CENTRAL REGION INTEGRATED SCIENCE PROGRAM

Brine Contamination to Prairie Potholes from Energy Development in the Williston Basin

Science Team for Energy in Prairie Pothole Environments [STEPPE]

Robert A. Gleason, Richard S. Sojda
(Biology)

Bruce D. Smith
(Geology)

Joanna N. Thamke
(Water)

steppe.cr.usgs.gov

USGS

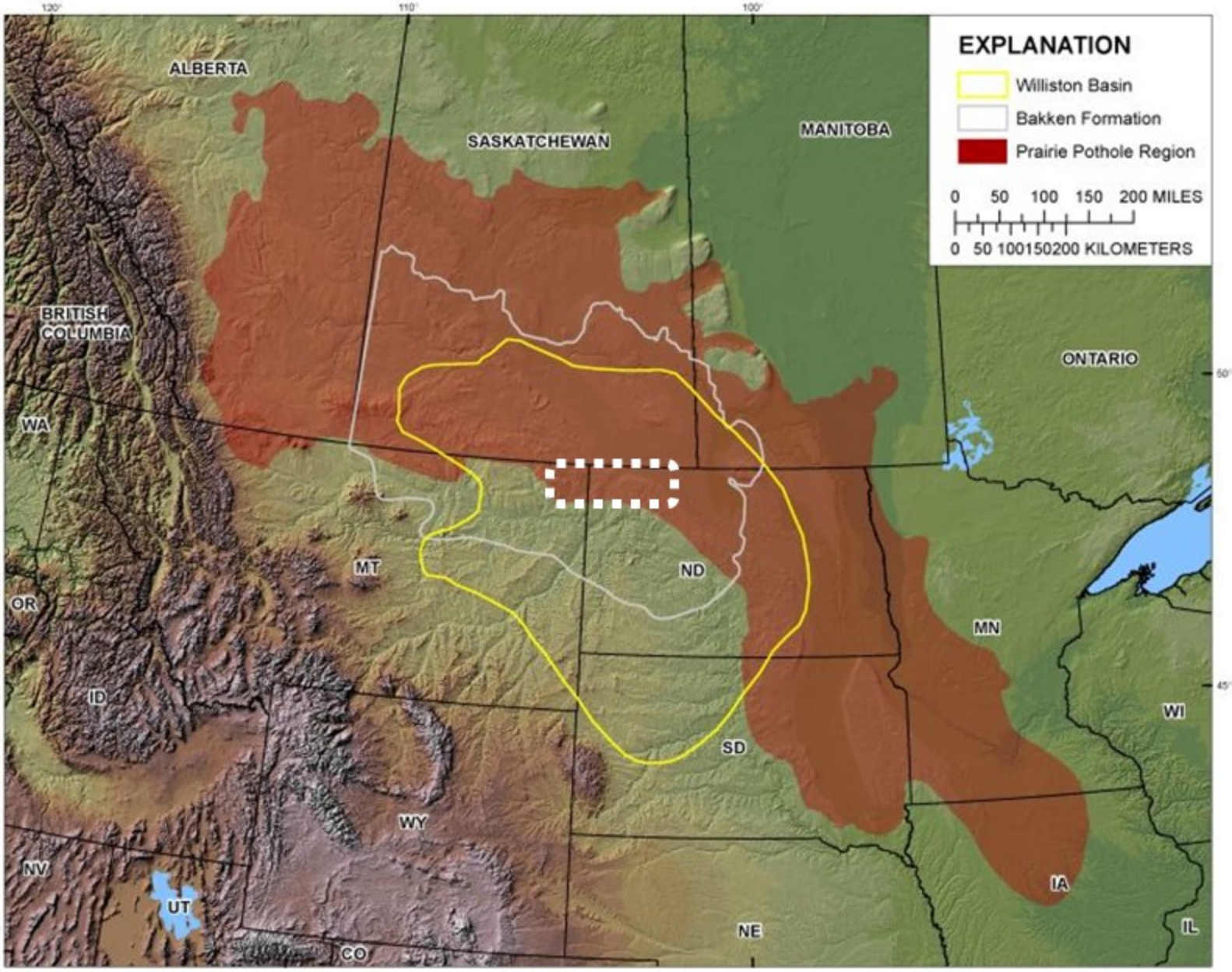


Figure 1. Williston Basin Study Area, with initial detailed study area outlined with dashed white line.

USGS

USGS
science for a changing world

National Assessment of Oil and Gas Fact Sheet

Assessment of Undiscovered Oil Resources in the Devonian-Mississippian Bakken Formation, Williston Basin Province, Montana and North Dakota, 2008

Using a geology-based assessment methodology, the U.S. Geological Survey estimated mean undiscovered volumes of 3.65 billion barrels of oil, 1.85 trillion cubic feet of associated/dissolved natural gas, and 148 million barrels of natural gas liquids in the Bakken Formation of the Williston Basin Province, Montana and North Dakota.

Introduction

The U.S. Geological Survey (USGS) completed an assessment of the undiscovered oil and associated gas resources of the Upper Devonian–Lower Mississippian Bakken Formation in the U.S. portion of the Williston Basin of Montana and North Dakota and within the Williston Basin Province (fig. 1). The assessment is based on geologic elements of a total petroleum system (TPS) that include (1) source-rock distribution, thickness, organic richness, maturation, petroleum generation, and migration; (2) reservoir-rock type (conventional or continuous), distribution, and quality; and (3) character of traps and time of formation with respect to petroleum generation and migration. Detailed framework studies in stratigraphy and structural geology and the modeling of petroleum geochemistry, combined with historical exploration and production analyses, were used

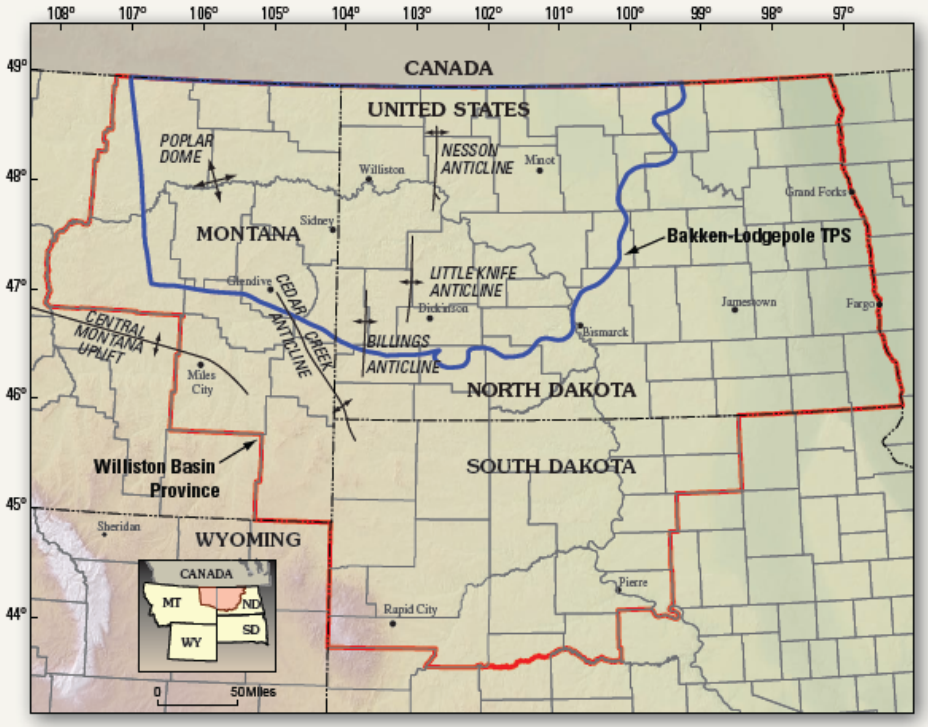


Figure 1. *Map showing Williston Basin Province boundary (in red), Bakken-Lodgepole Total Petroleum System (TPS) (in blue), and major structural features in Montana, North Dakota, and South Dakota.*

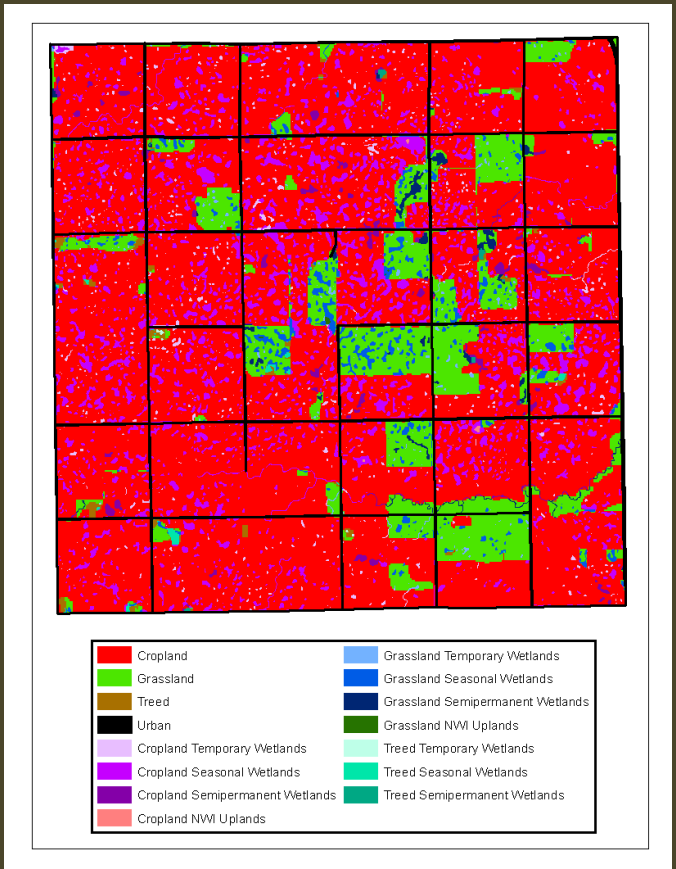
Impacts of Oil Exploration and Production to the U.S. Fish and Wildlife Service's Northeast Montana Wetland Management

Karen J. Nelson, USFWS, Helena MT
Jon C. Reiten, MBMG, Billings MT
Mike Rabenberg, USFWS, Medicine Lake, MT

USGS


MONTANA
ABP 338

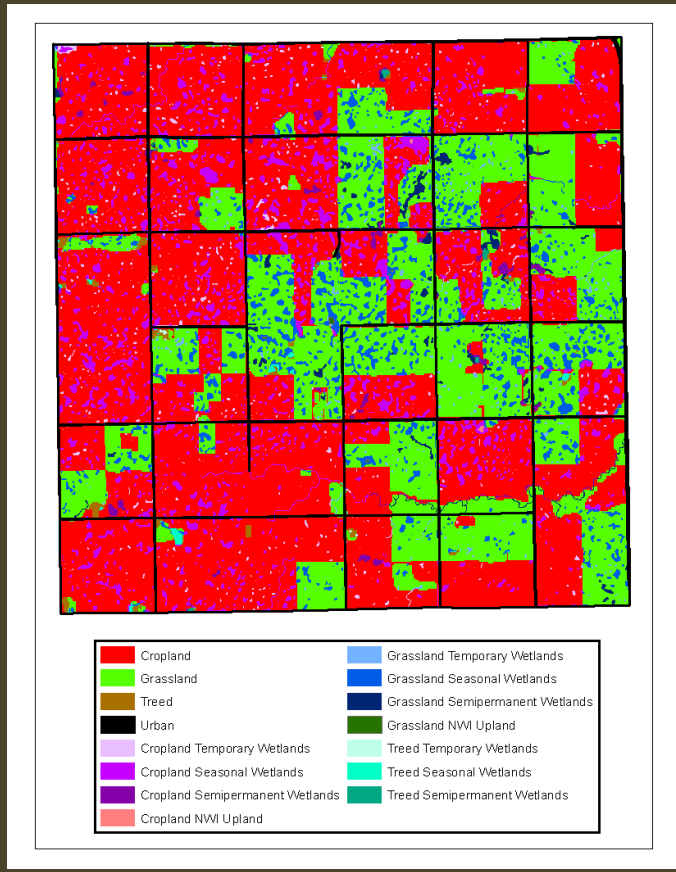
Land Use in a Single Township in the Glaciated Plains of the Prairie Pothole Region



Grassland

Cropland

Wetlands



Pre-CRP

Post-CRP

USGS

United States Department of the Interior
Fish and Wildlife Service
Medicine Lake National Wildlife Refuge Complex
223 North Shore Road
Medicine Lake, Montana 59247

Dr. Jeff Kershner
USGS Northern Rockies Mountain Science Center
Room 229 AJM Johnson Hall
Bozeman, MT 59717

Dear Dr. Kershner,

The Medicine Lake National Wildlife Refuge (NWR) and the Northeast Montana Wetland Management District (WMD) would like to express support for the proposed project: "Brine Contamination to Prairie Potholes from Energy Development in the Williston Basin." This is a well designed study which will provide much needed information about the effects of oil and gas activities on the mix-grass prairie in Montana and North Dakota.

