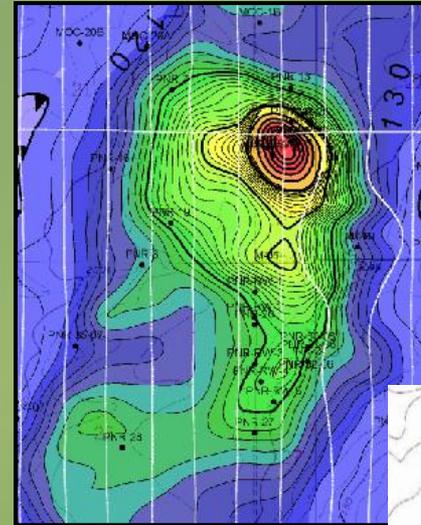


Ground EM
geophysics
surveys

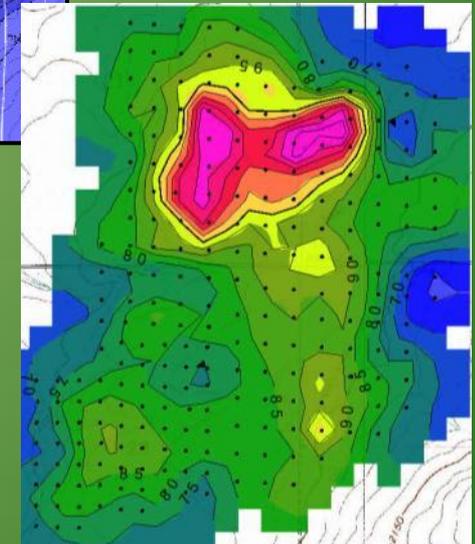


Electromagnetic dataset to map plume

- Geophysical data provide “snapshots” of brine plume
- Ground EM data: 1991-92, 2008, 2009, on-going monitoring
- HEM data: 2004
- Continued monitoring during remediation will guide effective removal of contaminated groundwater

