EERC Technology… Putting Research into Practice

Northern Great Plains Water Consortium (NGPWC)

North Dakota Legislative Council Energy Development and Transmission Committee Meeting
September 16, 2009
EERC
Grand Forks, ND

Northern Great Plains Water Consortium

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NATIONAL ENERGY TECHNOLOGY LABORATORY

Background

- Water is the most critical limiting resource throughout the world.
- Sustainable water supplies are needed for:
  - Energy production.
  - Growing and processing high-value crops.
  - Industrial manufacturing.
  - Expanding populations.

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NGPWC

- The Energy & Environmental Research Center (EERC) has developed a partnership between the U.S. Department of Energy and key stakeholders, representing electrical power generation utilities, oil and gas companies, industry, municipalities, and other interested entities to address critical issues that impact the water resources of the northern Great Plains region.

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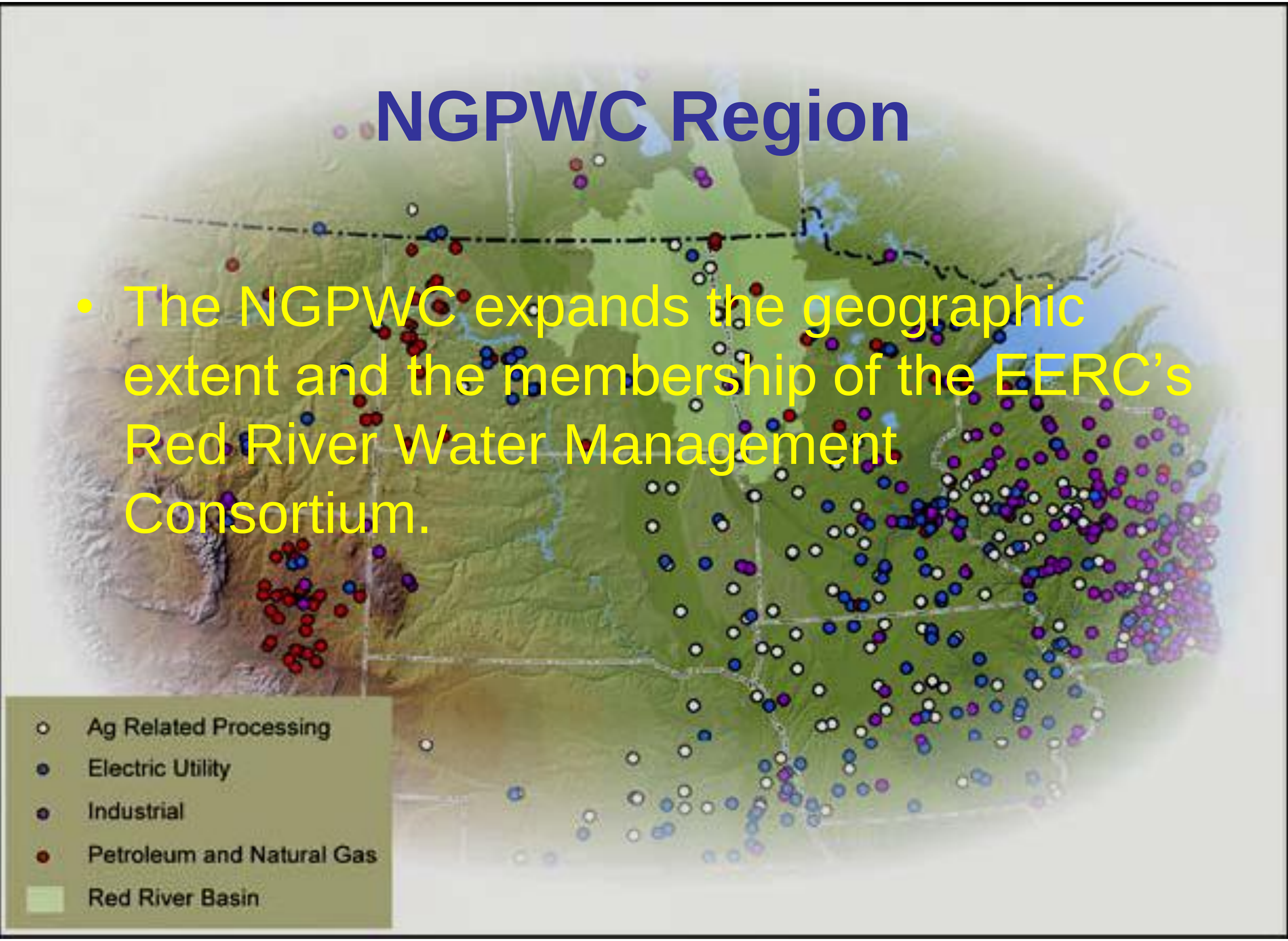
NGPWC Region

- The NGPWC expands the geographic extent and the membership of the EERC's Red River Water Management Consortium.



NGPWC Goals and Objectives

- The overall goal of this program is to assess, develop, and demonstrate technologies and methodologies that minimize water use and reduce impacted water discharges from a range of energy technologies, including coal combustion, coal gasification, coalbed methane, and oil and natural gas production.