The U.S. Fish and Wildlife Service manage over 63,000 acres of fee title and conservation easement lands in northeast Montana. These lands provide important breeding and migration habitat for thousands of migratory birds annually. As a result, the refuge is recognized as a "Globally Important Bird Area" by the American Bird Conservancy. Also, Medicine Lake and the adjacent Sandhills is a federally designated Wilderness Area consisting of 11,360 acres. The WMD provides breeding habitat for over ninety percent of the Montana piping plovers of the Northern Great Plains population. These and other private lands provide critical habitat for over thirty species of migratory birds of regional importance or species of management concern to the Fish and Wildlife Service and the State of Montana.

The recent increase in oil exploration and extraction activities in northeast Montana has raised concerns of habitat loss and degradation. Preliminar[illegible] in recent years by our Helena Ecological Services Office have raised concern regarding wate[illegible] produced water from existing and recent oil wells. This project will provide much [illegible] the threat to migratory birds and other wildlife of mixed-grass pr[illegible]

Thank you for considering this proposal

Sincerely,

Jerry Rodriguez
Project Leader

DUCKS UNLIMITED, INC.

Dr. Max Ethridge
Regional Executive, USDI-Geological Survey
1345 Corporate Center Curve
Egan, MN 55112

October 27, 2008

ear Dr. Ethridge,

cks Unlimited, Inc. heartily supports the "Brine Contamination to Prairie Potho[illegible]
gy Development in the Williston Basin" research project as proposed by the C[illegible]
rated Science Program (CRISP). Brine discharge from well drilling in north[illegible]
una and western North Dakota has had a catastrophic effect on many of our [illegible]
ll continue to degrade these important systems as energy exploration and [illegible]
s. Furthering our knowledge of how these systems function and possible[illegible]
impacts of brine [illegible] nt step in maintaining the [illegible]
give your highest level of

United States Department of the Interior
FISH AND WILDLIFE SERVICE
ECOLOGICAL SERVICES
MONTANA FIELD OFFICE
585 SHEPARD WAY
HELENA, MONTANA 59601
PHONE (406) 449-5225 FAX (406) 449-5339

November 12, 2008

Dr. Jeff Kershner
USGS Northern Rocky Mountain Science Center
Room 229 AJM Johnson Hall
Bozeman, MT 59717

Dear Dr. Kershner,

The Montana Field Office of the U.S. Fish and Wildlife Service (Service) would like to express support for a proposal submitted to the Central Region Integrated Science Program entitled "Brine Contamination to Prairie Potholes from Energy Development in the Williston Basin." The project area includes Medicine Lake National Wildlife Refuge (NWR), as well as the Northeast Montana Wetland Management District (WMD) (both areas located in the northeastern corner of Montana). These properties include over 31,000 acres of NWR lands, 44 waterfowl production areas (WPAs) totaling 12,507 acres; an additional 8,573 acres of wetlands protected under perpetual wetland easements; and perpetual grassland easements protecting 10,968 acres of grassland.

These lands are important as they provide habitat for approximately 200,000 waterfowl breeding pairs and in excess of 100,000 migrating shorebirds. The area has been used by endangered whooping cranes and supports 85% of Montana's breeding population of the threatened piping plover. Surveys completed in June, 2000 indicated 144 adult plovers (66 breeding pairs) were using the WPAs as well as state and private lands in the area.

The overlap of Service owned lands and oil production activities in the Williston Basin and have created concerns over habitat degradation. The majority of the WPAs were purchased without underground mineral rights, and perpetual wetland and grassland easements do not prevent oil exploration or drilling activities. Of the 44 WPAs managed by the Northeast Montana WMD, 32% had a well located within the WPA boundary. An additional 36% contained a well within one half mile of the WPA wetland, resulting in 68% of WPAs with a potential for impacts of oilfield waste. A project funded by the Service initiated in 2004 sampled 81 wetlands or lakes on 23 WPAs and Medicine Lake NWR. Water chemistry results indicated that approximately half of these lakes or wetlands were impacted by produced waters. The proposed project would assist the Service by providing risk assessment tools that may allow the Service to protect sensitive habitats in the future.

DUCKS UNLIMITE[illegible]
Montana Fiel
P.O.
Elliston, M
406/492-2002
rsanders@ducks.

February 12, 2008

Dr. Thomas J. Casadevall
Regional Director - Central Region
USDI - Geological Survey
PO Box 25046
Denver Federal Center - Bldg 810
Denver, CO 80225-0046

Sheridan County Conservation Board

Dear Dr. Casadevall,

I am writing this letter in support of the proposed project entitled, "Managing We[illegible] of Shifting Agricultural Practices, Energy Development, and Hydrologic Pattern[illegible]

This project is in direct line with the goals and objectives of the Sheridan Cour[illegible] District and its many partners. The project targets include a systematic, scientific[illegible] impacts on wetlands from oil field activities. This objective is a direct continuation [illegible] completed by the District that examined the movement of salt brines at a number [illegible] not adjacent to wetlands. The proposed project will extend our knowledge of this[illegible] and assist in the determination of the real and potential impacts to crucial irrigation[illegible] aquifers as well as surface wetlands.

Another area of critical concern to the District is the potential change in ground and [illegible] from the anticipated cor[illegible] CRP and grassland acreages to cropland as [illegible] continue to climb. There[illegible] ies into the procedures and potential [illegible] of converting wetlands i[illegible] t will help identify these iss[illegible] as aid in the determinat[illegible] any affect on the[illegible] of the brine plumes as[illegible]

The Conservation Di[illegible] thereby protecting, th[illegible] and land conversior[illegible] Lake Aquifer, which[illegible] maintains a 15,000[illegible] from this project[illegible] resource.

Regards,

Jeff Wivholm
Chairman

February 12, 2008

Dr. Thomas J. Casadevall
Regional Director - Central Region
USDI - Geological Survey
PO Box 25046
Denver Federal Center - Bldg 810
Denver, CO 80225-0046

Dear Dr. Casadevall:

Montana Bureau of Mines and Geology

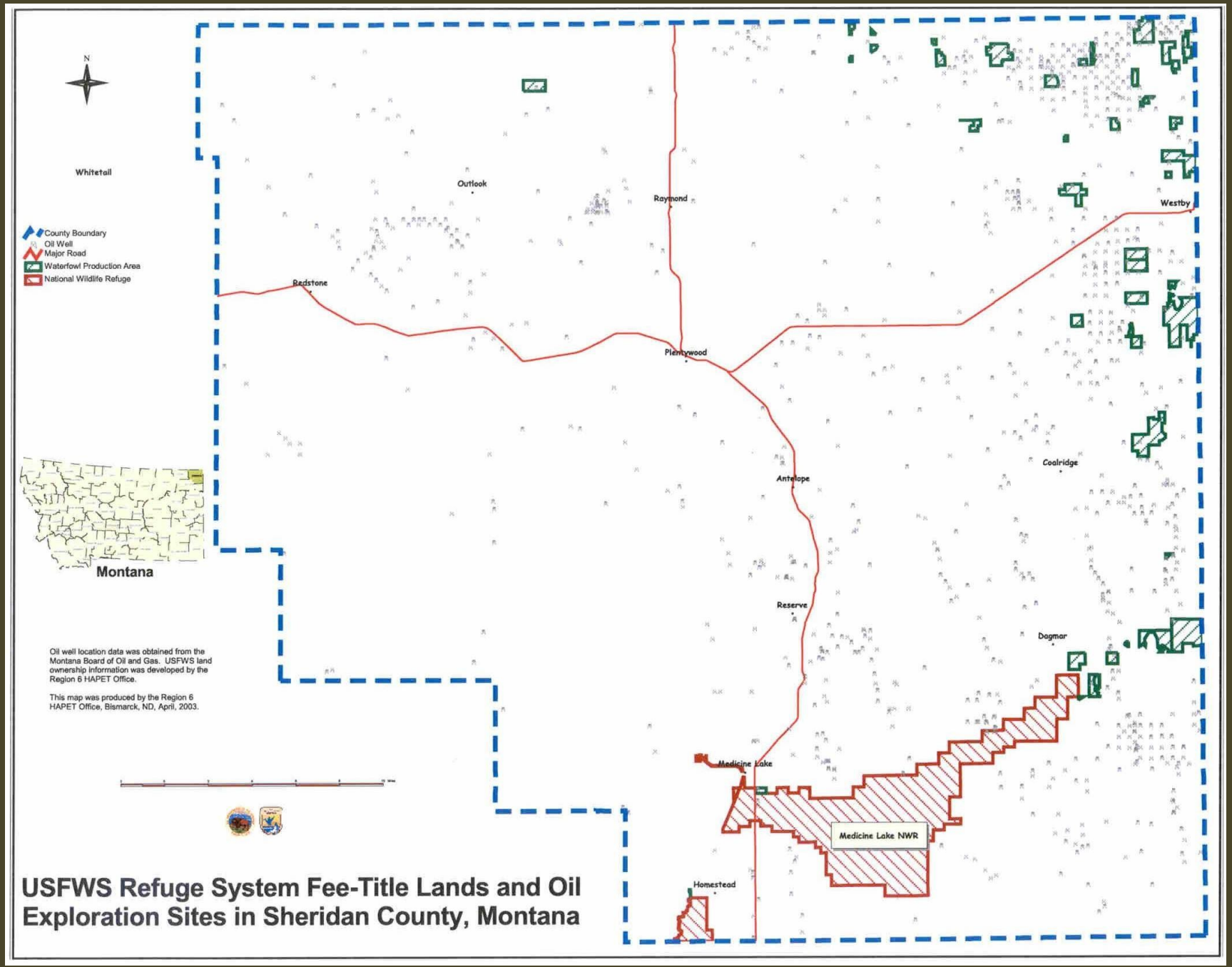
The proposed project entitled, "Managing Wetlands in the Face of Shifting Agricul[illegible] Energy Development, and Hydrologic Patterns" will provide insight into integrating [illegible] agricultural, wetland, and energy development issues in the glaciated regions of [illegible] Montana. I have worked on the hydrogeology of buried-channel aquifers and the [illegible] irrigation development on lakes and wetlands in this area. In addition, I have [illegible] evaluating the impacts of brine discharges associated with energy development in this p[illegible] Williston Basin. As a result of my strong interest and concerns, I support this propose[illegible]

My work for the Montana Bureau of Mines and Geology (MBMG) has been sponsored [illegible] Sheridan County Conservation District (SCCD) and the Medicine Lake Wildlife Refuge. O[illegible] brines have already impacted ground-water and surface-water resources in this a[illegible] Unfortunately, the extent and magnitude of these impacts have not been clearly document[illegible] Produced water in this part of the Williston Basin is composed of sodium-chloride brines havi[illegible] concentrations that may exceed 3-times the concentration of sea water. Salt-saturated wast[illegible] materials were traditionally buried at drilling locations. It has been estimated that a mass of salt[illegible] equivalent to a 260-ton salt block is buried at each of the 900+ drilling locations in Sheridan [illegible] County alone. Current practices are moving towards recycling fluids and reducing the volume of [illegible] wastes, but on-site burial is still a viable option under current regulations.

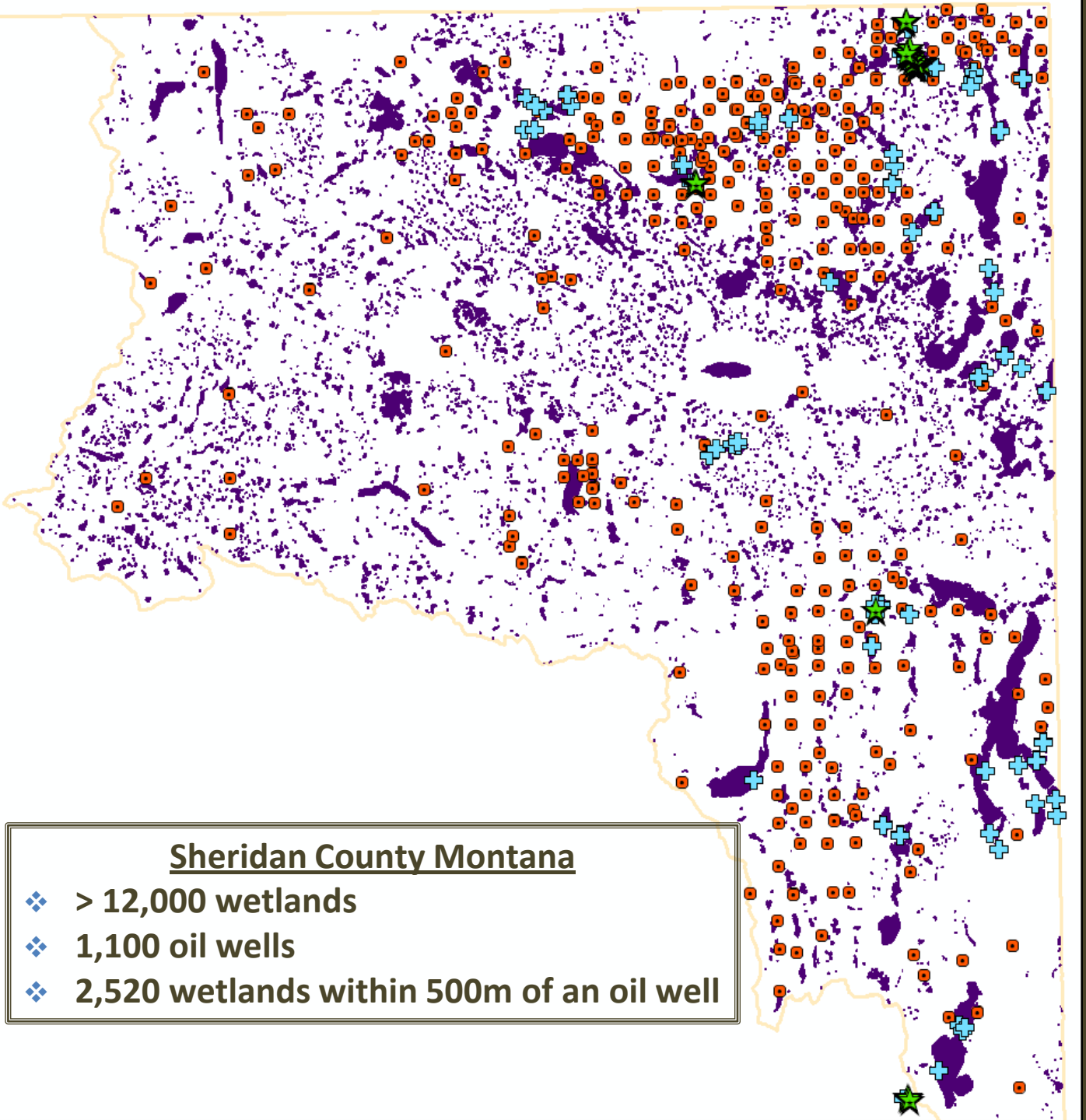
The project targets include a systematic, scientific examination of impacts on wetlands from oil-[illegible] field activities. This objective is a direct continuation of a project just completed by MBMG and the [illegible] SCCD that examined the movement of salt brines at a number of oil-well sites not adjacent to [illegible] wetlands. The proposed project will extend our knowledge of this phenomenon and assist in [illegible] determining the real and potential impacts to crucial aquifers developed for irrigation as well as [illegible] relationships of glacial till, glacial lake deposits, and glacial outwash are poorly understood. [illegible] These stratigraphic relationships strongly influence the movement of contaminants and wetland [illegible] development. In addition, the relationships of oil-well sites and shallow glacial sediments [illegible] underlying buried-channel aquifers are poorly defined. The Clear Lake aquifer is the only [illegible] channel aquifer mapped in this area and many parts of it require additional work to [illegible] extent. As a result, these stratigraphic relationships currently can be [illegible] provide additional knowledge that will increase our understanding of [illegible] underlain by the buried channel containing the Clear Lake aquifer. [illegible] current land-use practices.

