

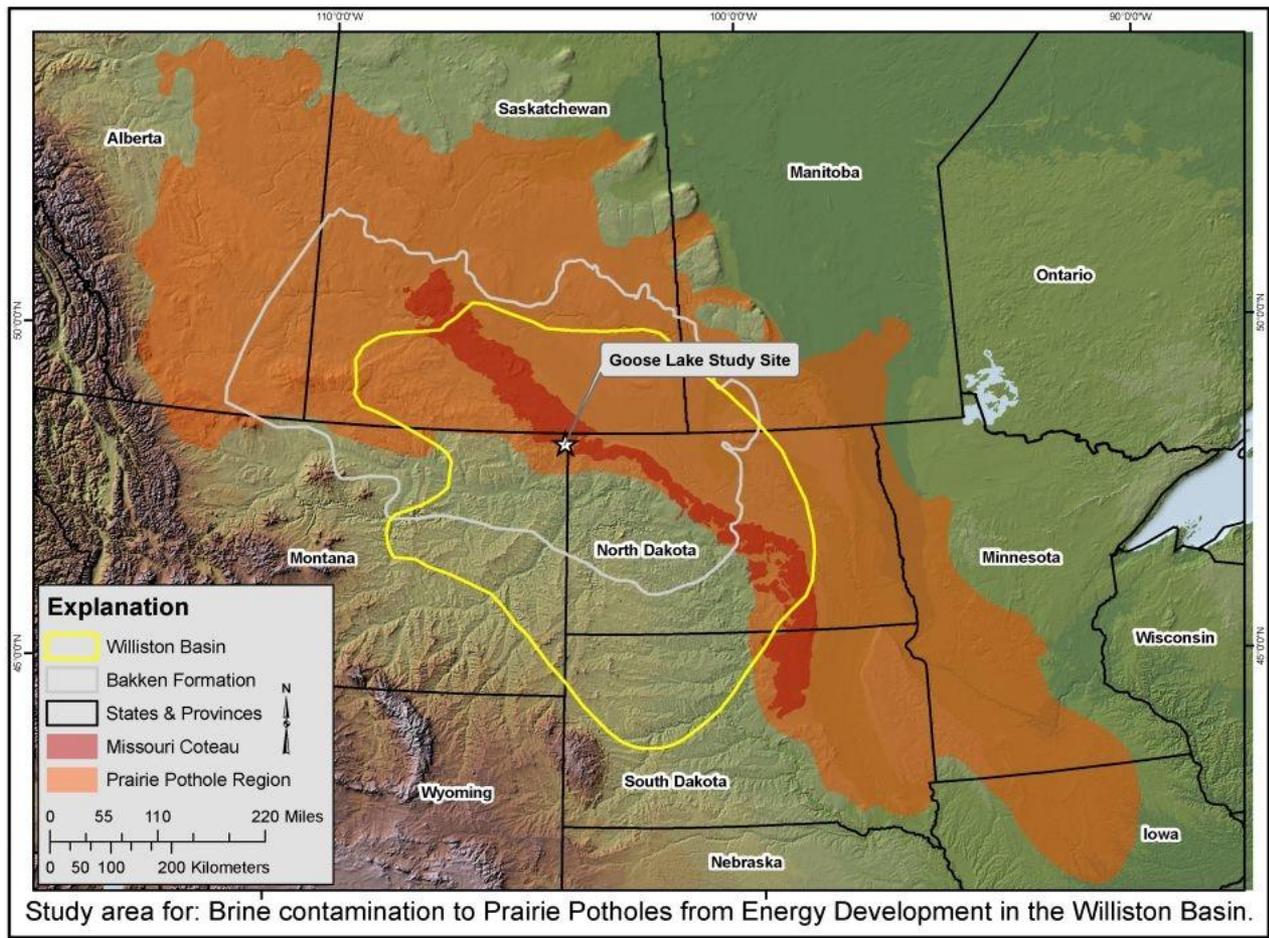


# Strontium Isotope Detection of Brine Contamination of Surface Water and Groundwater in the Williston Basin, Northeastern Montana

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**U.S. Geological Survey**

**GeoCanada, May 14, 2010**

# Prairie Pothole Region and Williston Basin



# Prairie Potholes

- Lakes, wetlands, and sloughs are recharged by precipitation, runoff, and inflow from groundwater
- Evaporation increases natural salinity of some lakes
- Some lakes are perennially saline as a result of a delicate balance between evaporation and recharge
- Contamination by produced water also increases salinity
- Some lakes are economic sources of mirabilite (sodium sulfate)
- Region is a major nesting ground for ducks and other waterfowl