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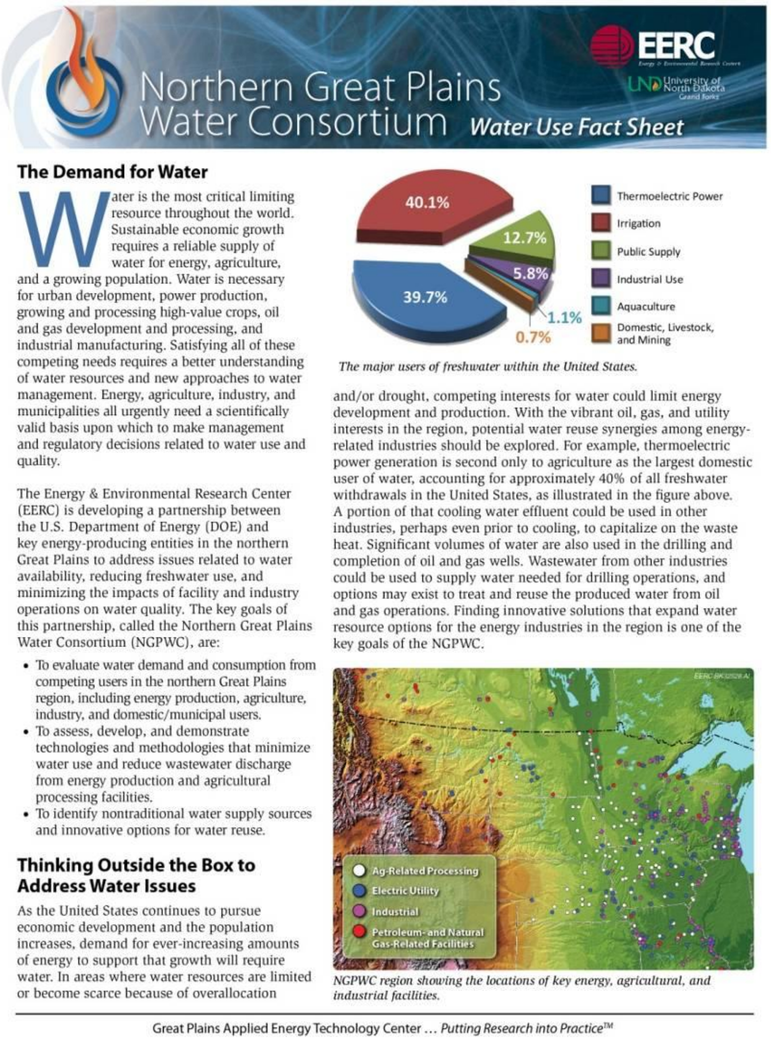
NGPWC Fact Sheets



Northern Great Plains Water Consortium *Water Use Fact Sheet*

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The Demand for Water

Water is the most critical limiting resource throughout the world. Sustainable economic growth requires a reliable supply of water for energy, agriculture, and a growing population. Water is necessary for urban development, power production, growing and processing high-value crops, oil and gas development and processing, and industrial manufacturing. Satisfying all of these competing needs requires a better understanding of water resources and new approaches to water management. Energy, agriculture, industry, and municipalities all urgently need a scientifically valid basis upon which to make management and regulatory decisions related to water use and quality.

The Energy & Environmental Research Center (EERC) is developing a partnership between the U.S. Department of Energy (DOE) and key energy-producing entities in the northern Great Plains to address issues related to water availability, reducing freshwater use, and minimizing the impacts of facility and industry operations on water quality. The key goals of this partnership, called the Northern Great Plains Water Consortium (NGPWC), are:

- To evaluate water demand and consumption from competing users in the northern Great Plains region, including energy production, agriculture, industry, and domestic/municipal users.
- To assess, develop, and demonstrate technologies and methodologies that minimize water use and reduce wastewater discharge from energy production and agricultural processing facilities.
- To identify nontraditional water supply sources and innovative options for water reuse.

Thinking Outside the Box to Address Water Issues

As the United States continues to pursue economic development and the population increases, demand for ever-increasing amounts of energy to support that growth will require water. In areas where water resources are limited or become scarce because of overallocation and/or drought, competing interests for water could limit energy development and production. With the vibrant oil, gas, and utility interests in the region, potential water reuse synergies among energy-related industries should be explored. For example, thermoelectric power generation is second only to agriculture as the largest domestic user of water, accounting for approximately 40% of all freshwater withdrawals in the United States, as illustrated in the figure above. A portion of that cooling water effluent could be used in other industries, perhaps even prior to cooling, to capitalize on the waste heat. Significant volumes of water are also used in the drilling and completion of oil and gas wells. Wastewater from other industries could be used to supply water needed for drilling operations, and options may exist to treat and reuse the produced water from oil and gas operations. Finding innovative solutions that expand water resource options for the energy industries in the region is one of the key goals of the NGPWC.