As land-use practices change, impacts of [illegible] acreages to cropland will need to be [illegible] currently consumed by CRP [illegible] contaminants? How will [illegible] the proposed project [illegible]

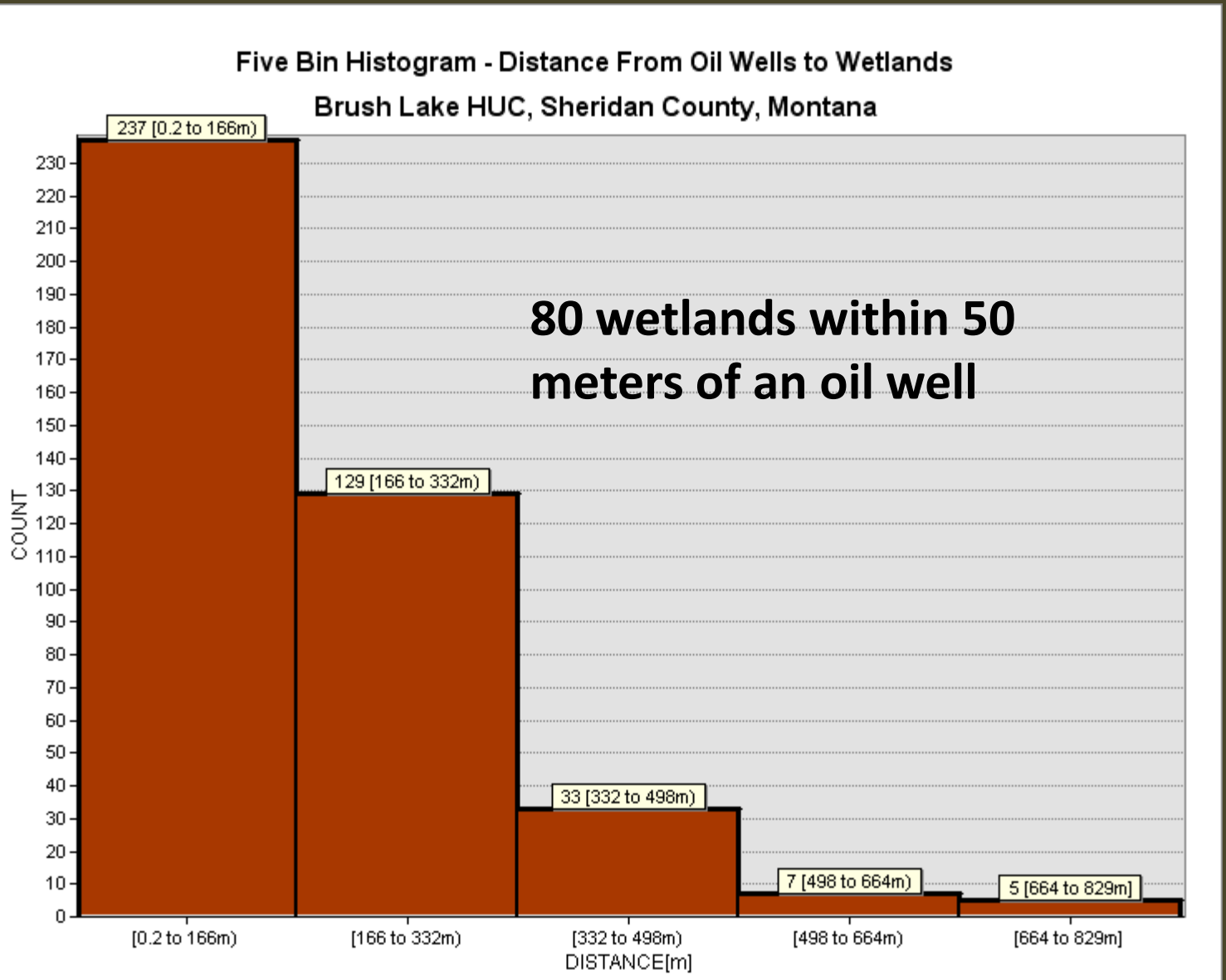
USGS

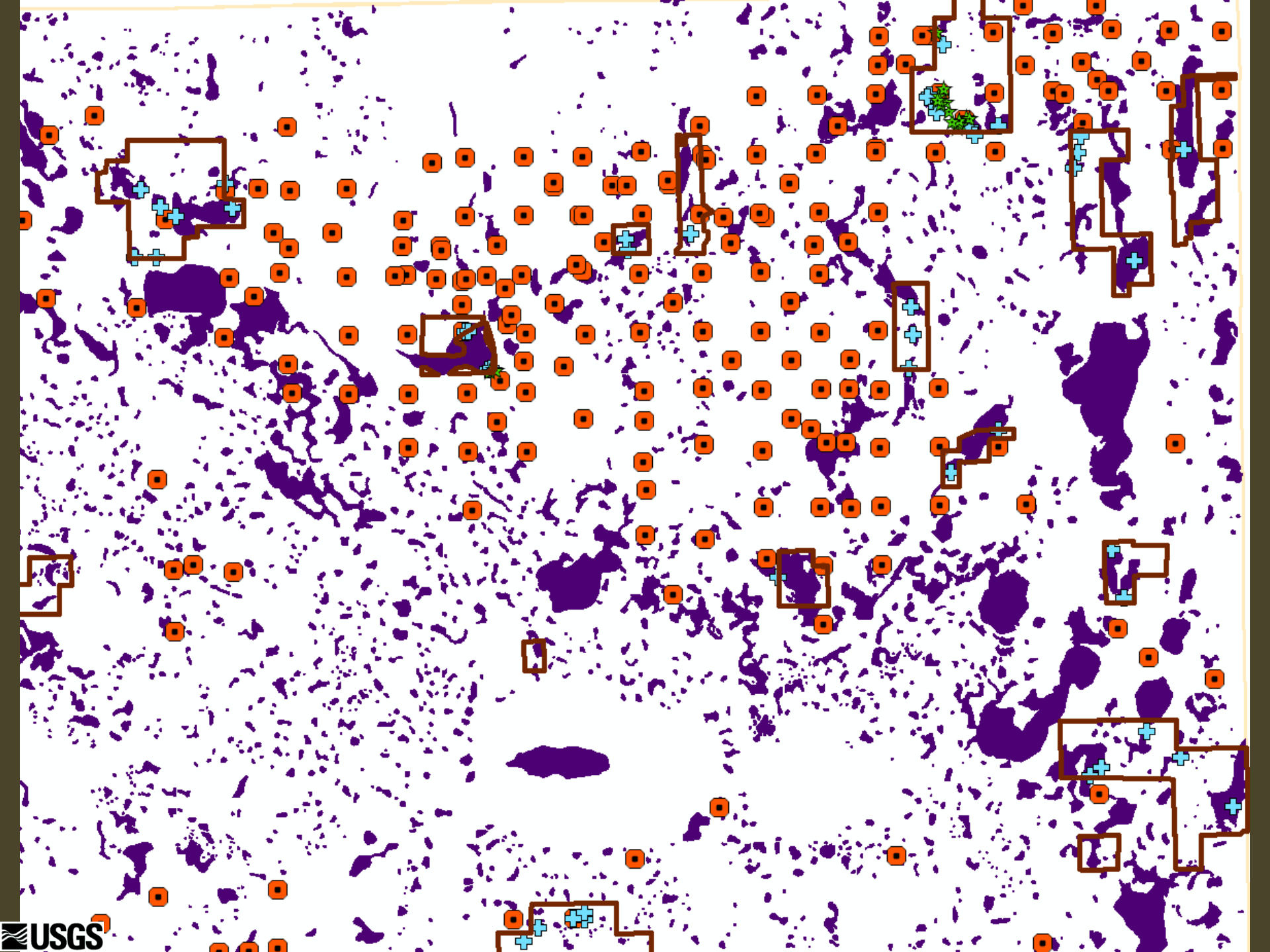

N
Whitetail
County Boundary
Oil Well
Major Road
Waterfowl Production Area
National Wildlife Refuge
Outlook
Raymond
Westby
Redstone
Plentywood
Coalridge
Antelope
Reserve
Dagmar
Medicine Lake
Medicine Lake NWR
Homestead
Montana
Oil well location data was obtained from the Montana Board of Oil and Gas. USFWS land ownership information was developed by the Region 6 HAPET Office.
This map was produced by the Region 6 HAPET Office, Bismarck, ND, April, 2003.
USFWS Refuge System Fee-Title Lands and Oil Exploration Sites in Sheridan County, Montana

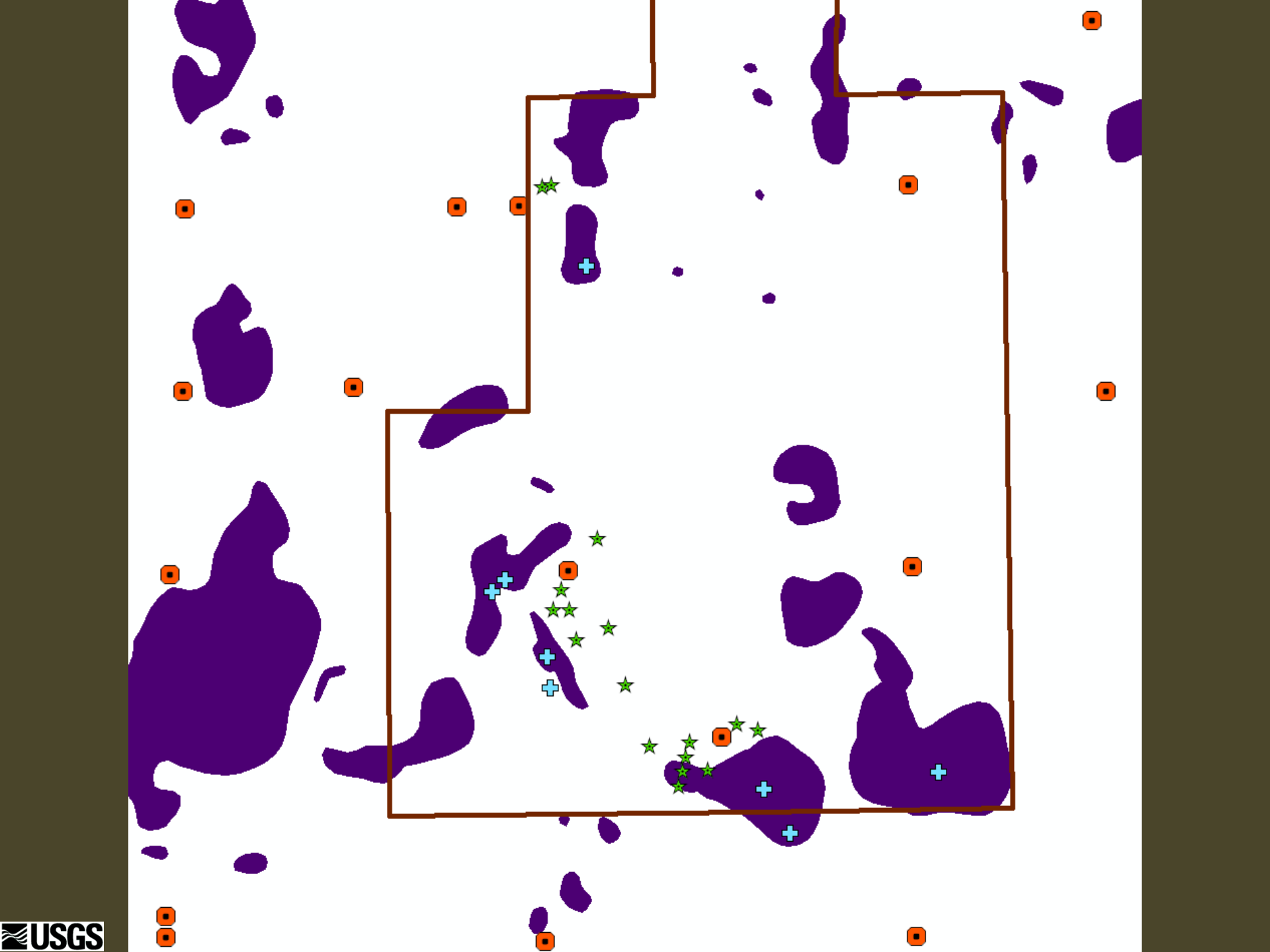
USGS


Sheridan County Montana
> 12,000 wetlands
1,100 oil wells
2,520 wetlands within 500m of an oil well