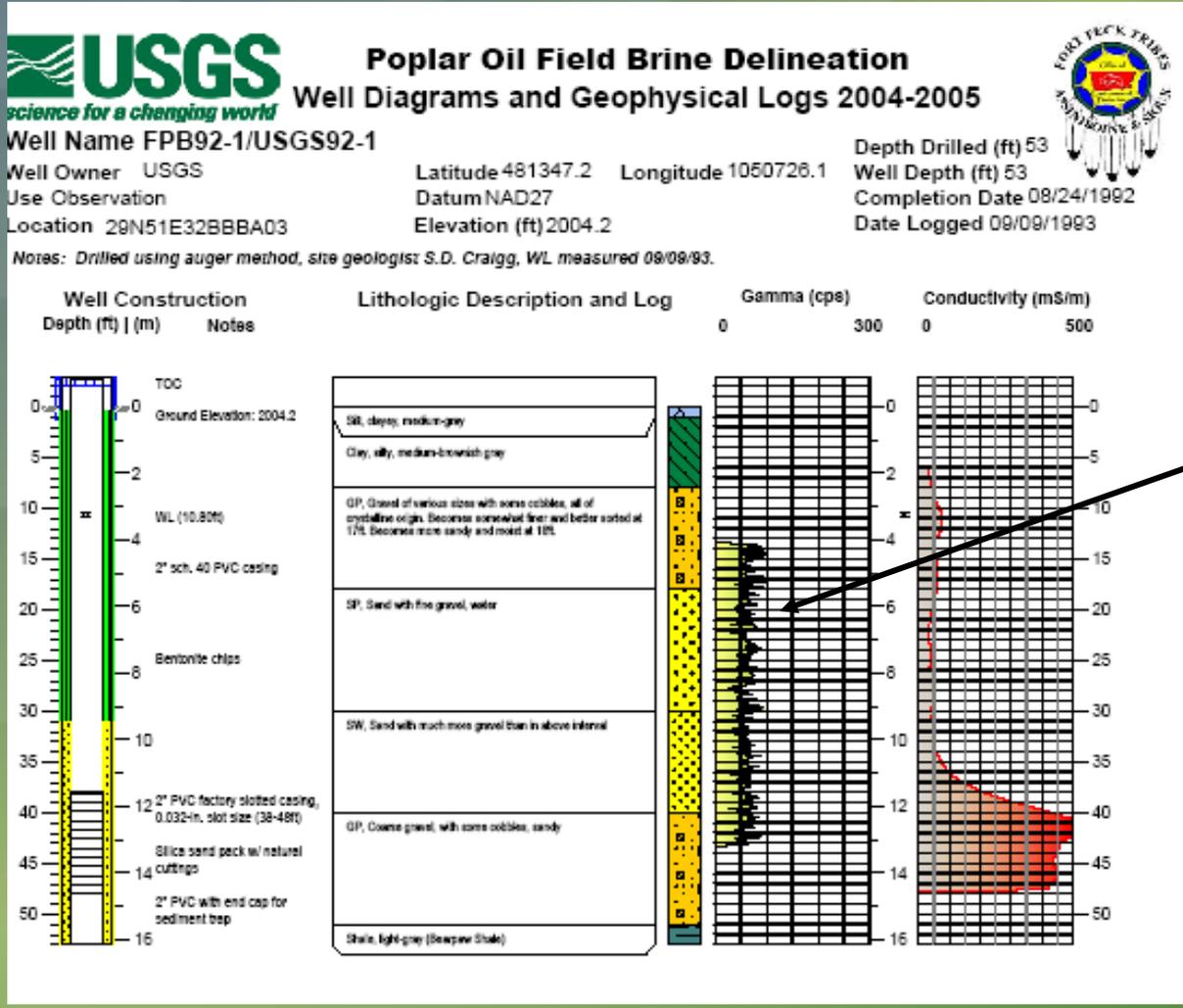


HEM data



EM34 data

Borehole geophysical data



- Used at specific locations to verify EM results

- Gamma indicates that geology is fairly uniform with depth

- Conductivity profile reflects the increased conductivity with depth

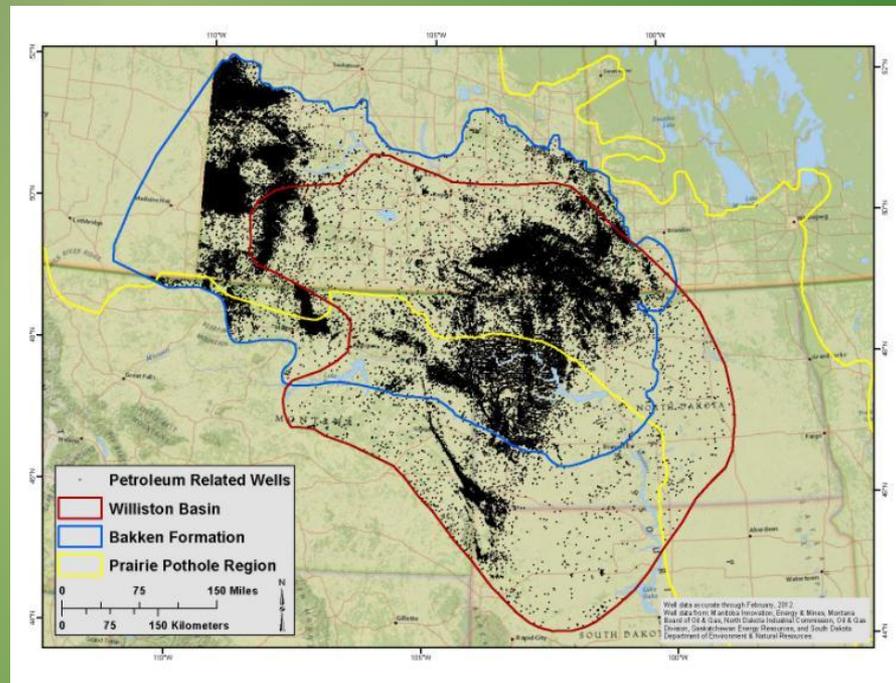
- In this example, groundwater becomes contaminated at depth

Water-quality types

Water type	Domestic water use	Concentration range (mg/L)	
		Chloride	Dissolved solids
Type 1--Uncontaminated groundwater	Suitable for most domestic purposes	1.5-250	427-5,500
Type 2—Moderately contaminated groundwater	Suitable for some domestic purposes; generally not used for drinking water	257-5,000	972-11,400
Type 3—Considerably contaminated groundwater	Unsuitable for domestic purposes	5,040-58,000	8,600-91,100
Type 4—Brine (from oil production)	Unused	19,100-120,000	37,882-201,000

Prairie Pothole Region

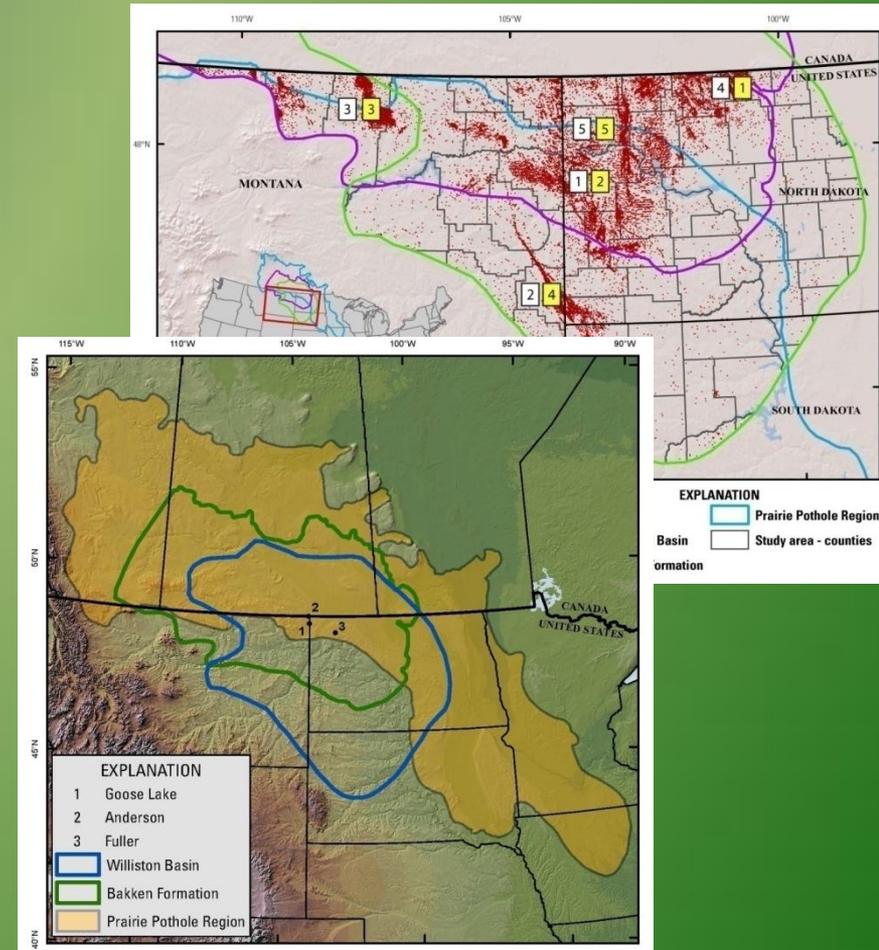
- Includes critical wetland and grassland habitats for breeding, nesting, and migrating waterfowl, and wetland and grassland birds
- Led to the project: ‘Brine Contamination of Prairie Potholes from Energy Development in the Williston Basin’
- Science Team about Energy and Prairie Pothole Environments (STEPPE)