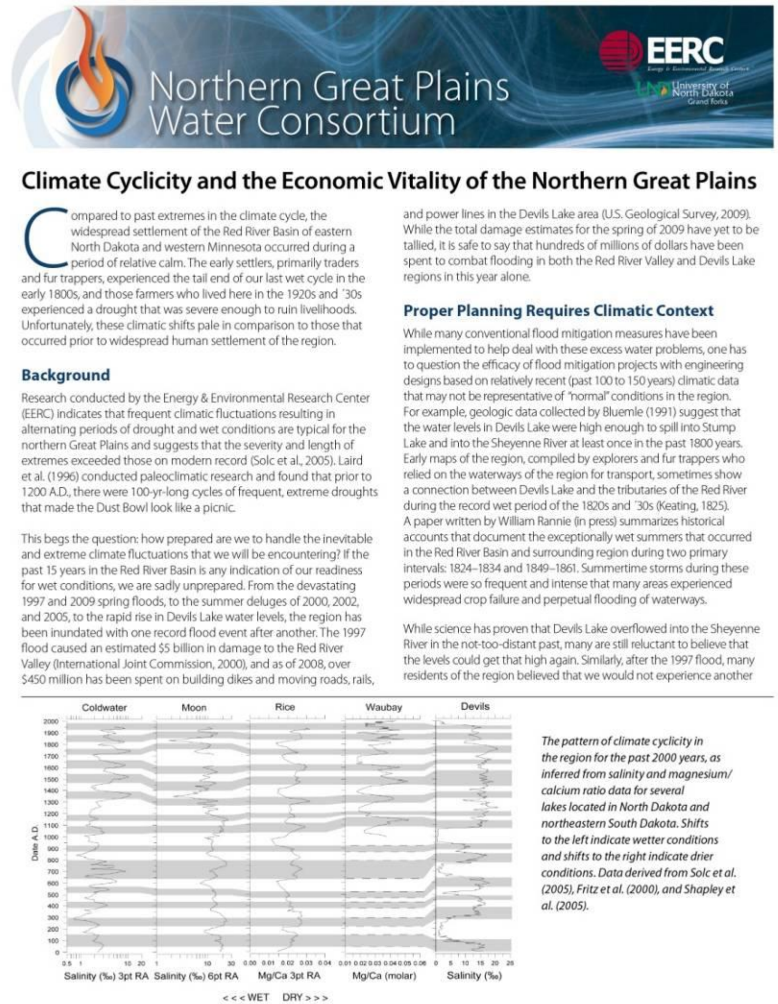
40.1%
12.7%
5.8%
39.7%
1.1%
0.7%
Thermoelectric Power
Irrigation
Public Supply
Industrial Use
Aquaculture
Domestic, Livestock, and Mining

The major users of freshwater within the United States.

Ag-Related Processing
Electric Utility
Industrial
Petroleum- and Natural Gas-Related Facilities

NGPWC region showing the locations of key energy, agricultural, and industrial facilities.

Great Plains Applied Energy Technology Center … *Putting Research into Practice*™



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Climate Cyclicity and the Economic Vitality of the Northern Great Plains

Compared to past extremes in the climate cycle, the widespread settlement of the Red River Basin of eastern North Dakota and western Minnesota occurred during a period of relative calm. The early settlers, primarily traders and fur trappers, experienced the tail end of our last wet cycle in the early 1800s, and those farmers who lived here in the 1920s and '30s experienced a drought that was severe enough to ruin livelihoods. Unfortunately, these climatic shifts pale in comparison to those that occurred prior to widespread human settlement of the region.

Background

Research conducted by the Energy & Environmental Research Center (EERC) indicates that frequent climatic fluctuations resulting in alternating periods of drought and wet conditions are typical for the northern Great Plains and suggests that the severity and length of extremes exceeded those on modern record (Solc et al., 2005). Laird et al. (1996) conducted paleoclimatic research and found that prior to 1200 A.D., there were 100-yr-long cycles of frequent, extreme droughts that made the Dust Bowl look like a picnic.

This begs the question: how prepared are we to handle the inevitable and extreme climate fluctuations that we will be encountering? If the past 15 years in the Red River Basin is any indication of our readiness for wet conditions, we are sadly unprepared. From the devastating 1997 and 2009 spring floods, to the summer deluges of 2000, 2002, and 2005, to the rapid rise in Devils Lake water levels, the region has been inundated with one record flood event after another. The 1997 flood caused an estimated $5 billion in damage to the Red River Valley (International Joint Commission, 2000), and as of 2008, over $450 million has been spent on building dikes and moving roads, rails, and power lines in the Devils Lake area (U.S. Geological Survey, 2009). While the total damage estimates for the spring of 2009 have yet to be tallied, it is safe to say that hundreds of millions of dollars have been spent to combat flooding in both the Red River Valley and Devils Lake regions in this year alone.

Proper Planning Requires Climatic Context

While many conventional flood mitigation measures have been implemented to help deal with these excess water problems, one has to question the efficacy of flood mitigation projects with engineering designs based on relatively recent (past 100 to 150 years) climatic data that may not be representative of "normal" conditions in the region. For example, geologic data collected by Bluemle (1991) suggest that the water levels in Devils Lake were high enough to spill into Stump Lake and into the Sheyenne River at least once in the past 1800 years. Early maps of the region, compiled by explorers and fur trappers who relied on the waterways of the region for transport, sometimes show a connection between Devils Lake and the tributaries of the Red River during the record wet period of the 1820s and '30s (Keating, 1825). A paper written by William Rannie (in press) summarizes historical accounts that document the exceptionally wet summers that occurred in the Red River Basin and surrounding region during two primary intervals: 1824–1834 and 1849–1861. Summertime storms during these periods were so frequent and intense that many areas experienced widespread crop failure and perpetual flooding of waterways.

While science has proven that Devils Lake overflowed into the Sheyenne River in the not-too-distant past, many are still reluctant to believe that the levels could get that high again. Similarly, after the 1997 flood, many residents of the region believed that we would not experience another

Coldwater
Moon
Rice
Waubay
Devils
Date A.D.
Salinity (‰) 3pt RA
Salinity (‰) 6pt RA
Mg/Ca 3pt RA
Mg/Ca (molar)
Salinity (‰)
< < < WET   DRY > > >

The pattern of climate cyclicity in the region for the past 2000 years, as inferred from salinity and magnesium/calcium ratio data for several lakes located in North Dakota and northeastern South Dakota. Shifts to the left indicate wetter conditions and shifts to the right indicate drier conditions. Data derived from Solc et al. (2005), Fritz et al. (2000), and Shapley et al. (2005).