USGS


Five Bin Histogram - Distance From Oil Wells to Wetlands
Brush Lake HUC, Sheridan County, Montana
237 [0.2 to 166m)
129 [166 to 332m)
33 [332 to 498m)
7 [498 to 664m)
5 [664 to 829m]
80 wetlands within 50 meters of an oil well
COUNT
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
[0.2 to 166m)
[166 to 332m)
[332 to 498m)
[498 to 664m)
[664 to 829m]
DISTANCE[m]


USGS

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Pitless drilling possible

Required in Alaska, Alberta, Saskatchewan

Several companies use pitless drilling exclusively

USGS

U.S. FISH & WILDLIFE SERVICE

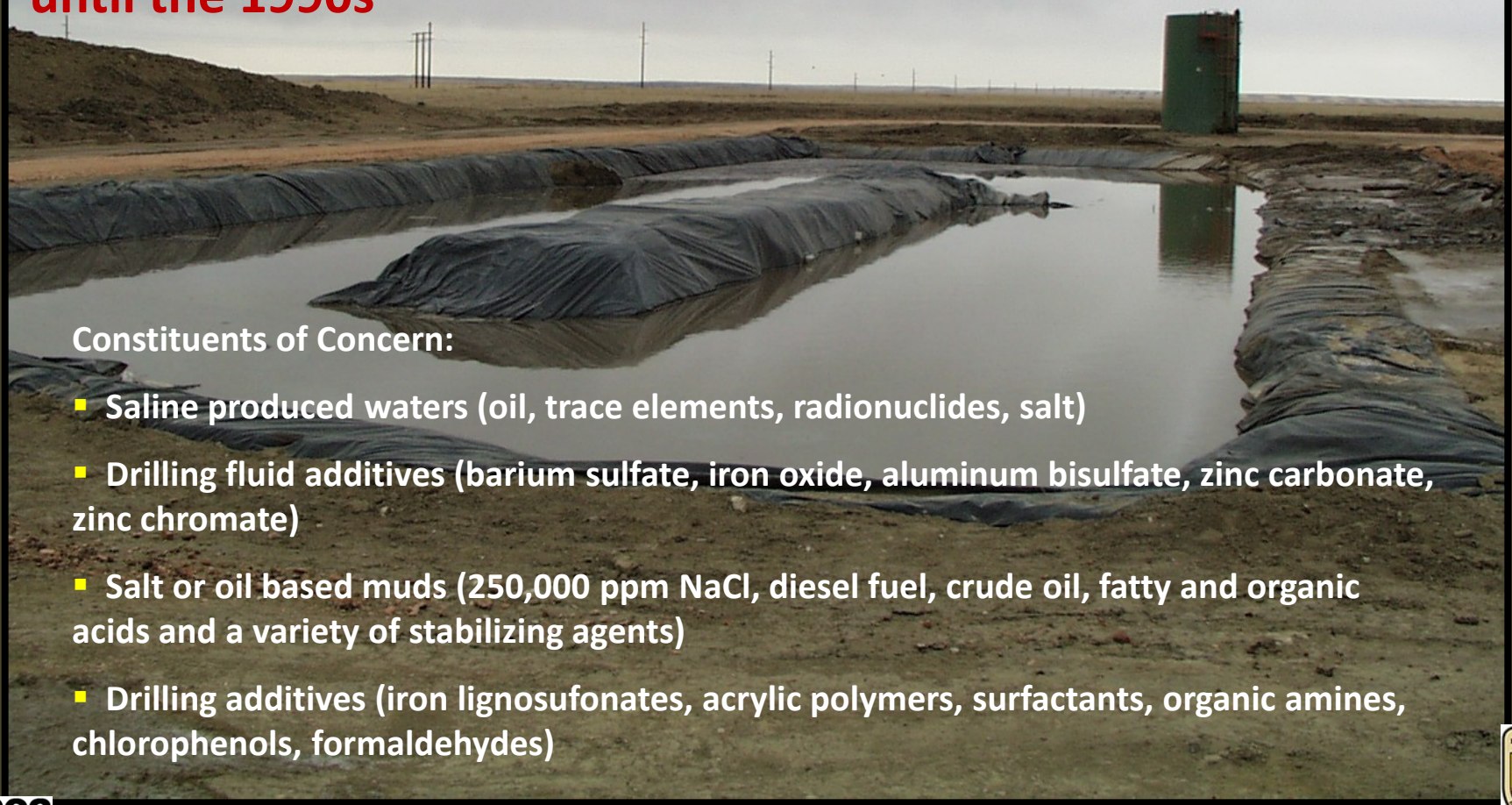
Contaminant Pathways in the Williston Basin

Flow lines and produced water lines

Reserve Pits (Measure 150 ft x 60 ft x10 ft)

Each pit contains an estimated 52,000 to 1,000,000 gallons of drilling wastes, and 250 tons of NaCl salts

Pits were unlined until the late 1970s, and trenching occurred until the 1990s



Constituents of Concern:

- **Saline produced waters (oil, trace elements, radionuclides, salt)**
- **Drilling fluid additives (barium sulfate, iron oxide, aluminum bisulfate, zinc carbonate, zinc chromate)**
- **Salt or oil based muds (250,000 ppm NaCl, diesel fuel, crude oil, fatty and organic acids and a variety of stabilizing agents)**
- **Drilling additives (iron lignosufonates, acrylic polymers, surfactants, organic amines, chlorophenols, formaldehydes)**

USGS

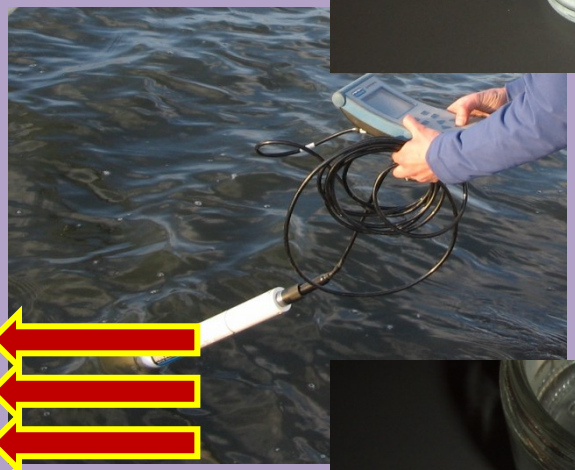
Produced Water Contamination Index

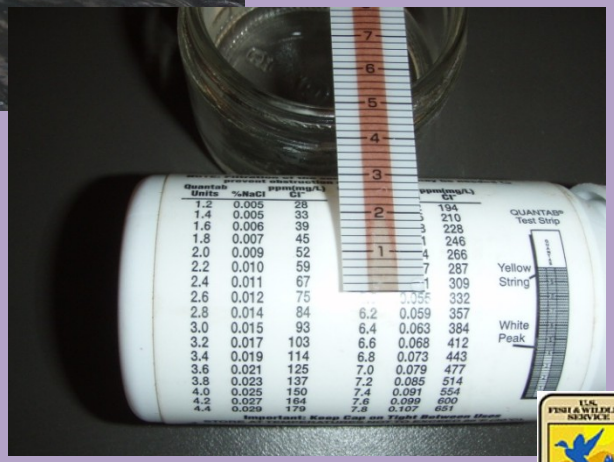
SC µs/cm:Cl mg/L >0.034 Produced water impacts

Surface water samples collected from 80 wetlands and lakes

50 % revealed impacts from produced water

WPA/NWR	Site	SC µs/cm	Cl mg/L	CI
Parry	PAR1	4902	53	0.0108
Parry	PAR1E	4680	53	0.0113
Parry	PAR2	55185	1547	0.0280
Parry	PAR3	4351	61	0.0140
Parry	PAR3	5928	84	0.0142
Parry	PAR4	2669	27	0.0101
Parry	PAR4	3396	30.5	0.0090
Rabenberg	RABE1	22480	8362	0.3720
Rabenberg	RABE2A	4130	953	0.2308
Rabenberg	RABE2	5150	1485	0.2883
Rabenberg	RABE3	4011	908	0.2264
Rabenberg	RABE3A	2731	650	0.2380
Rabenberg	RABE4	8658	3145	0.3632
Rabenberg	RABE5	7509	2420	0.3223
Rabenberg	RABE5	8126	2690	0.3310
Rabenberg	RABE5+	8437	2908	0.3447
Rabenberg	RABE6	8812	2614	0.2966





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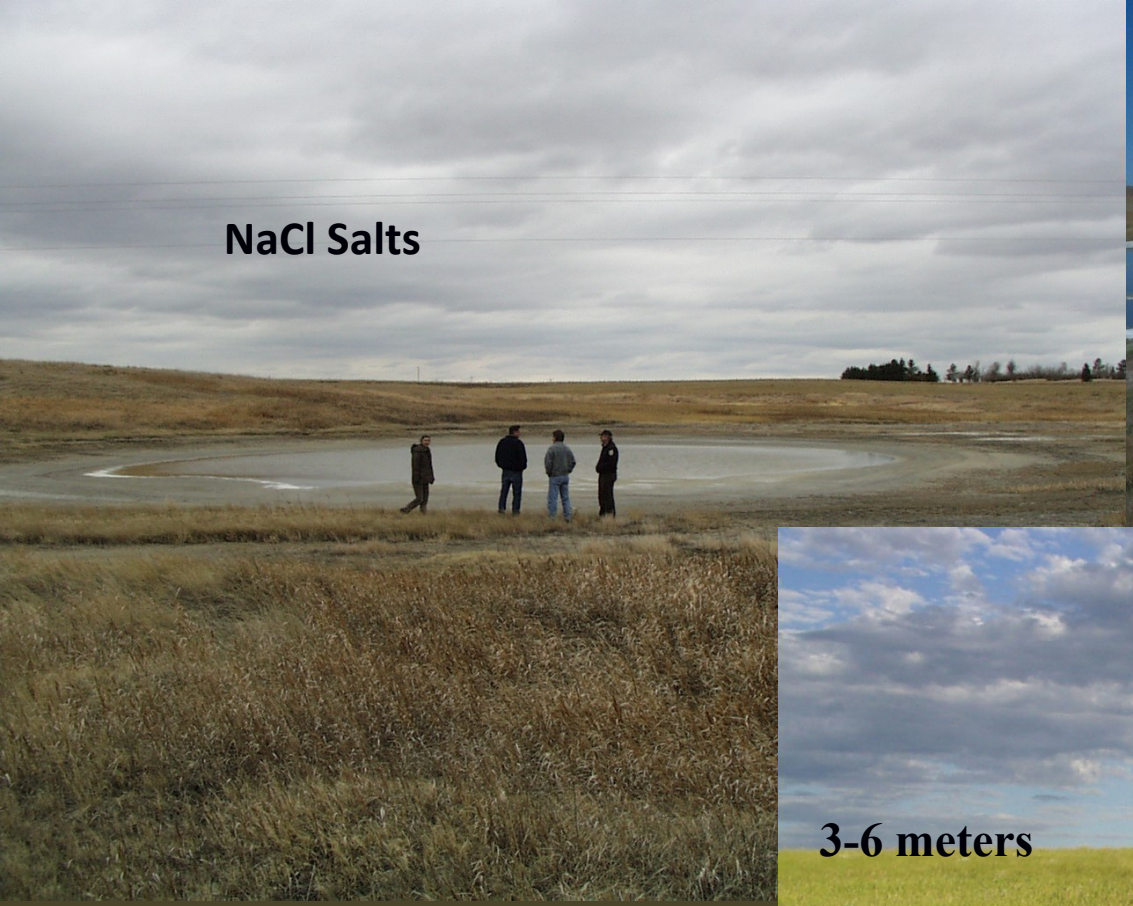
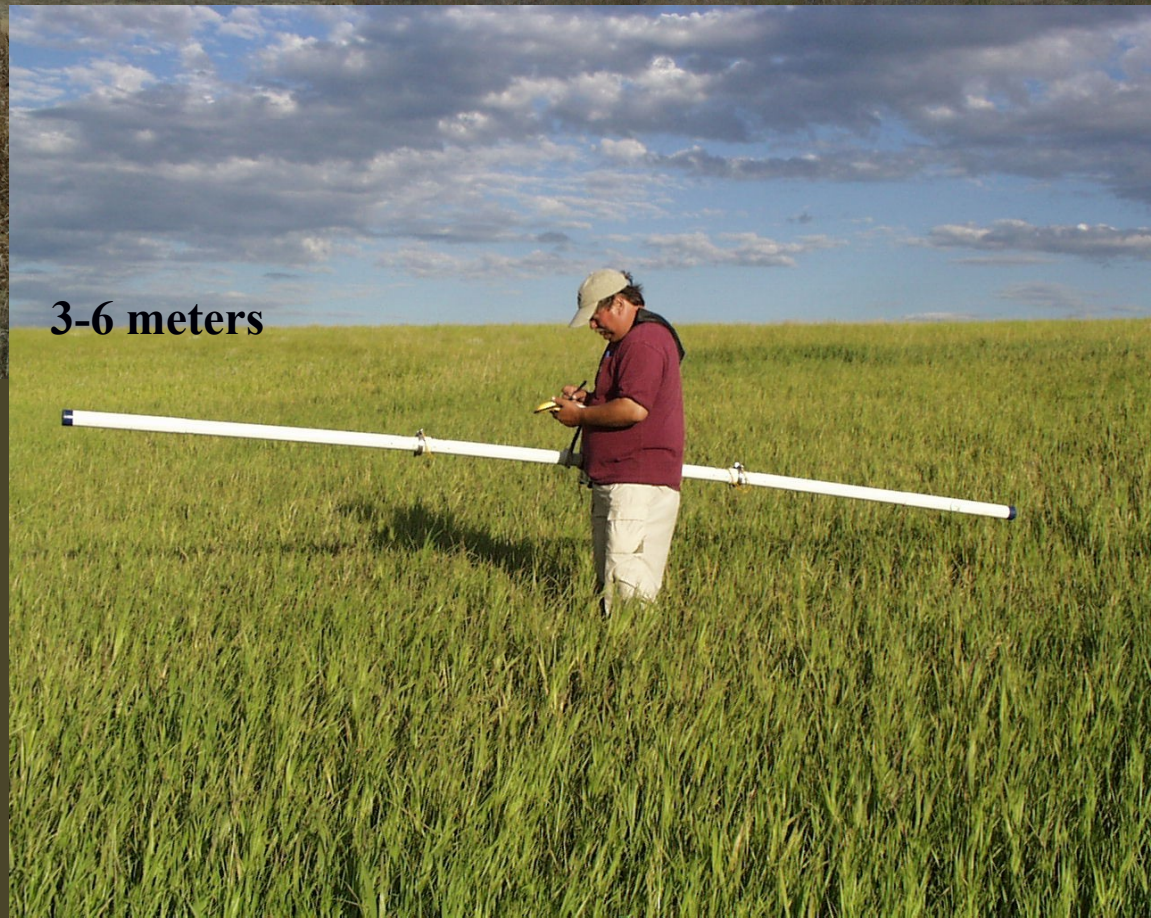
U.S. FISH & WILDLIFE SERVICE