# Science Team on Energy in Prairie Pothole Environments (STEPPE)

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

- **STEPPE is a USGS multidisciplinary team studying impact of energy production on prairie pothole region in Williston Basin**
  - **Evaluating potential risk to natural resources**
  - **Determining spatial extent of impact**

# Produced Water Factoids

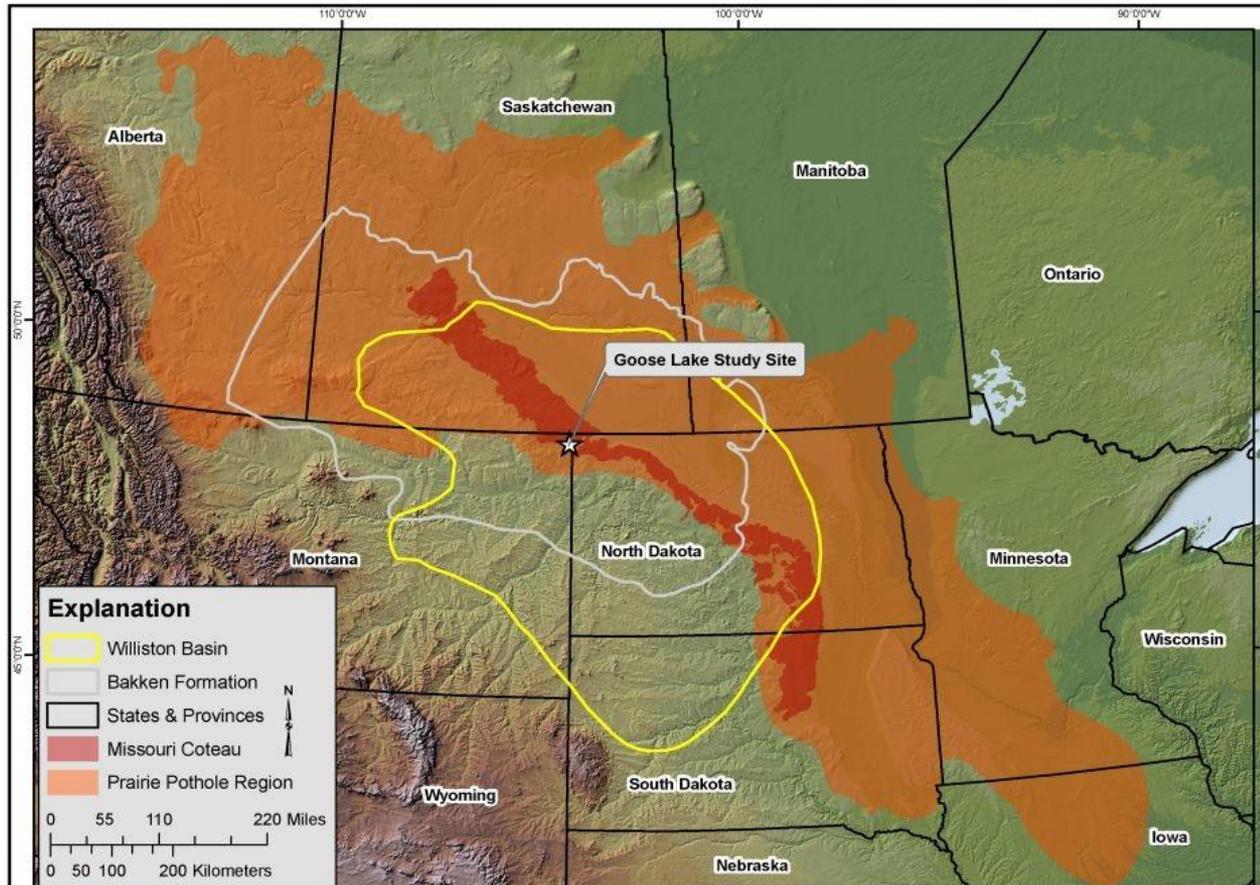
(National Energy Technology Laboratory, Argonne National Laboratory, and Produced Water Society)

- Approximately 20 billion barrels produced annually in US (about 55 million barrels/day)
  - 3 to 4 barrels per barrel of oil in Williston Basin
- Salinity as much as 400,000 mg/L (sea water is 35,000 mg/L)
- Disposal
  - 65% is re-injected into producing units
  - 30% injected into deep formations for disposal
  - 5% is disposed of at the surface

# Strontium (Sr) Isotope Study

- Test use of strontium isotopes for detecting very small amounts of produced water (aka formation water, oil-field brine) contamination
- Goose Lake site in northeastern Montana
  - Hydrochemical, geophysical, and biological studies being conducted by STEPPE
- Sr study is a Work in progress

# Prairie Pothole Region and Goose Lake Study Site



Study area for: Brine contamination to Prairie Potholes from Energy Development in the Williston Basin.