NGPWC Fact Sheet

Northern Great Plains Water Consortium (NGPWC)

Water Use Fact Sheet

EERC Energy & Environmental Research Center

University of North Dakota Grand Forks

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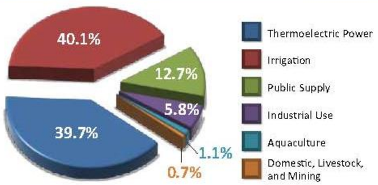

Figure 1. The major users of freshwater within the United States.

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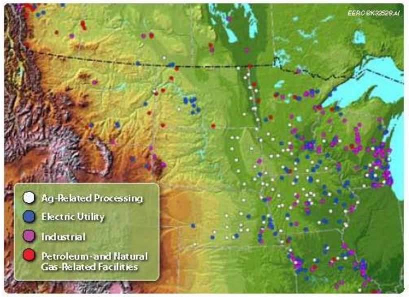

Northern Great Plains Water Consortium region showing the locations of key energy, agricultural, and industrial facilities.

Putting Regional Water Use in Perspective

The various industries and water users within the region often use different units of reference when referring to water consumption and discharge. To gain a perspective on the relationship between municipal, industrial, and agricultural water use, it is helpful to compare some common units and examples of water use among the sectors.

Approximate Volumetric Equivalents

barrels	gallons	acre-ft	cubic feet	cubic meters
1	42	0.000129	5.6146	0.15897
7,758	325,851	1	43,560	1,233
23,810	1,000,000	3.1	133,681	3,785

Conversion Factors

1 cubic foot = 7.4805 gallons
1 gallon = 3.785 liters
1 cubic meter = 1,000 liters
1 acre = 43,560 square feet

Approximate Flow Equivalents

barrels per day (bbl/day)	million gallons per day (Mgd)	gallons per minute (gpm)	cubic feet per second (cfs)	cubic meters per second (m^3/s)
23,810	1.0	694.4	1.55	0.04381
34.3	0.00144	1.0	0.0022	0.00006
100	0.0042	2.9167	0.0065	0.000184

Water Use Comparisons

Use	gallons (millions)	barrels (thousands)	acre-ft	cubic meters
Typical **daily** use for a 50,000-person midwestern city	10	238.1	30.7	37,850
Daily pumping volume for a center-pivot irrigator for 130 acres (¼ section)	1.008	24	3.1	3,815
Average **daily** water withdrawal for once-through cooling at a 400-MW coal-fired power plant	365	8,691	1,120	1,381,525
Water used to fracture the formation for an oil well in the Bakken Formation (**one-time use**)	0.5–1.0	11.9–23.8	1.5–3.1	1,893–3,785
Proposed maximum **daily** volume of water imported for the Red River Valley Water Supply Project	77.56	1,847	238	293,556

Interested in Joining?

The EERC is actively seeking charter members to complement secured DOE funding and to help direct the program's efforts. The NGPWC is currently engaged in Phase I of the program, wherein future program efforts and demonstration projects will be selected and prioritized. Phase II of the effort, scheduled to begin in 2009, will focus on demonstrating the water minimization and beneficial reuse strategies and technologies prioritized in Phase I.

The NGPWC is a partnership of key public and private water users in the northern Great Plains region. New members are welcome. To learn more, contact:

John A. Harju, EERC Associate Director for Research, (701) 777-5157
Daniel J. Stepan, Senior Research Manager, (701) 777-5247
Bethany A. Kurz, Senior Research Manager, (701) 777-5050