<http://steppe.cr.usgs.gov/>

Brine Contamination to Prairie Potholes from energy development in the Williston Basin

- Evaluate the spatial extent and potential risk to natural resources from past and ongoing energy development in the Williston Basin using Geographic Information System (GIS) analyses
- Reassess brine contamination movement in pilot areas
- Conduct an analysis of user needs and design a decision support system



<http://steppe.cr.usgs.gov/>

Impacts of brine contamination on resources

Natural salinity = High sulfate



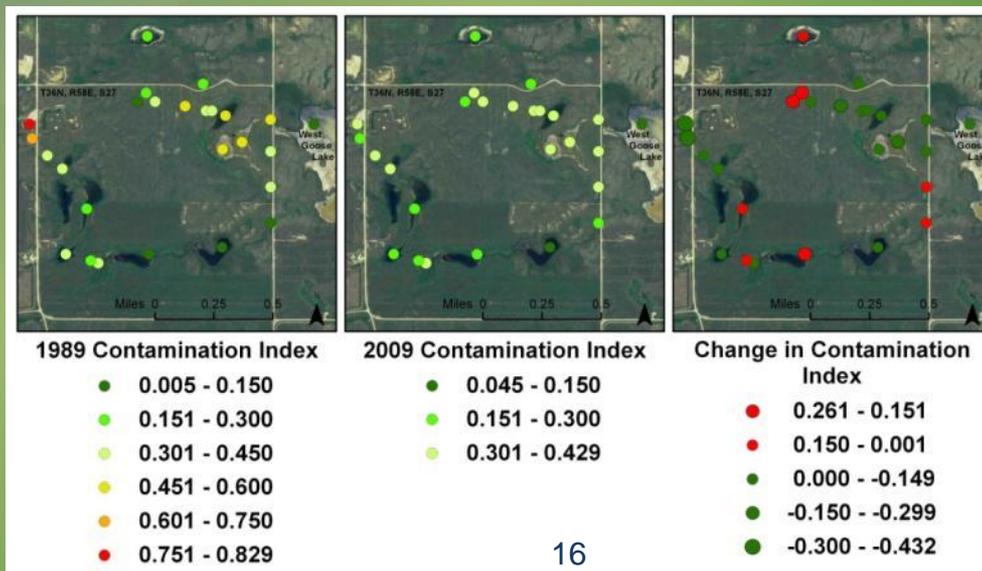
Oil-field brine salinity = High chloride



Salt crystals at naturally saline wetland

Using previous work

- Reiten and Tischmak, 1993 (MBMG)
 - Mapped the surficial geology of eastern Sheridan County
 - Sampled numerous wetlands and groundwater wells
 - Conducted geophysical surveys
- Developed a contamination index (CI)
CI = Chloride Concentration (mg/L)
Specific Conductance ($\mu\text{S}/\text{cm}$)
Values > 0.035 indicate contamination from oil field brine