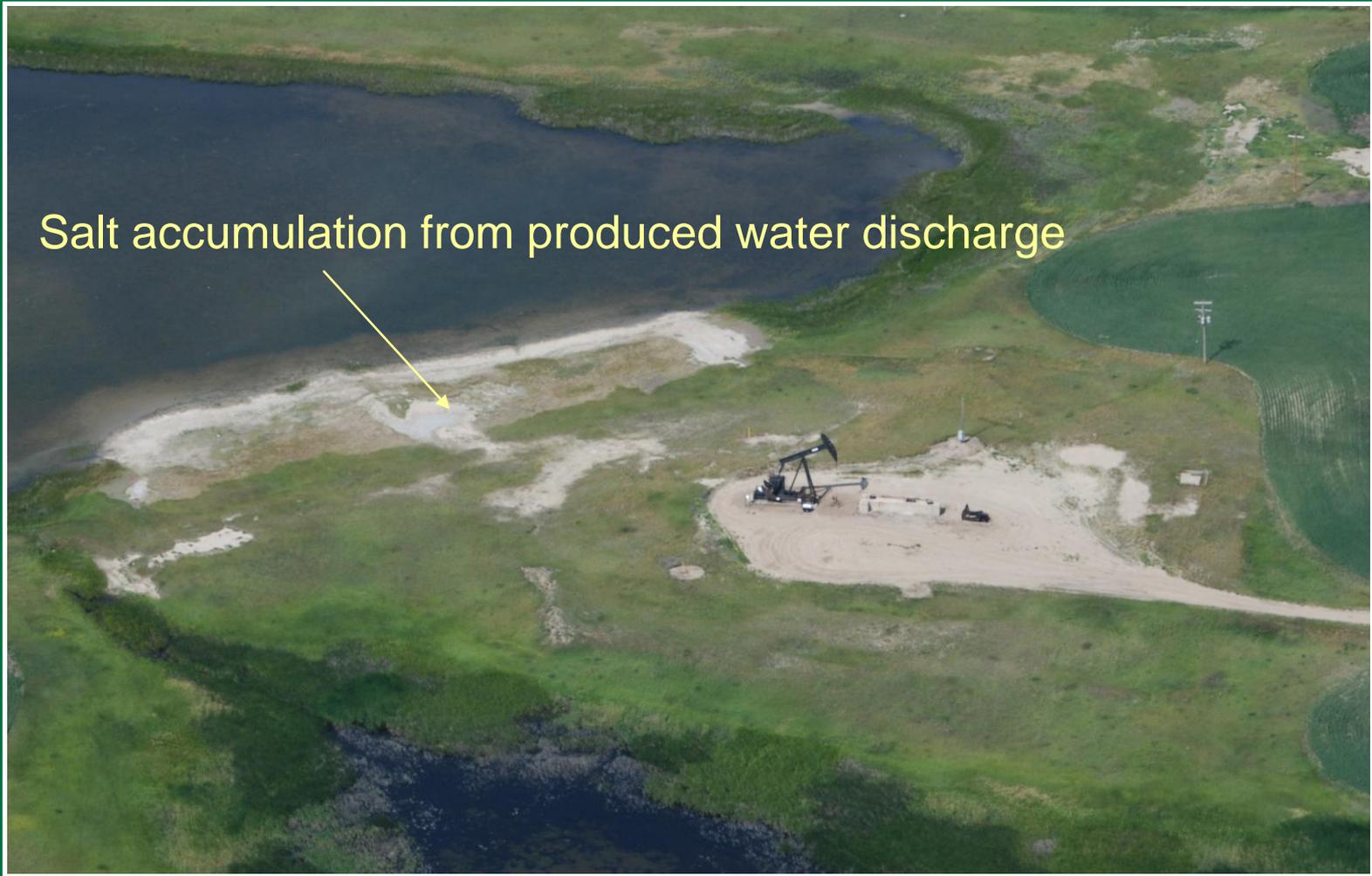
# Oil Spill Impact on Wetland

(Photo by Jerry Rodriguez, Medicine Lake National Wildlife Refuge)