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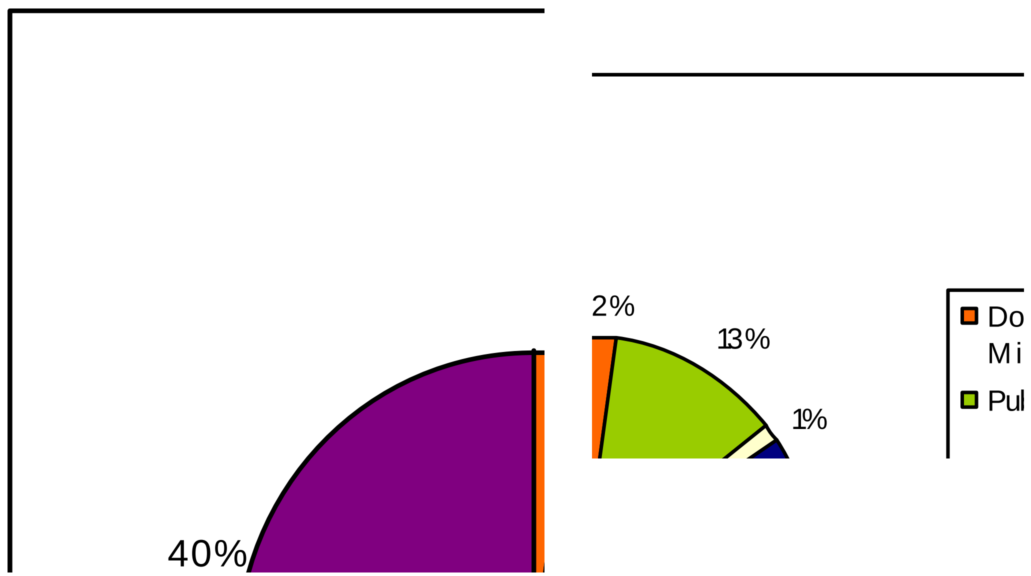
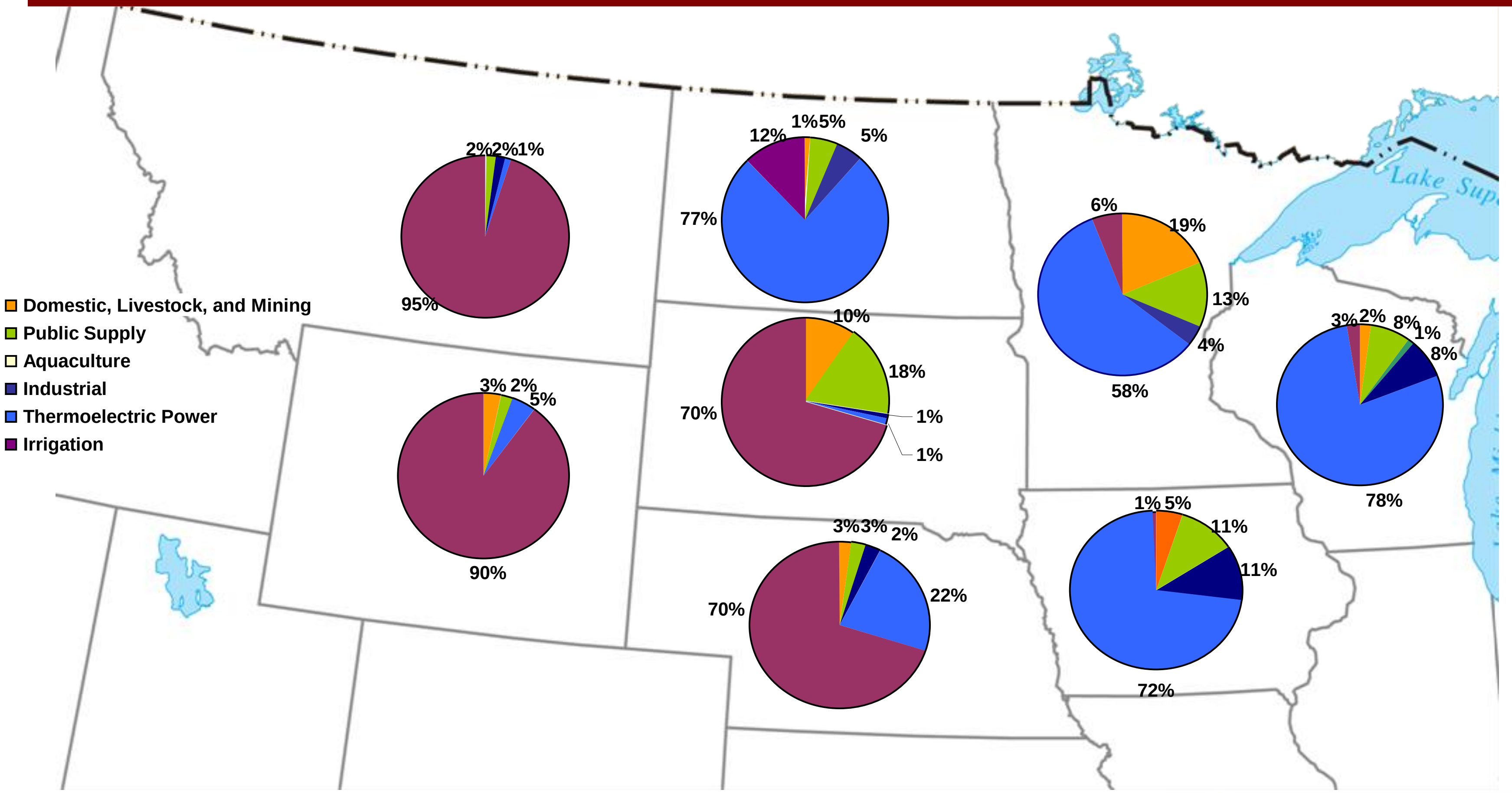
U.S. Water Withdrawals



(USGS Circular 1268, 2004)

Regional Water Withdrawal Comparison



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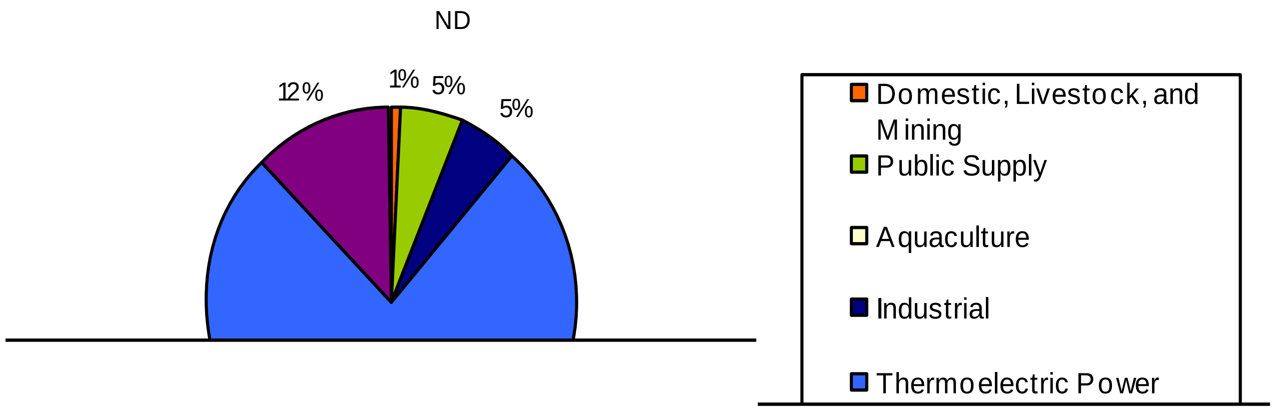
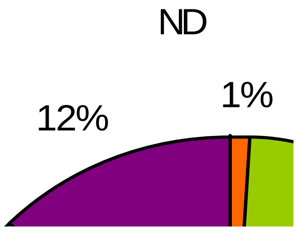
North Dakota Water Withdrawals