Soil Conductivity Surveys

- Conducted using an EM-31 and a Trimble GeoXT
- Completed on 30 sites, on or near Service owned land
- Plumes delineated at all but one survey location

USGS

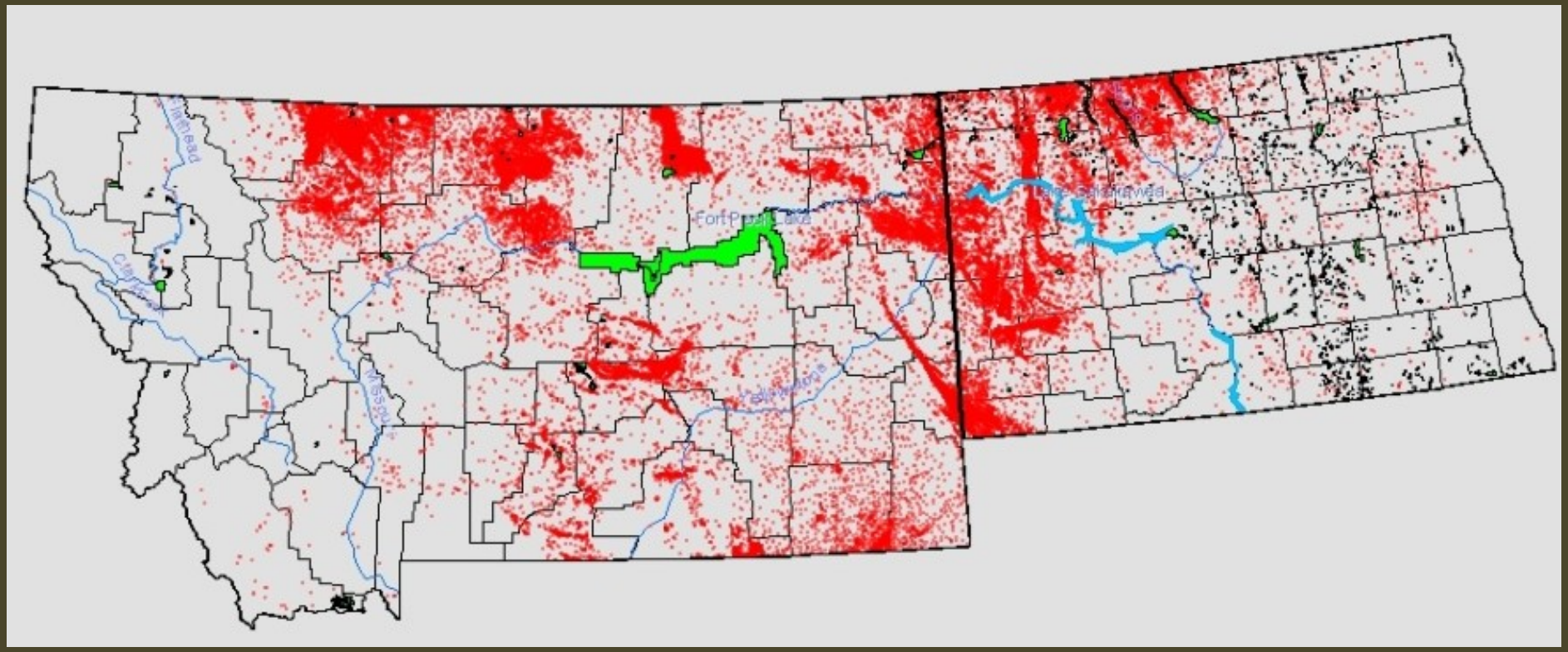
Beaver Lake Waterfowl Production Area, ND

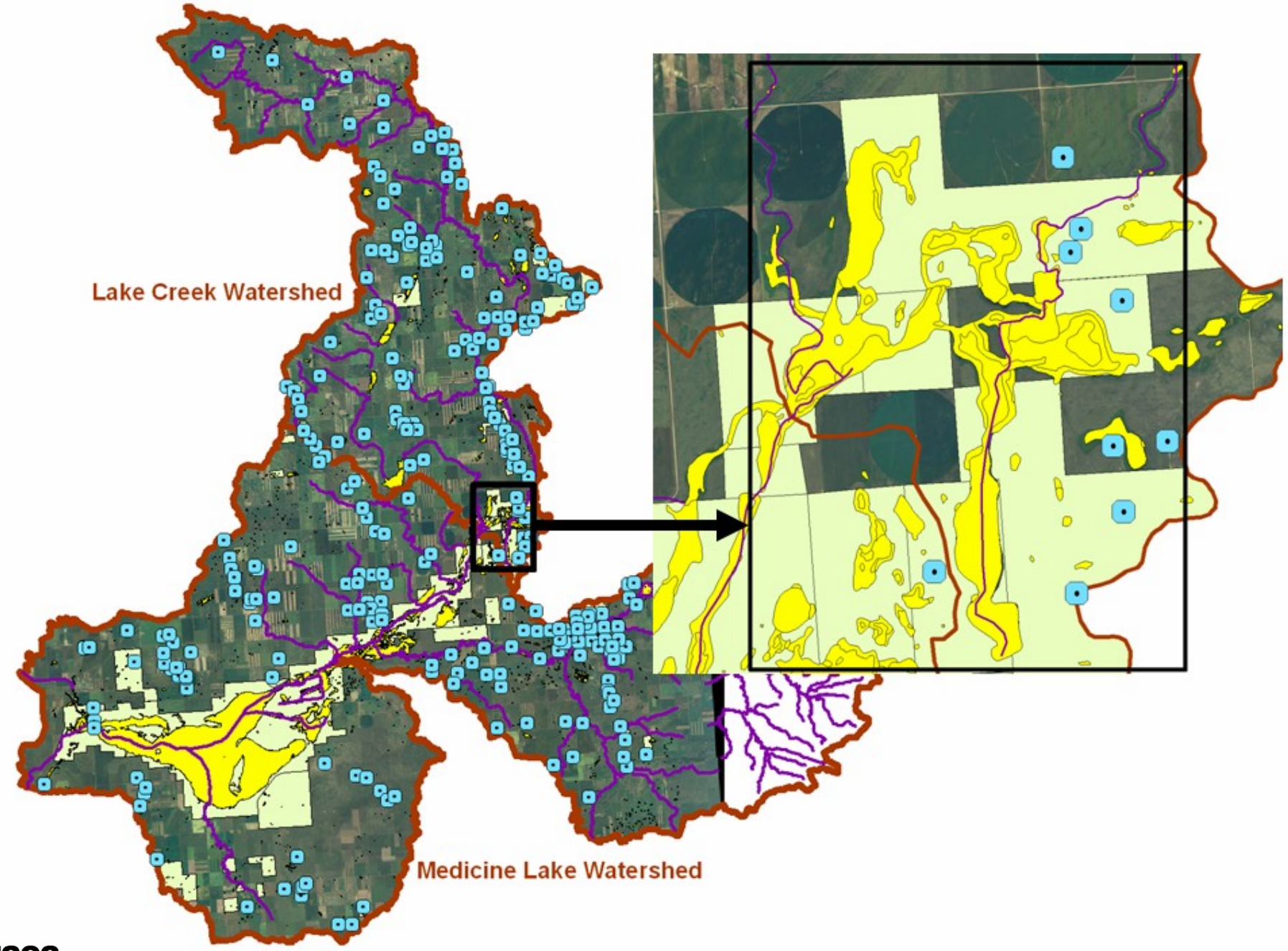
EM31 Operations February 2008

Kevin Johnson, USFWS Bismark ND
Bruce Smith, USGS Denver, CO
Ryan Tompkins, USGS Lincoln, NE

USGS


Objectives:
1. Evaluate the spatial extent and potential risk to natural resources of past and ongoing energy development using GIS analyses
2. Reassess brine contamination movement in previously studied areas (also SPP)
3. Conduct a user needs analysis and design a prototype decision support system
4. Establish an Interagency Energy Contamination Science Team
USGS