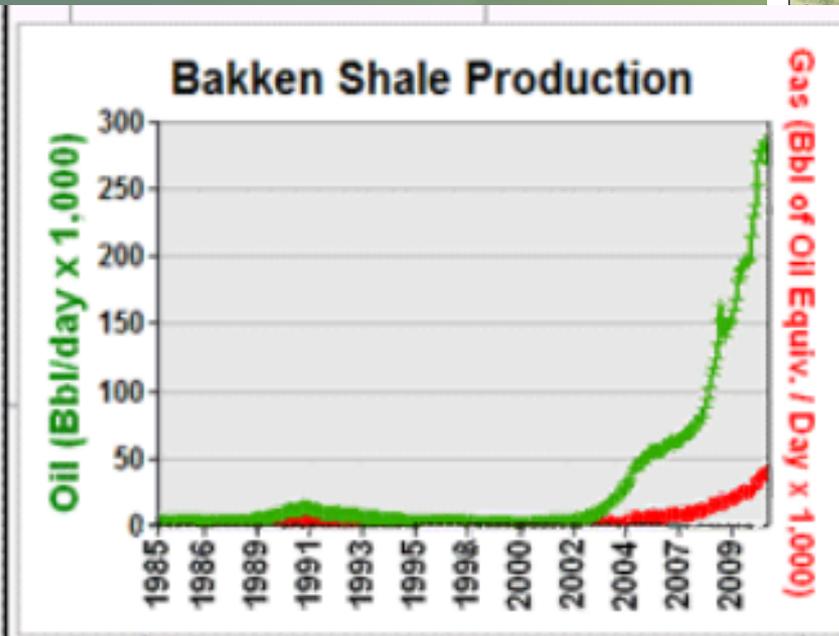
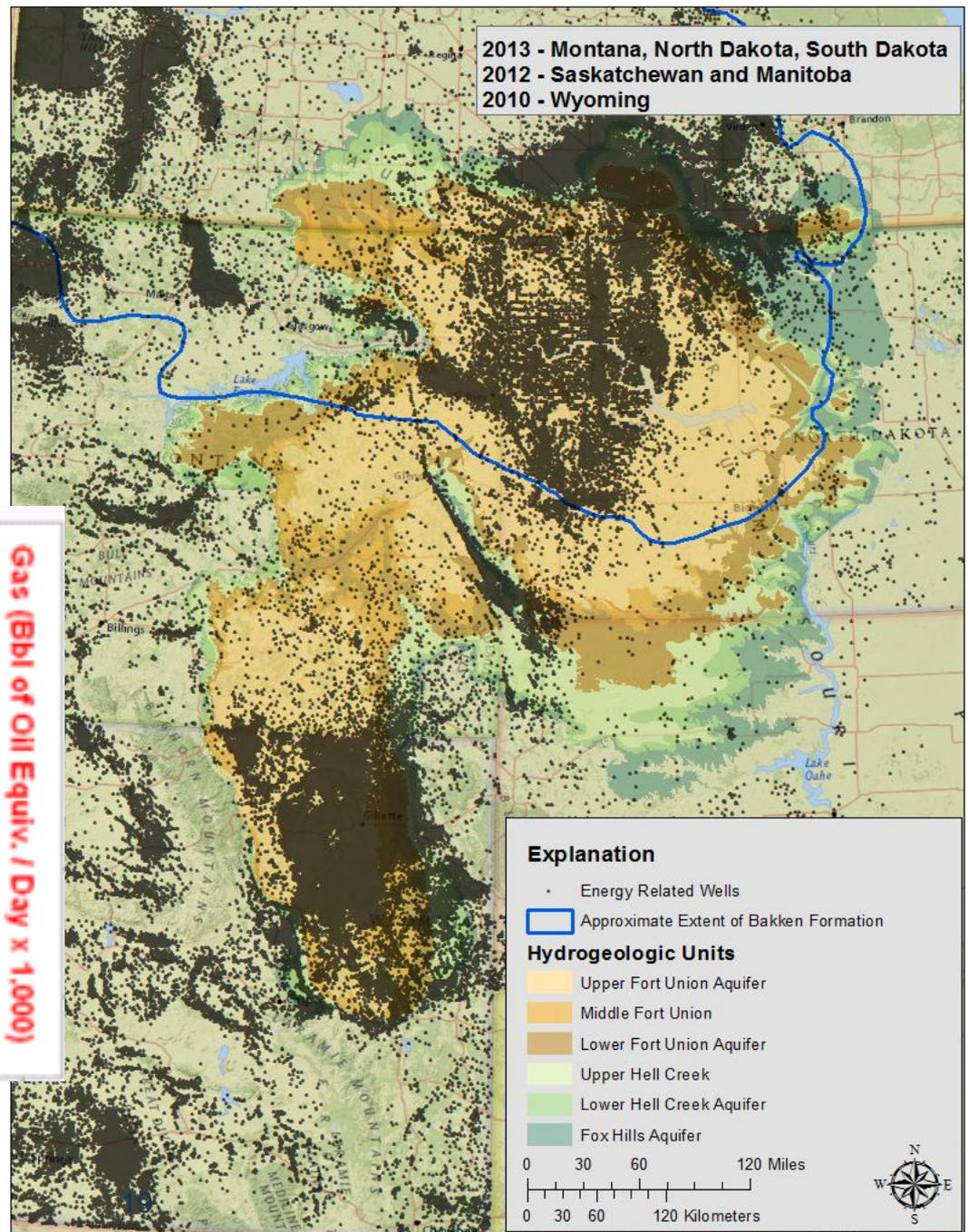
STEPPE projects related to water resources

- **GIS-Based Vulnerability Assessment of Brine Contamination to Aquatic Resources from Oil and Gas Development in Eastern Sheridan County, MT**
- **Developing maps depicting the biological impacts of brine contamination on wetlands of the Prairie Pothole Region**
- **Spatial characterization of wetland surface water contamination risk from oil development in the Prairie Pothole Region of North Dakota**
- **Comprehensive wetland assessment and monitoring program within the Lostwood Complex of northeast Montana and northwest North Dakota**
- **Landscape change, ecological impacts, and DOI information needs associated with energy production in the Williston Basin, Northern Great Plains**

Overall STEPPE Study Conclusions

- High levels of saline contamination are present consistently in the impacted wetlands
- Natural remediation is very slow
- Contamination can spread long distances (> 1 mile)
- Hundreds of thousands of wetlands are in close proximity to oil wells
- Need better understanding regarding impacts to biological communities
- Preliminary biological impacts will be evaluated using:
 - Rapid assessment techniques
 - Novel, plant focused, contamination indicators
 - Intensive sampling techniques on a subset of sites