# Produced Water Impact on Wetland

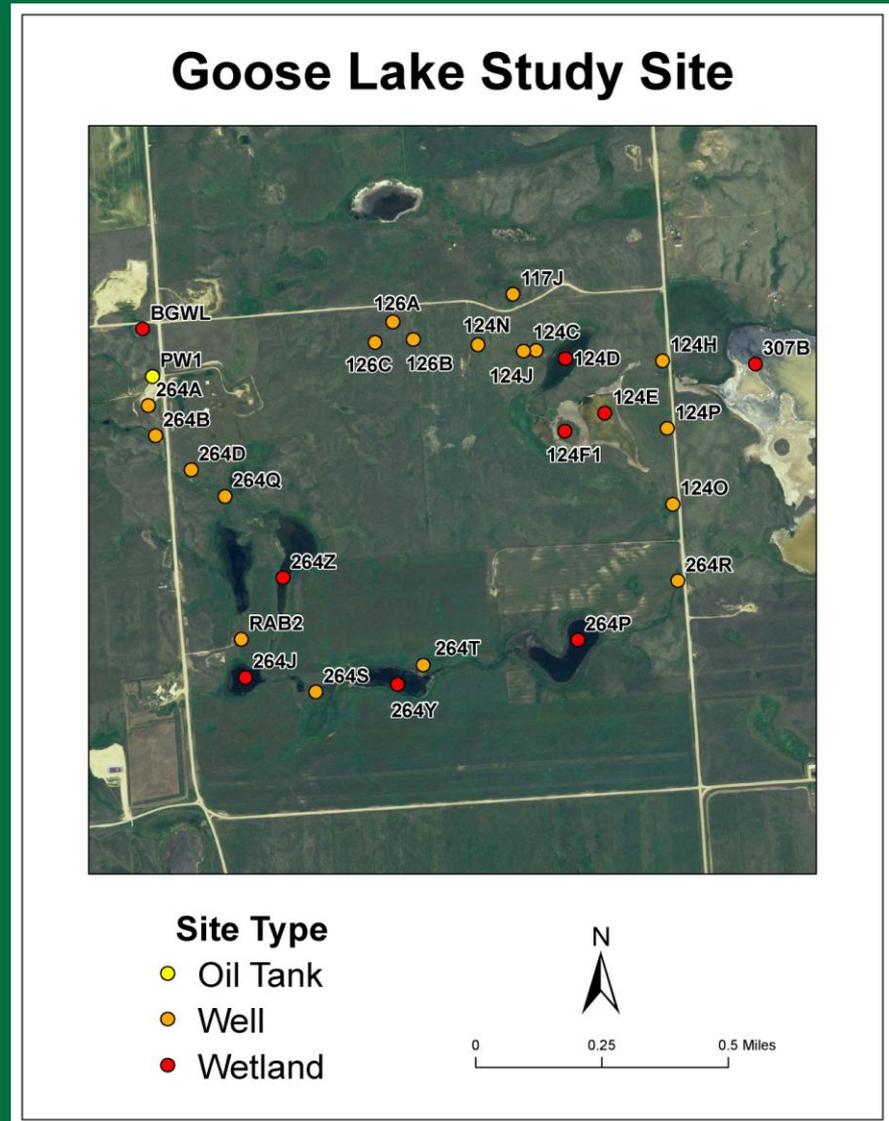
(Photo by Jerry Rodriguez, Medicine Lake National Wildlife Refuge)



# Goose Lake Study Site

USGS activities include:

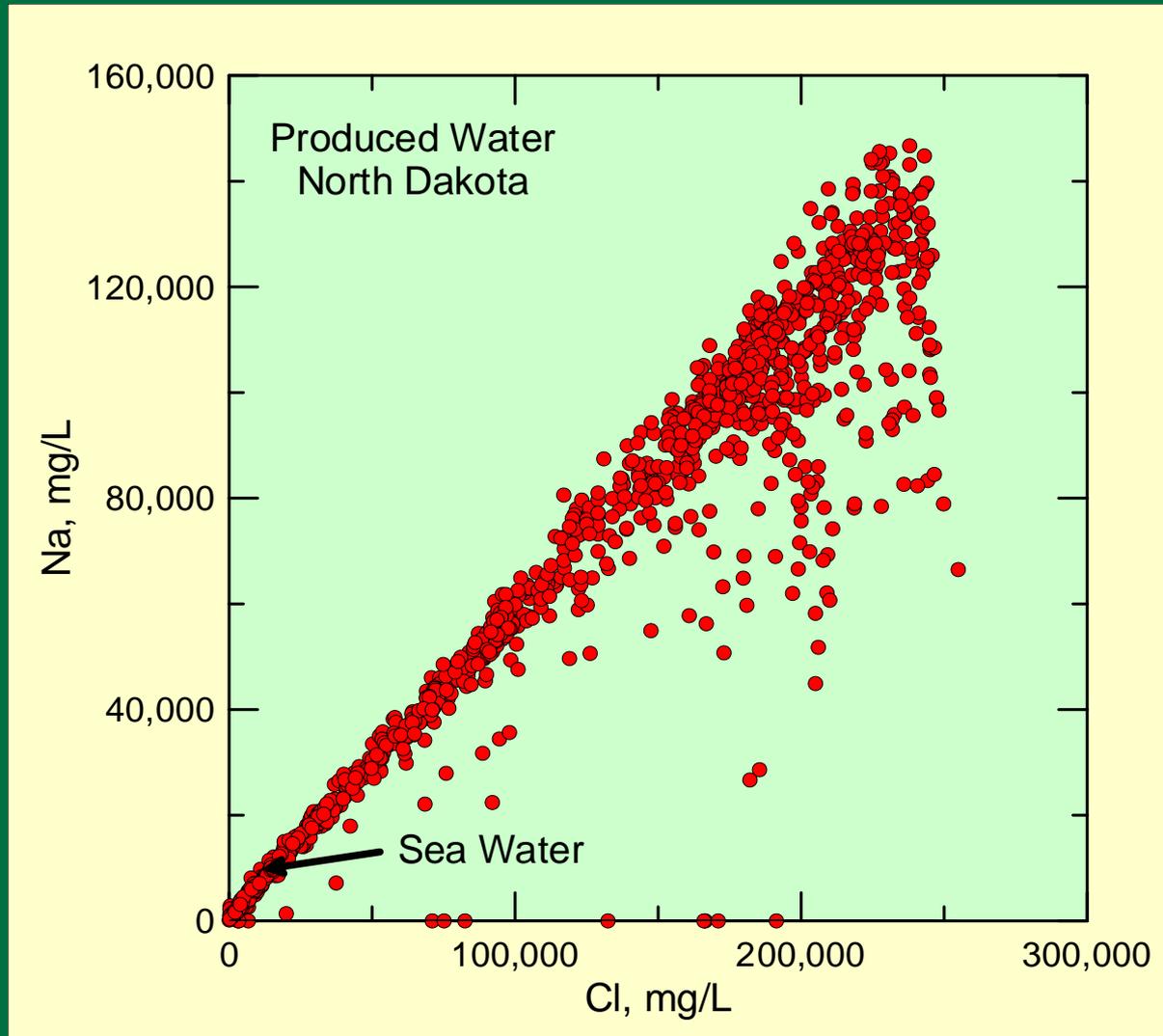
- Hydrochemical analyses identify contamination
  - Majors and trace elements
  - Strontium isotopes (this study)
- Electromagnetic studies
  - High conductivity zones delineate brine plumes (Bruce Smith et al.)