Fort Peck Lake
Missouri
Yellowstone



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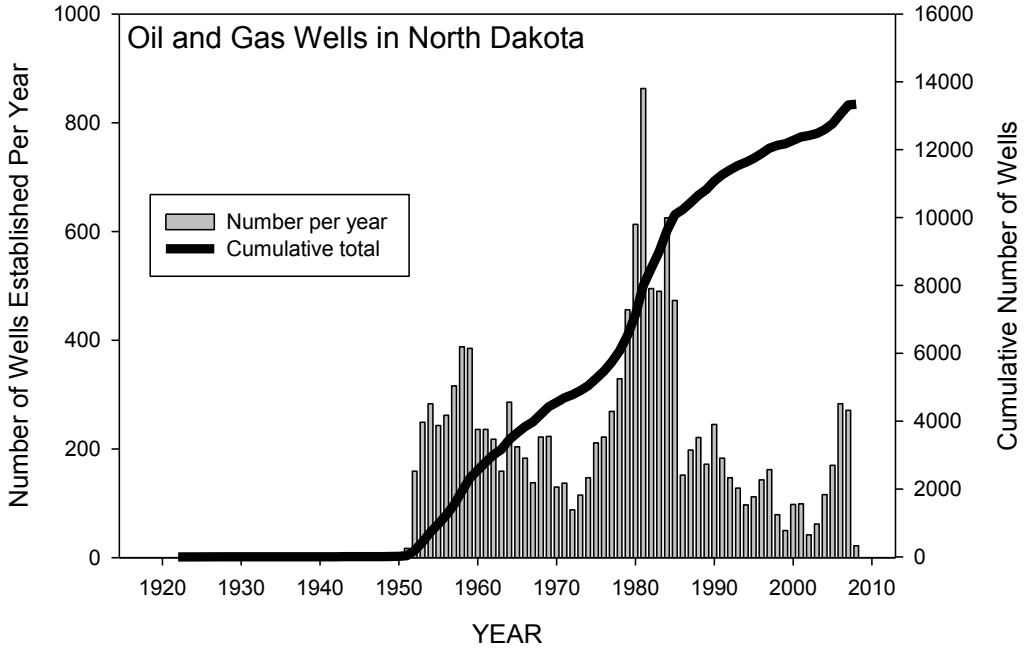
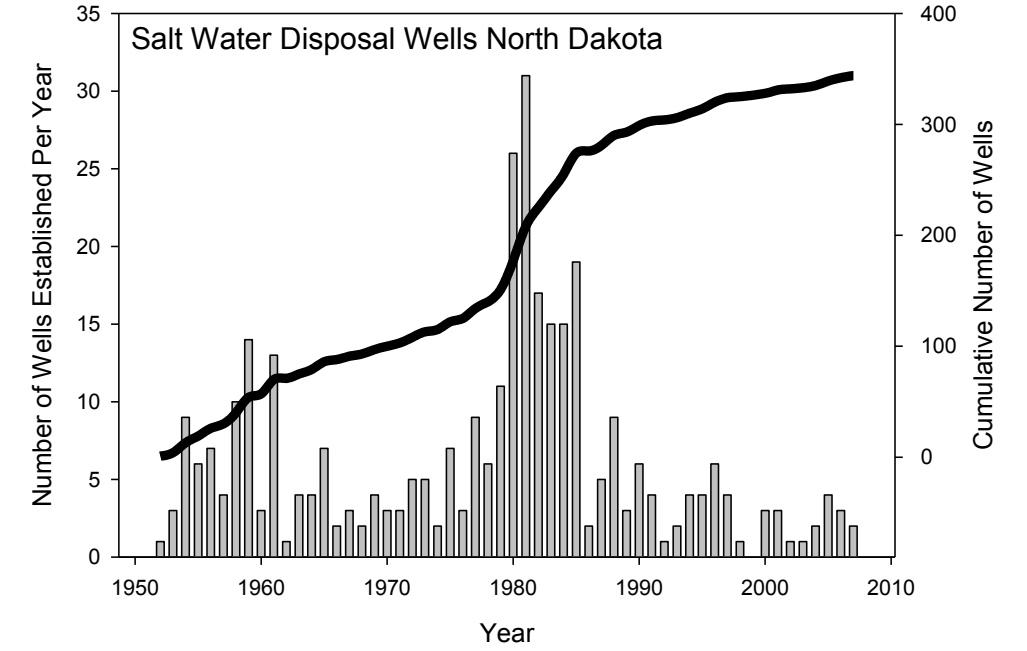
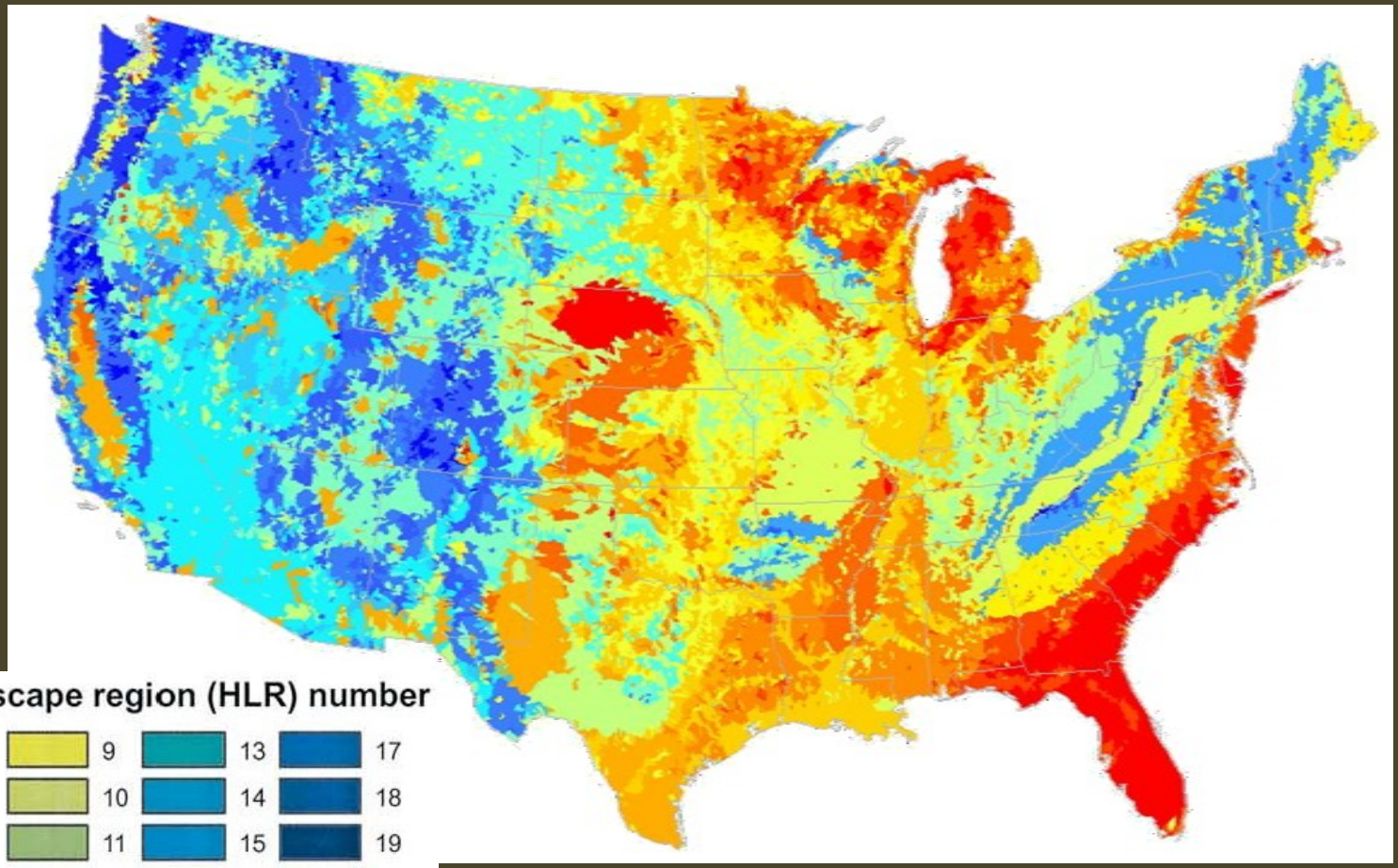

Oil and Gas Wells in North Dakota
Number per year
Cumulative total
Number of Wells Established Per Year
Cumulative Number of Wells
YEAR
0
200
400
600
800
1000
0
2000
4000
6000
8000
10000
12000
14000
16000
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010


Salt Water Disposal Wells North Dakota
Number of Wells Established Per Year
Cumulative Number of Wells
Year
0
5
10
15
20
25
30
35
0
100
200
300
400
1950
1960
1970
1980
1990
2000
2010

USGS

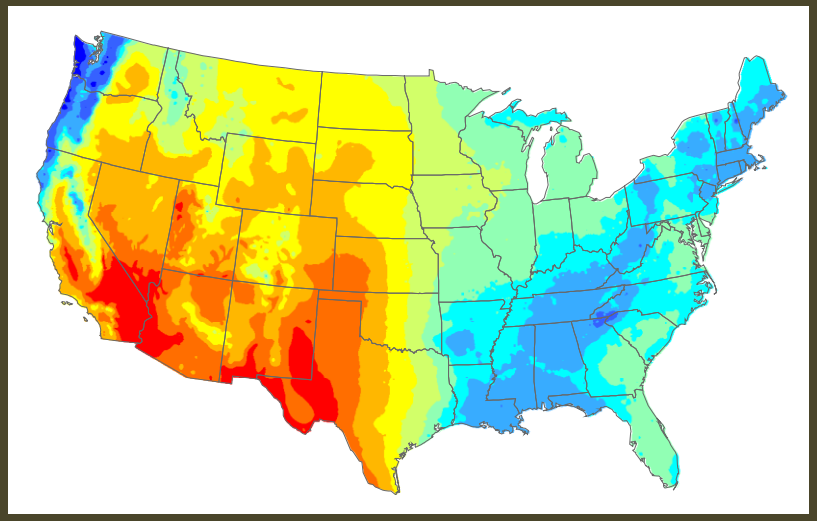


The 20 HLR categories are sequential; thus, the closer the HLR numbers, the more similar the characteristics between those HLRs (e.g., HLRs 7 to 9 are more similar than HLRs 4 to 16). Similarly, the color scheme depicted is graduated; therefore, similar colors represent more similar HLRs.

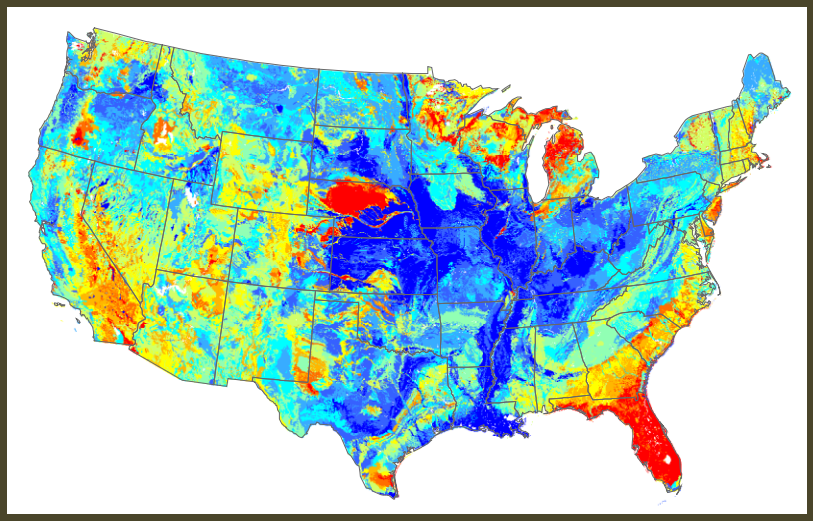
USGS

Factors used to define hydrologic landscape regions (HLRs)