Williston and Powder River Basins—energy-related wells 2013



Williston Basin baseline groundwater-quality assessment

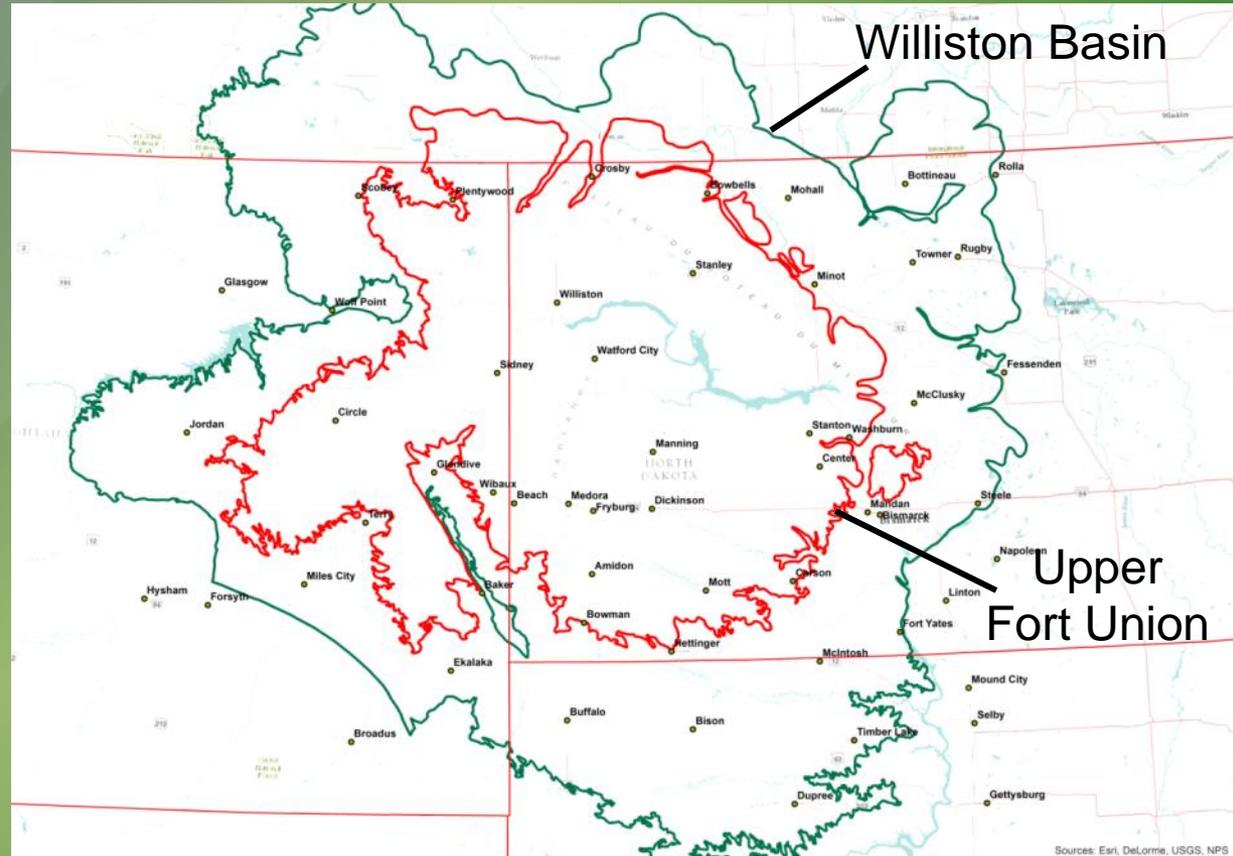
- Characterize current water-quality conditions of most used groundwater resources in the energy development area of eastern Montana and western North Dakota
- Regional study conducted with collaborative effort by USGS Water Science Centers in CO, MT, ND, and SD
- Coordination with other agencies



Williston Basin water-quality sampling

--Selection of the Upper Fort Union Formation

- Widely used domestic and municipal supply
- Historical datasets have limited suite of water-quality constituents
- Interest in understanding the interaction of groundwater between glacial deposits and upper Fort Union formation
- Numerous studies have focused on the Fox Hills and Hell Creek aquifers