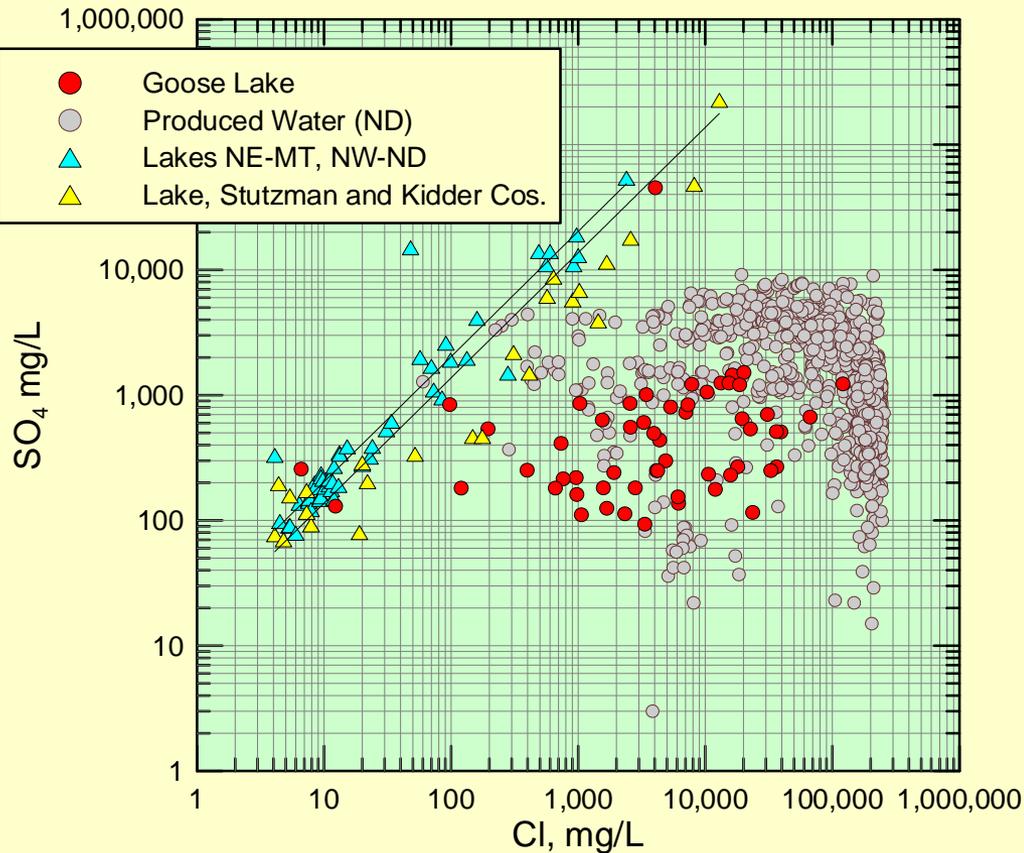
# Sources of Salinity in Potholes

- Natural solutes are acquired by water-soil-rock interaction
- Evaporation increases solute concentrations
- $\text{SO}_4/\text{Cl}$  will not change unless mirabolite or halite precipitates
- Contamination with Cl rich produced water will increase Cl while decreasing  $\text{SO}_4/\text{Cl}$  ratios
- Sr isotope ratios are not changed by evaporation