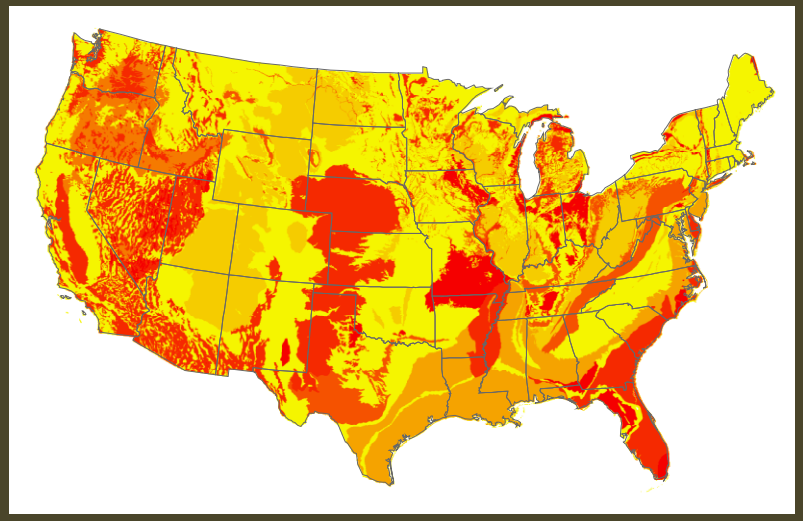
Precip – Potential Evapotranspiration



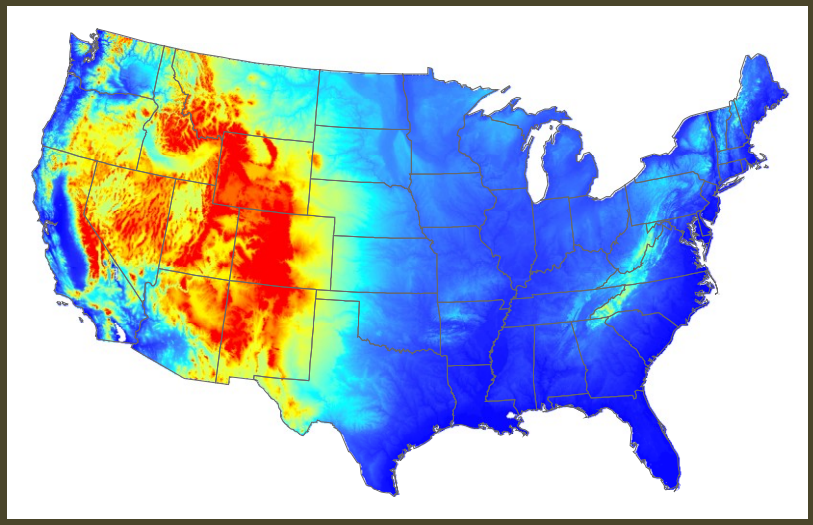
Percent sand



Aquifer permeability



Topography



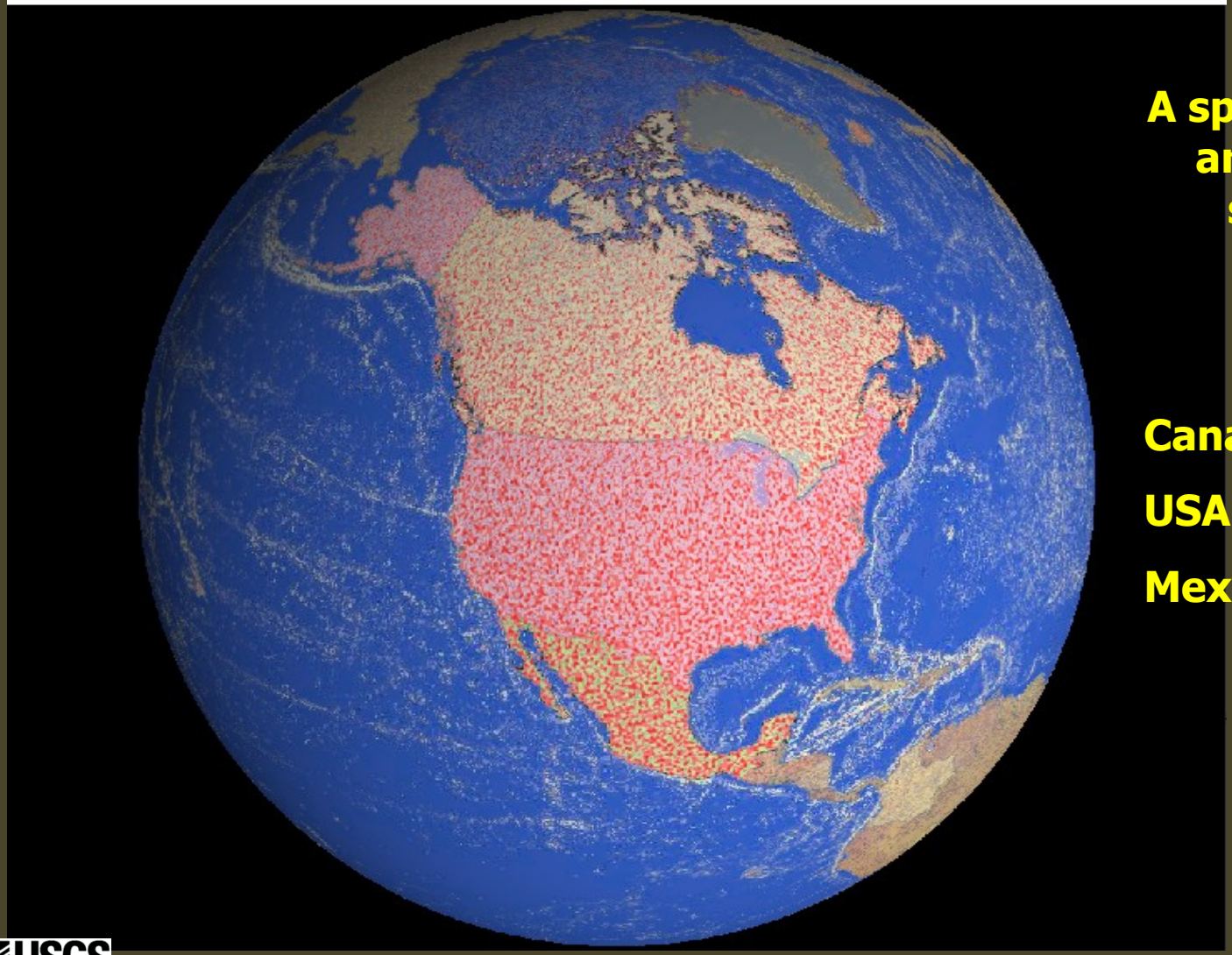
USGS

Servicio Geológico Mexicano

CANADA 1842 GEOLOGICAL SURVEY · COMMISSION GÉOLOGIQUE

USGS science for a changing world

North American Soil Geochemical Landscapes Project

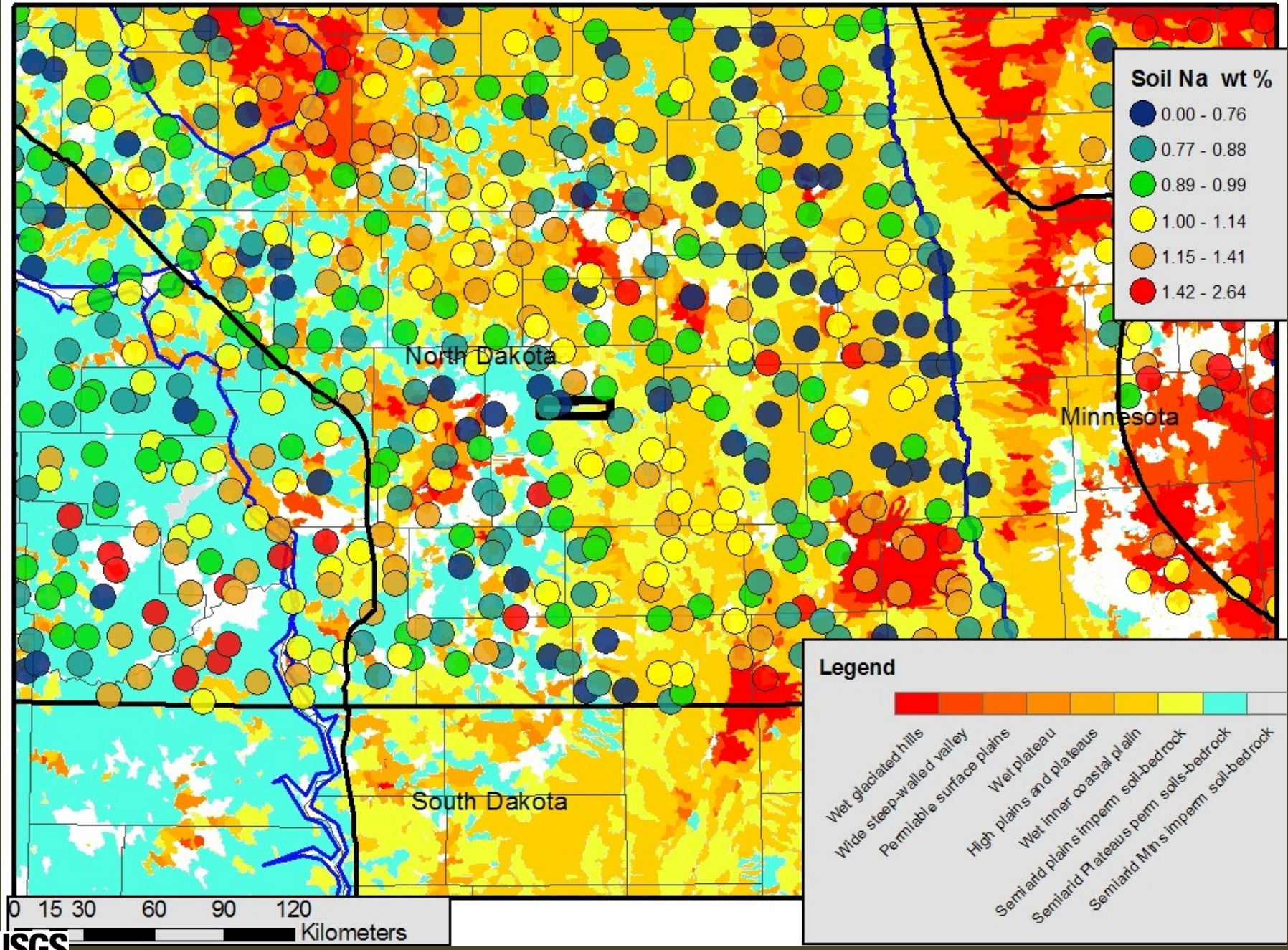


A spatially balanced array of 13,215 sample sites

Canada	6,183
USA	5,813
Mexico	1,216

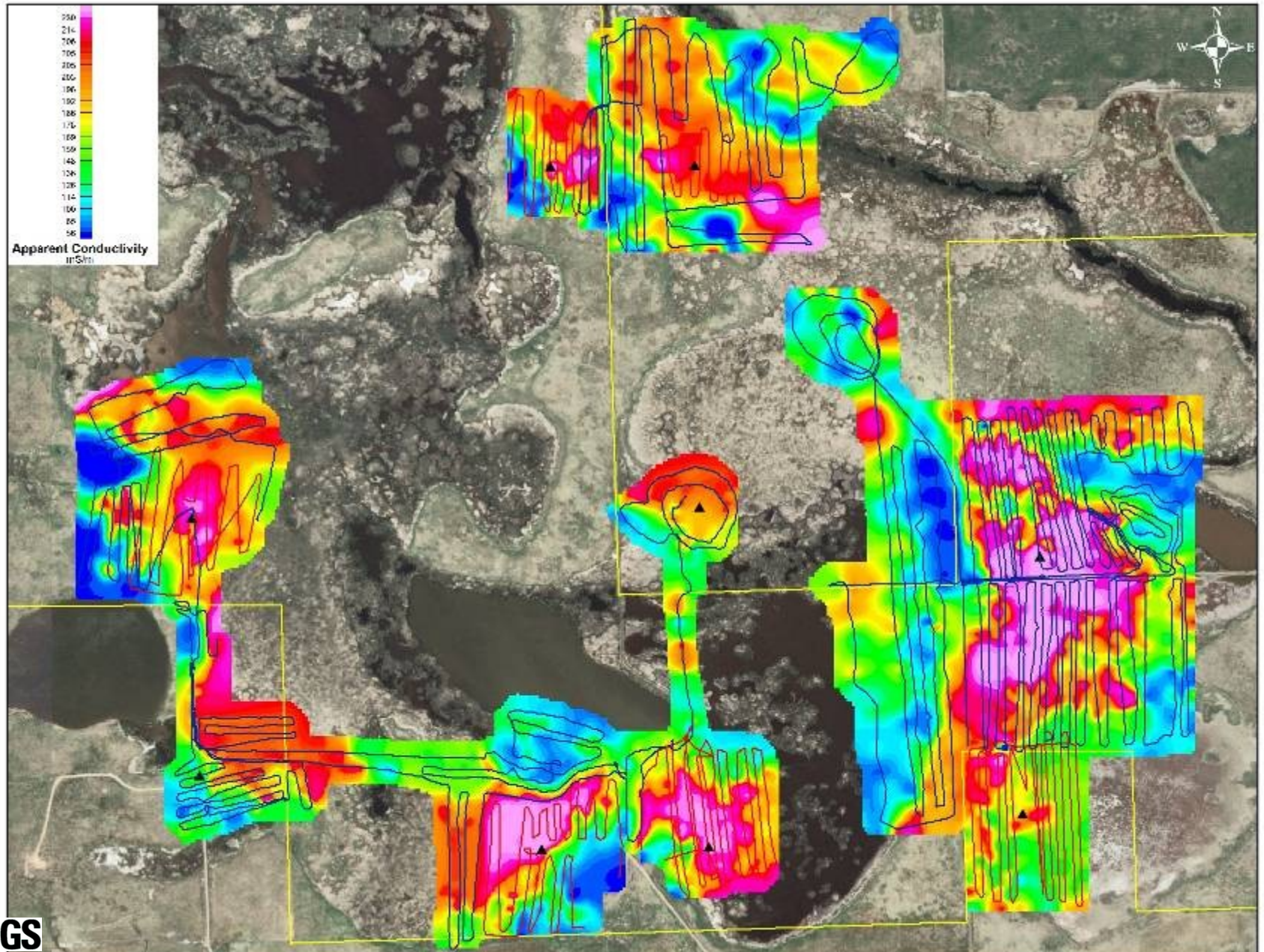
USGS

Hydrologic Landscapes / Soil Na



USGS

EM31 Beaver Lake WPA, Burke Co., ND



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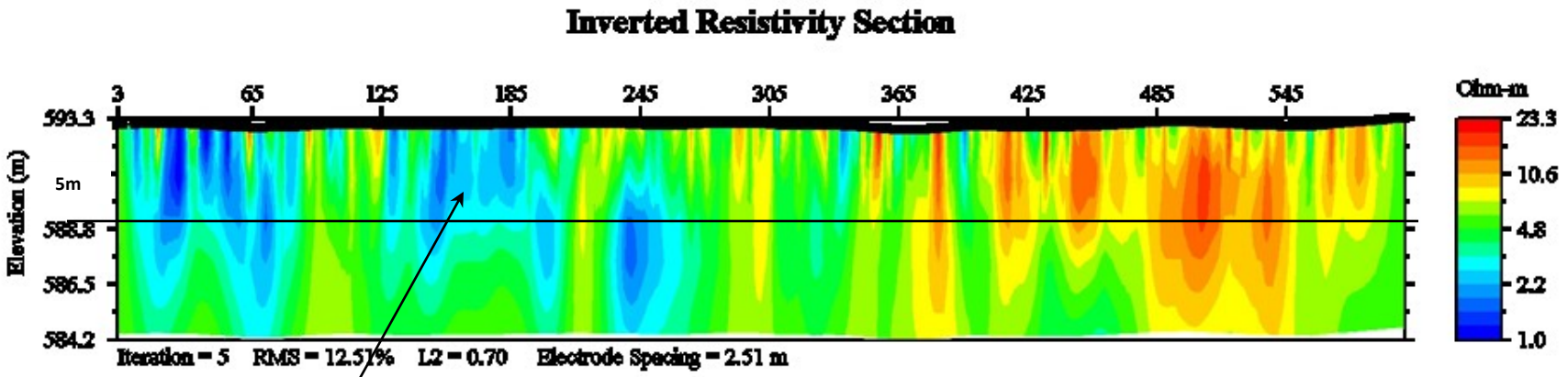
Ohm-mapper Resistivity