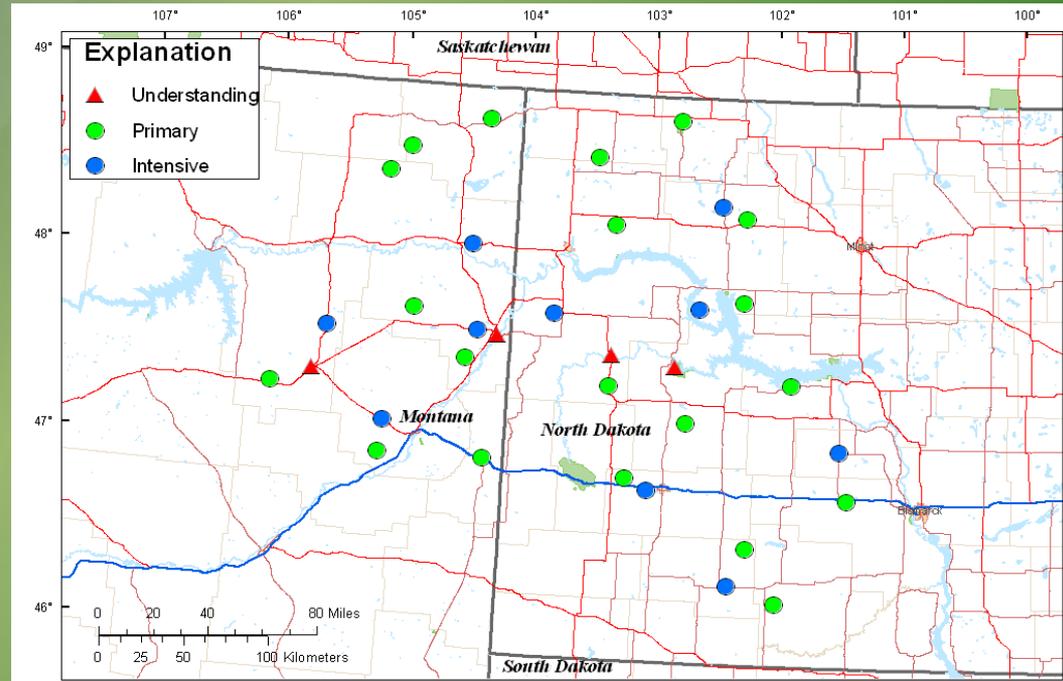
Williston Basin water-quality sampling

--Site selection

Thirty spatially located wells screened in the Upper Fort Union

- Twenty primary wells
- Ten intensive wells (expanded constituent list)

Four understanding wells screened in the Hell Creek or Fox Hills formations



Williston Basin water-quality sampling

- Primary/Baseline and Understanding well constituents include:
 - Inorganic constituents
 - Trace elements (metals)
 - Major ions
 - Uranium
 - Nutrients
 - Volatile organic carbons (VOCs)
 - Methane and ethane
 - Hydrogen and carbon isotopes of methane
 - Hydrocarbon gas composition (methane thru hexane)



Williston Basin water-quality sampling

- Intensive constituents include:
 - Baseline constituents PLUS:
 - Gasoline and diesel range organics
 - Dissolved organic carbon
 - Hydrogen, oxygen, and strontium isotopes
 - Sulfur hexafluoride
 - Dissolved and noble gases
 - Tritium
 - Carbon-14



Project status

- **Workplan development**
April-June, 2013
- **Project planning:**
June-August, 2013
- **Site reconnaissance and owner permissions:**
August-September, 2013
- **Sampling:**
August-September, 2013
- **Results**
Pending

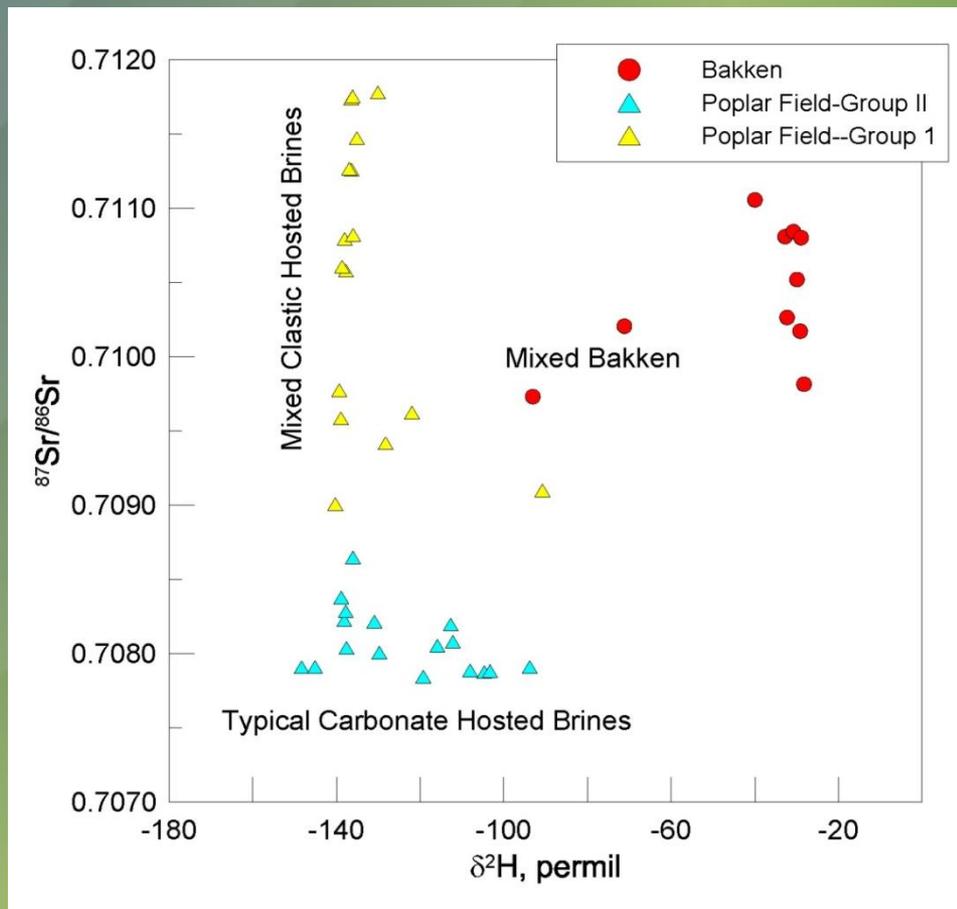


Baseline chemical and isotopic data for produced water from the Bakken Formation

- Sampling of production water from 8 wells
 - 3 in Montana
 - 5 in North Dakota
- Conducted in Fall 2012
- Water analyzed for
 - Major ions
 - Strontium
 - Trace Elements
 - Oxygen/Deuterium
 - Radium isotopes