# Produced Water is very Saline



# Produced Waters are High in Chloride

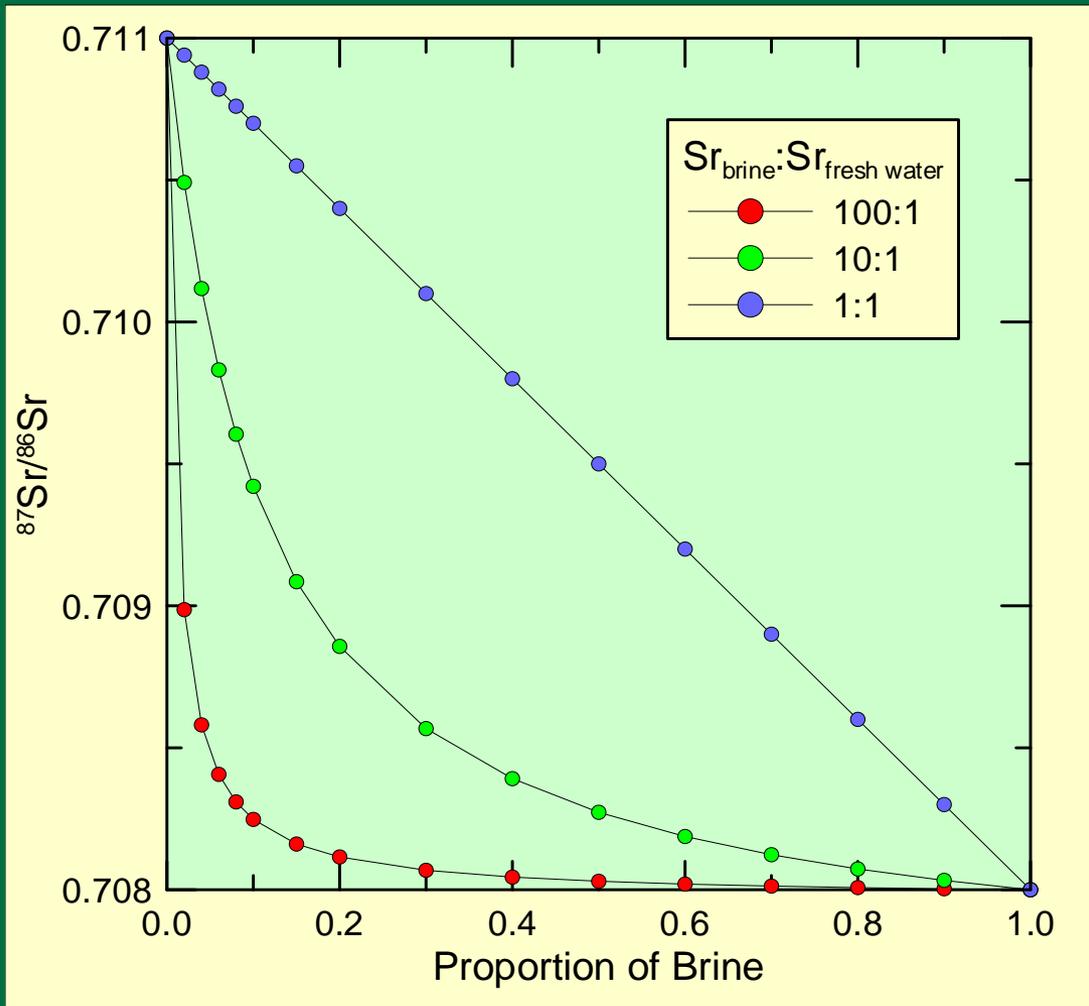


- Uncontaminated surface waters show evaporation trends in Cl and SO<sub>4</sub>
- Produced waters can attain saturated with NaCl but show no covariance with SO<sub>4</sub>
- Many Goose Lake samples are contaminated

# Small Amounts of Contamination Can be Detected by Sr Isotopes

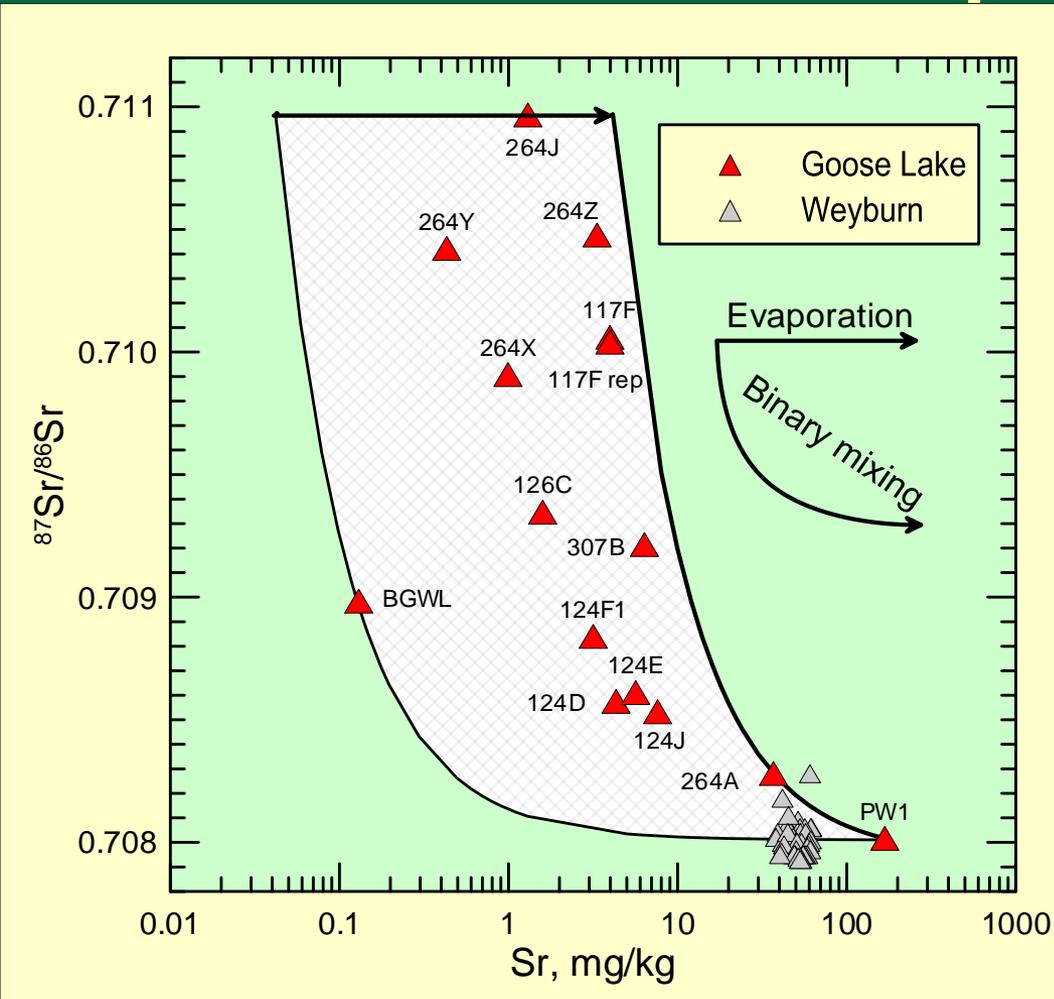
- Sr contents of fresh water and produced water differ by several orders of magnitude
- Where Sr isotopic composition of fresh water and produced water differ, binary mixing trends are produced
- Process can involve multiple episodes of evaporation and contamination but net effect will be the same