Light blue is low resistivity or high conductivity showing general extent of plume with depth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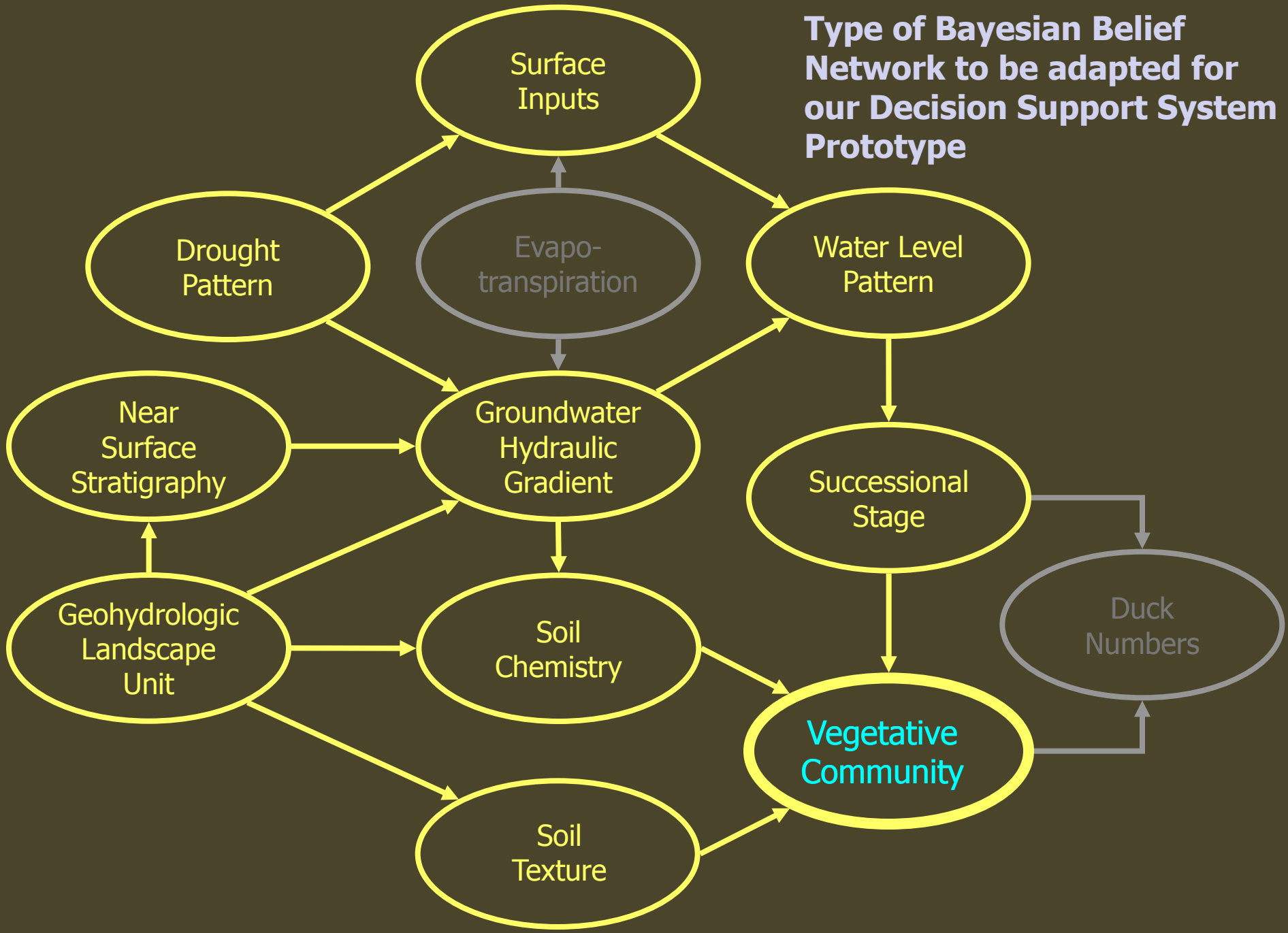
Type of Bayesian Belief Network to be adapted for our Decision Support System Prototype



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Establish Interagency Energy Contamination Science Team

- Led By All Five USGS Center Directors
- Includes FWS Project Leaders and Regional Office Representatives
- Invites Other Federal, Tribal, and State Agencies
- Geographic Focus Is Northern Great Plains and Rockies

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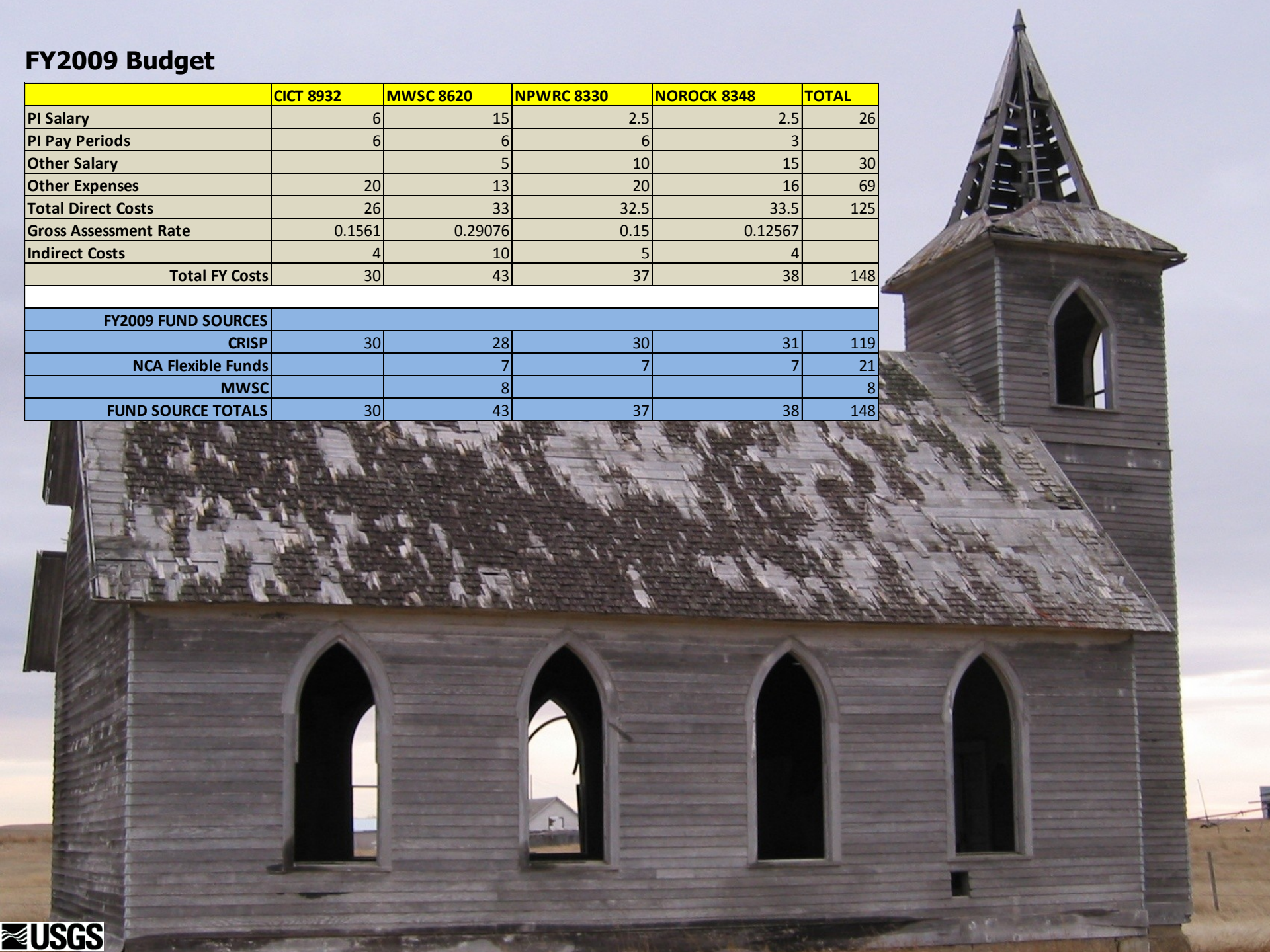
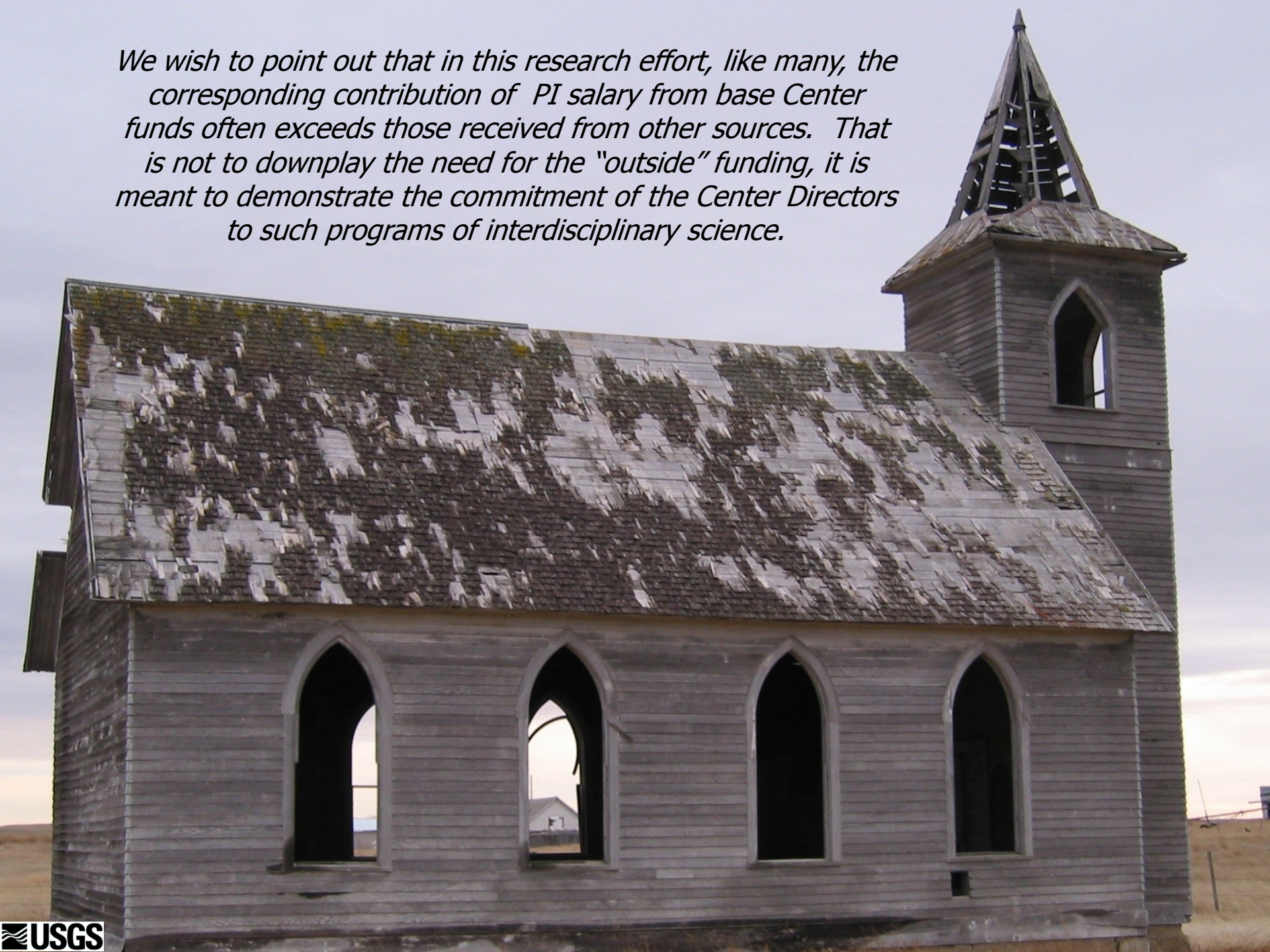
FY2009 Budget

	CICT 8932	MWSC 8620	NPWRC 8330	NOROCK 8348	TOTAL
PI Salary	6	15	2.5	2.5	26
PI Pay Periods	6	6	6	3	
Other Salary		5	10	15	30
Other Expenses	20	13	20	16	69
Total Direct Costs	26	33	32.5	33.5	125
Gross Assessment Rate	0.1561	0.29076	0.15	0.12567	
Indirect Costs	4	10	5	4	
Total FY Costs	30	43	37	38	148
FY2009 FUND SOURCES					
CRISP	30	28	30	31	119
NCA Flexible Funds		7	7	7	21
MWSC		8			8
FUND SOURCE TOTALS	30	43	37	38	148




We wish to point out that in this research effort, like many, the corresponding contribution of PI salary from base Center funds often exceeds those received from other sources. That is not to downplay the need for the "outside" funding, it is meant to demonstrate the commitment of the Center Directors to such programs of interdisciplinary science.
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Expertise Needed By Our Team to Further Develop Our Interdisciplinary Science Beyond Current Capabilities

- Glacial geomorphology linking near-surface stratigraphy and hydrology
- Decision analysis and resource economics
- Effects of oil brine contamination on biota: aquatic vegetation, invertebrates, waterfowl, and shorebirds
- Application of remote sensing and modelling to detect surface chemistry change (hyperspectral data?)
- Additional electromagnetic inductance equipment to conduct surveys over greater areas
- Development of hydrologic landscape unit models at local scales; explore applicability of LIDAR
- Geochemistry of wetlands at a landscape scale

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