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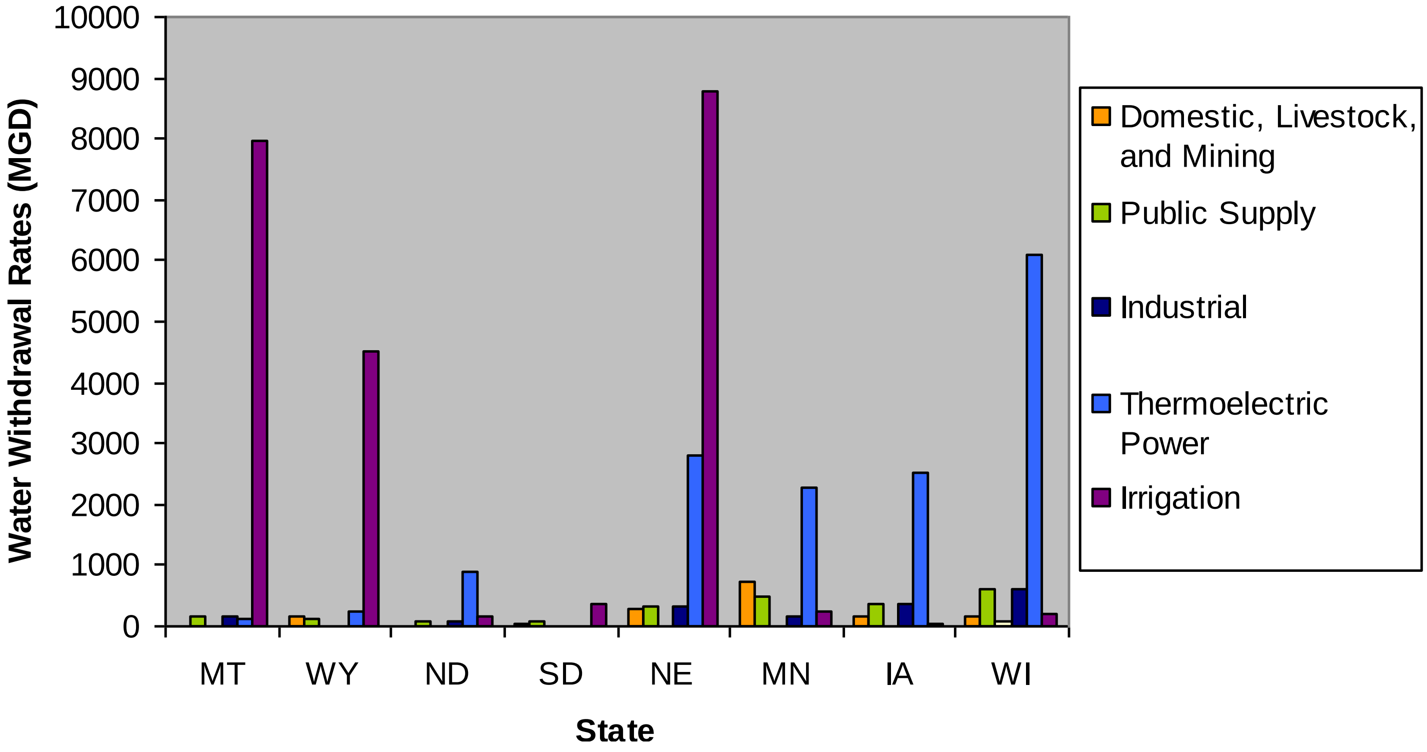
Withdrawal Rate Comparison



Bakken Water Opportunities

- Project to assess the economic potential to recycle frac flowback water in the Bakken play
- Project Sponsors
  - U.S. Department of Energy
  - North Dakota Petroleum Council
  - North Dakota Industrial Commission Oil & Gas Research Council