Bakken Formation geochemistry



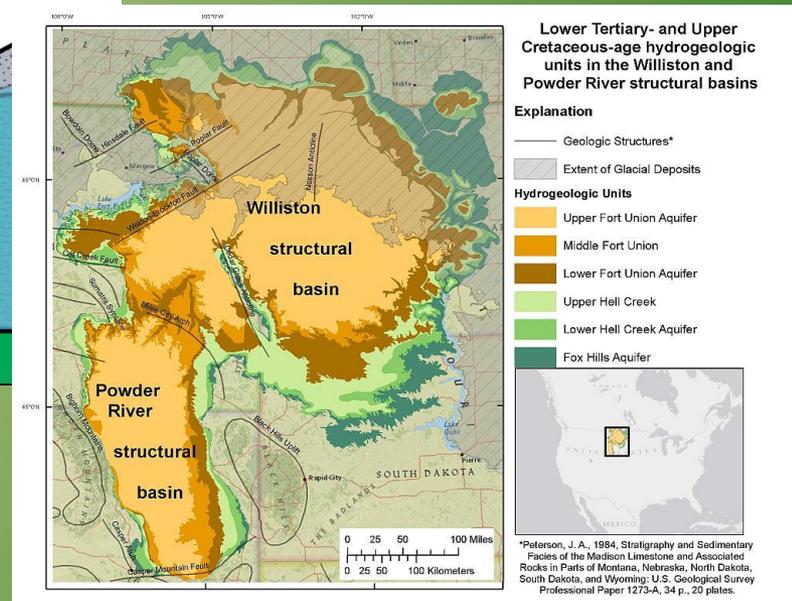
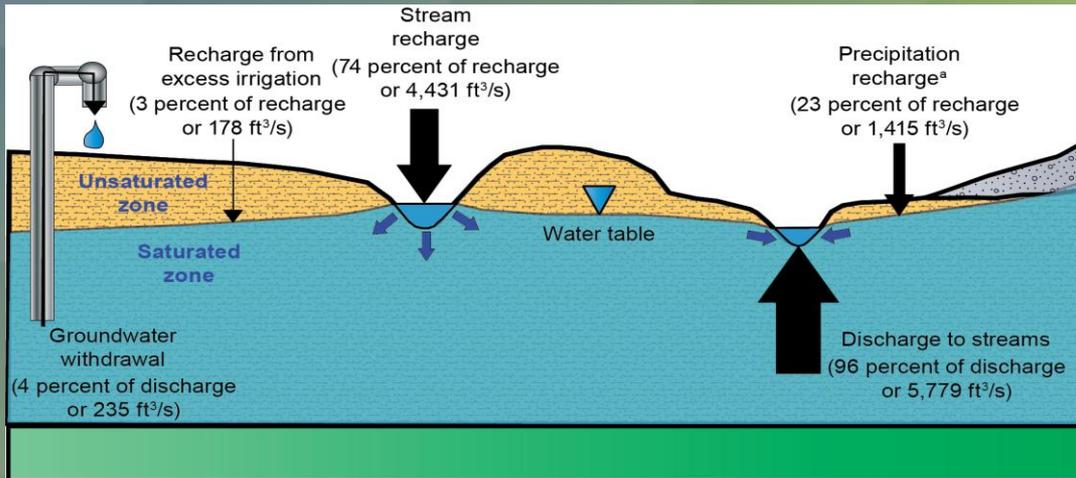
Isotopic signature of Bakken produced water differs from conventional marine wastewater

Bakken produced waters study: other notable results

- Extreme chlorinity of six of the eight samples (salinity is near saturation)
- Bakken waters have strontium concentrations that are significantly larger and distinguishable from most of the brines produced in the Williston Basin for the past 60 years
- Unique chemical and isotopic data may be useful in tracking the water produced from the Bakken Shale



Williston and Powder River basins groundwater availability study



Conceptual model and water budget:

- Develop a hydrogeologic framework,
- Estimate hydrologic budget components,
- Refine the conceptual model of groundwater flow,
- Within the Williston, numerically simulate the regional groundwater flow for the lower Tertiary and Upper Cretaceous aquifer system.

Other USGS activities related to energy development in the Williston:

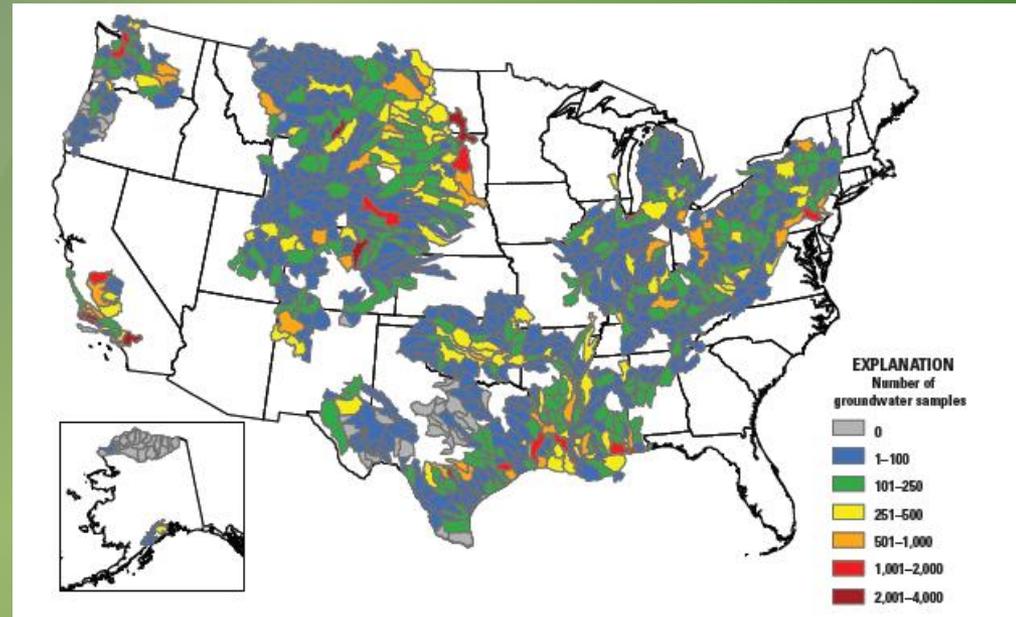
- **Quantifying water-use requirements for the variable conditions and processes associated with hydraulic fracturing within the Williston Basin in North Dakota, South Dakota, and Montana**
- **Analyses of water-quality data and resources on the Fort Berthold Reservation, North Dakota**
- **Establishment of a baseline groundwater monitoring program in areas identified for energy development on the Blackfeet Reservation, Montana**
- **Chemical characterization and isotopic indications of fluid flow in the Bakken Formation, Williston Basin**
- **Proposed: Characterizing waters related to hydraulic fracturing and production of tight-oil formations in the Williston Basin**
- **Proposed: Determination of travel times in streams in western North Dakota**

Other USGS activities related to energy development:

USGS Powell Center

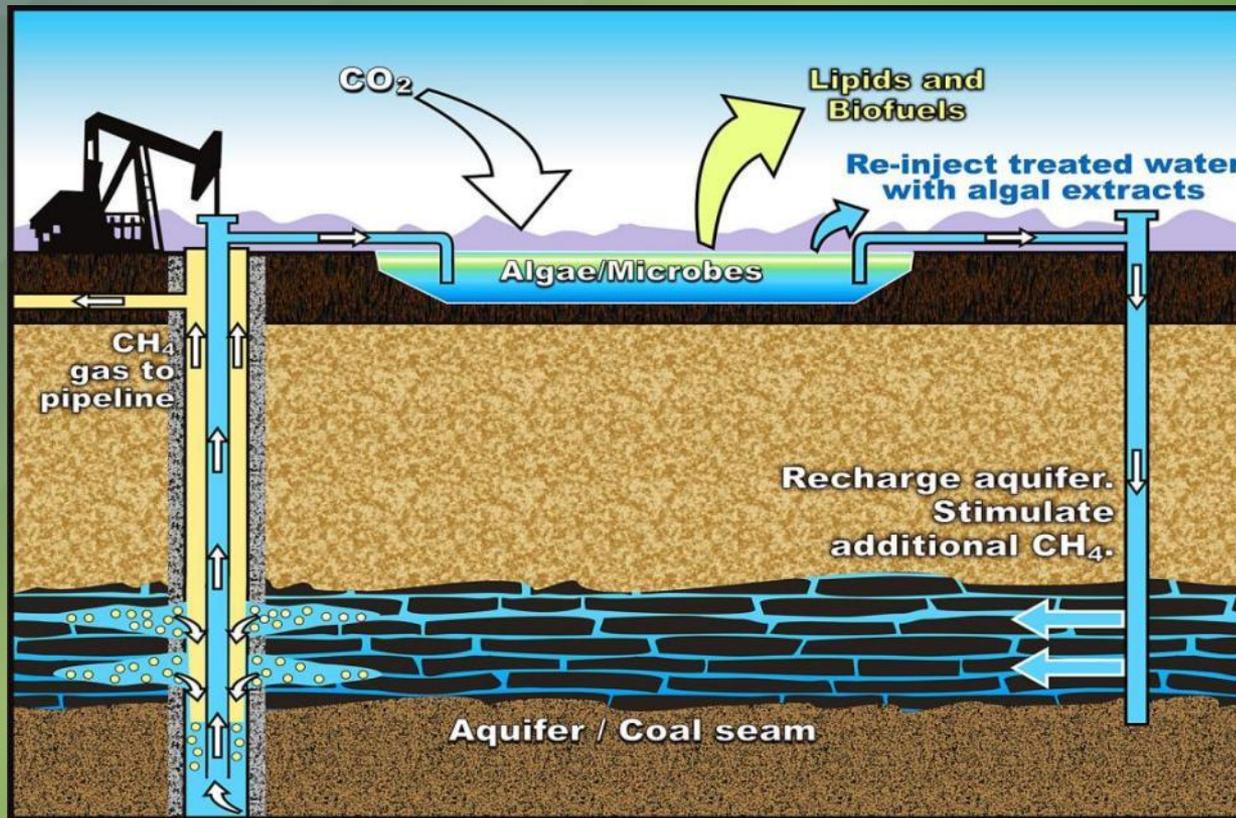
Interdisciplinary Workgroup

- Better understand hydraulic fracturing in the United States
- Broadly assess surface-water and groundwater quality in areas of unconventional oil and gas production
- Evaluate potential changes in water quality over time
- Identify spatial and temporal gaps water-quality data
- Identify future research needed to better understand the effects of oil and gas production and hydraulic fracturing on surface-water and groundwater quality



Other USGS activities related to energy development: Coal Bed Methane

USGS Energy Program/Montana State University
Enhanced natural gas production from coals



Questions?