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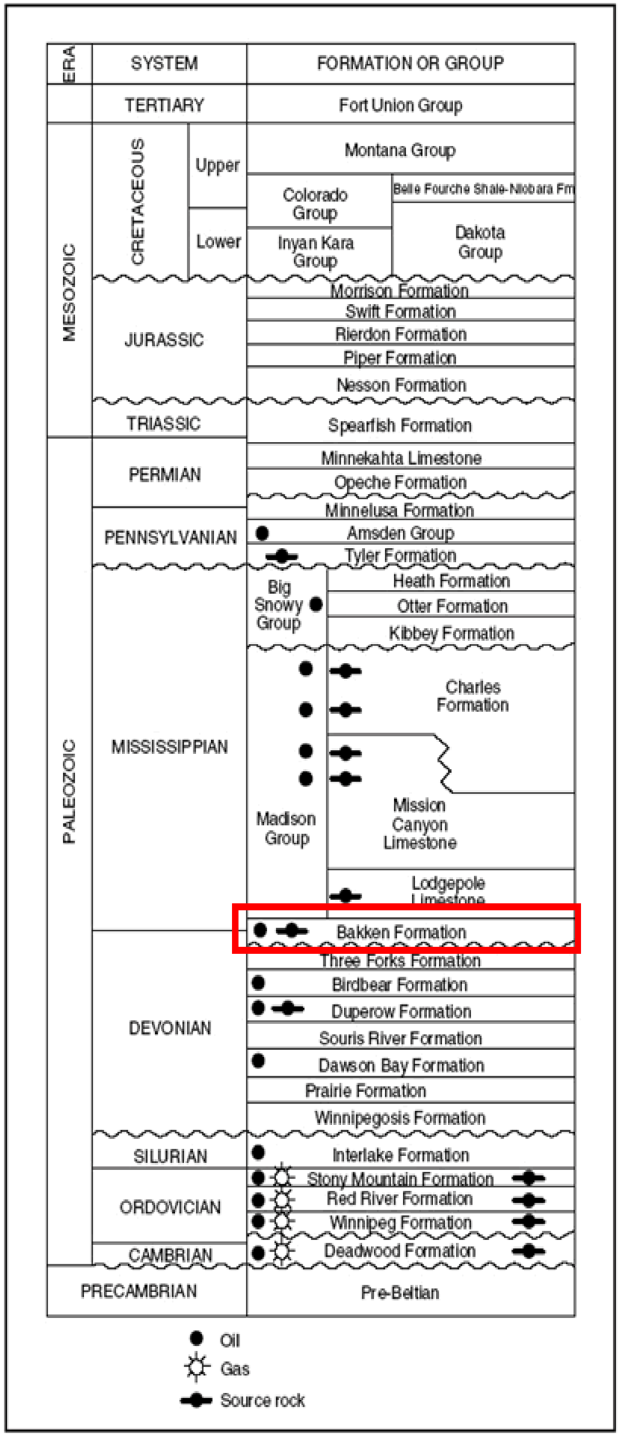
Bakken Formation

- Estimated 3.0 to 4.3 billion barrels of technically recoverable oil.
- Largest "continuous" oil accumulation ever assessed by the U.S. Geological Survey.
- Located mainly in North Dakota and Montana.

Bakken Formation

- Described in 1953 by J.W. Nordquist.
- Late Devonian to Early Mississippian age.
- 200,000 square miles covering parts of Montana, North Dakota, and Saskatchewan.
- Bakken Formation consists of three members:
  - Lower shale
  - Middle dolomite
  - Upper shale
- Upper and lower shales are the source rock; Middle Bakken is the reservoir.
- April 2008 USGS estimate of 3.0 to 4.3 billion bbls of technically recoverable oil.
- 2.1 billion bbls technically recoverable in the North Dakota portion of the Bakken.



Bakken Frac Water

- Frac water is freshwater that is used to pressurize and fracture oil-bearing formations to increase permeability and enhance the flow and recovery of oil.
- As much as 1.0 million gallons of water per well to fracture the Bakken Formation.
- Typically transported to well site in 7500- to 8000-gallon tanker trucks.
- Transportation costs for long haul distances can be excessive.

Water Permitting Issues in North Dakota

- Permits to obtain water from high-quality groundwater sources can be difficult and time-consuming to obtain.
- The North Dakota State Water Commission (SWC) is encouraging withdrawal of water from the Missouri River system for uses like fracing.
- The SWC and Corps of Engineers are currently working together to identify “low-risk” corridors for water extraction (i.e., easy access, low probability of cultural features, etc…).

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Bakken Water Opportunities

- Task 1 – Inventory Industry Freshwater Use
  - Water acquisition locations
  - Current Bakken reuse/recycling efforts
  - Key water quality constraints for use/reuse
- Task 2 – Assess Flowback Quality with Time and Location
  - Detail general chemical makeup and variation with different technology, geology, etc.
  - Develop sampling and analysis plan
  - Conduct a sampling and analysis campaign at selected industry locations

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Bakken Water Opportunities

- Task 3 – Evaluate Current Water-Handling Costs
  - Detail water acquisition costs (including transportation)
  - Detail water disposal costs (including transportation)

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Bakken Water Opportunities

- Task 4 – Evaluate Feasibility of Recycle/Reuse Technologies
  - Evaluate technical suitability of existing technologies for Bakken flow
  - Evaluate economic suitability of existing technologies for Bakken flowback
- Task 5 – Assess Current State of Existing Recycling Technologies
  - Interview technology vendors and operators utilizing technologies (Barnett) – visit locations

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Bakken Water Opportunities

- Task 6 – Detail Phase II Recommendations and Plans

Project Status

- Samples have been analyzed and/or data have been collected from four of five producers participating in the assessment.
- Extensive, but not comprehensive, frac flowback water chemistry data.
- Technology review and capabilities assessment.
- Preliminary economic assessment.

Frac Flowback Water Characteristics

- Relatively low recovery of the original frac water within the first 10 days.
  - Ranges from 15% to 50% recovery
- Very high salinity in flowback water.
  - Salinity levels as high as 200,000 mg/L
- Water chemistry is predominantly sodium chloride (NaCl), with lesser amounts of calcium, potassium, and sulfate.

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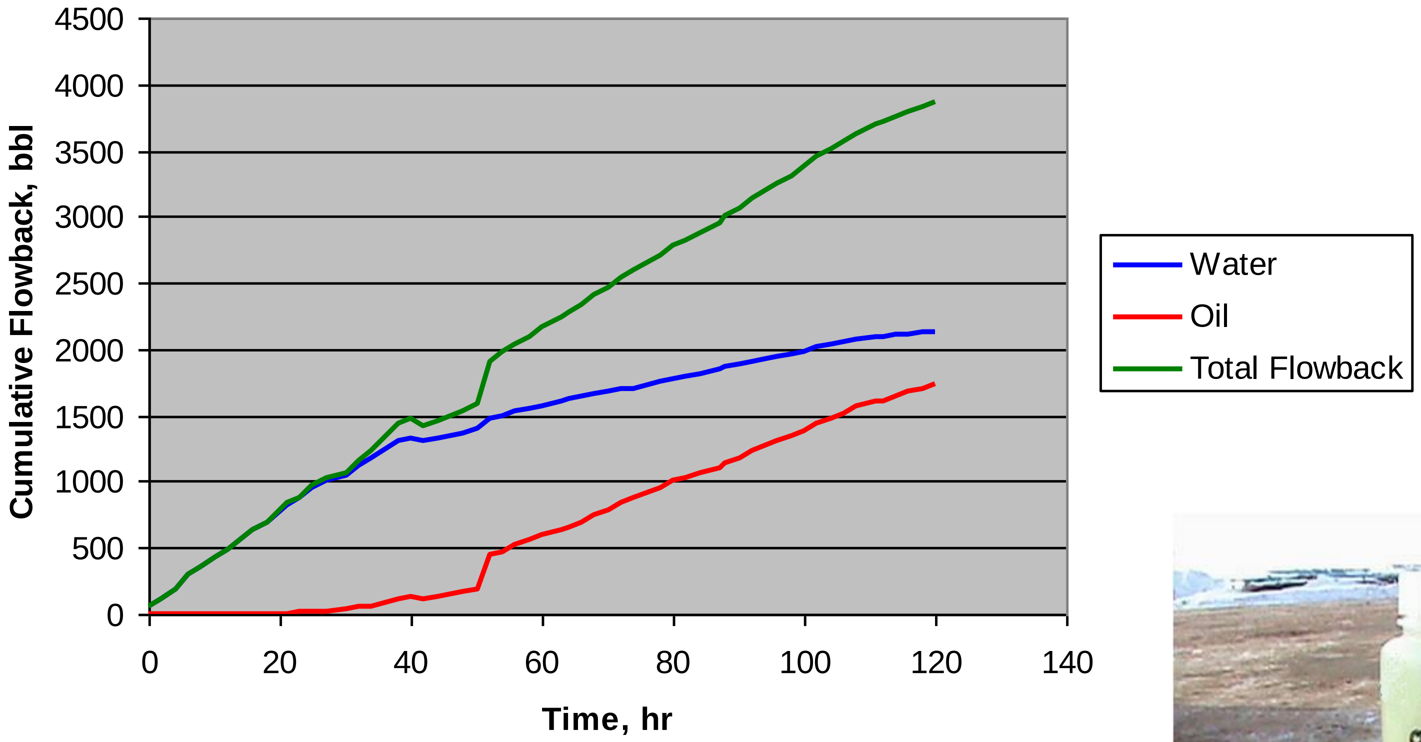
Flowback Water Samples



Frac Flowback Water Chemistry

(values in mg/L unless otherwise noted)

Cations	
Barium	13
Calcium	9020
Iron	77
Magnesium	720
Potassium	3550
Sodium	45,100
Anions	
Chloride	91,300
Sulfate	440
Other	
pH, units	6.3
Salinity	200,000
Conductivity, mS/cm	180

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Frac Flowback Water Treatment

- Oil field-compatible
- Robust
- Mobile
- Existing technology
- High treated water recovery


ESD

Bakken Recycling Challenges

- Slow recovery of flowback water
- Relatively low volume initial recovery
- Extremely high dissolved salts early in the flowback
- Treatment very challenging, even with the most robust technologies
- Treatment very likely not cost-effective in most cases

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Current Frac Water Costs

- Acquisition costs
  - $0.25–$0.75 raw water cost
  - $0.63–$5.00 transportation costs
- Disposal costs
  - $0.63–$5.00 transportation
  - $0.50–$1.00 disposal via deep well injection
- Total costs
  - $2.00–$11.75/bbl

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New Water Opportunity

- Access to freshwater for hydraulic fracturing continues to be a challenge.
- Abundant supply of marginal-quality groundwater that is not a potential USDW.
- Treatment of nonpotable groundwater may provide an economical alternative resource.

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Groundwater Treatment Demonstration

- Phase II of the existing Bakken Water Opportunities project could provide a portion of the necessary financial resources.
- Industry partner and potential demonstration location tentatively identified.
- EERC in discussions with technology providers (MVR and RO)

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Water Supply Potential of the Dakota Aquifer

- One of the most widespread aquifers in North America.
- Historically used as a water source for livestock (and some limited municipal use in Buffalo and Wahpeton, North Dakota).
- In the early 1900s, flowing well yields as high as 4000 gallons per minute (gpm) were observed.

USGS photo; circa 1890.

Hydrologic Properties of the Dakota Aquifer in Eastern North Dakota

- Up to 300 feet thick.
- Approximately 95 to 900 feet deep.
- Pumping rates between 500 and 1000 gpm (0.7 to 1.4 million gallons per day) may be feasible for individual wells.
- Water quality is typically slightly to moderately saline.

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