# Sr Isotope Binary Mixing Curves



- Binary mixing curves as function of proportion of end members and ratios of Sr contents
- The greater the contrast in Sr contents, the greater the sensitivity for detecting small amounts of brine

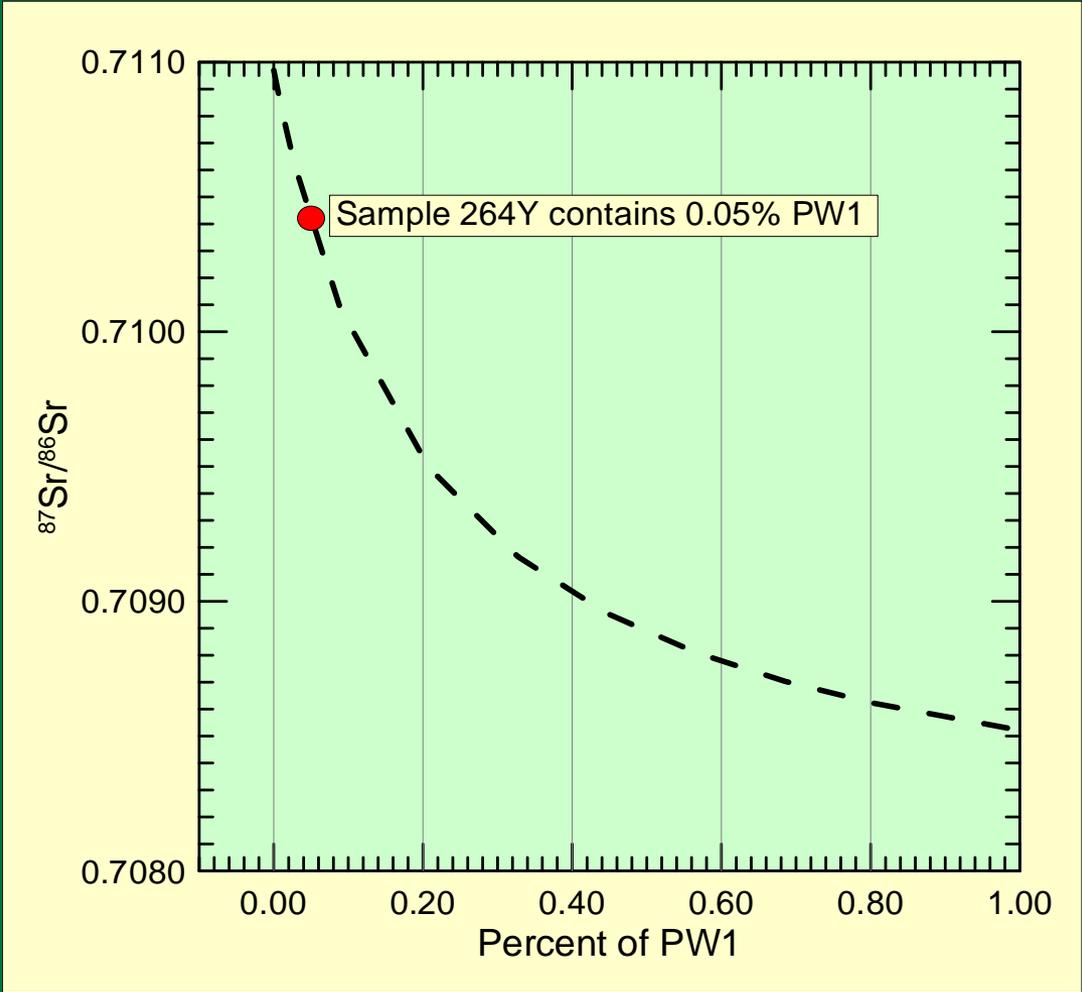
# Sr Isotope Systematics of Goose Lake Samples



- Largest  $^{87}\text{Sr}/^{86}\text{Sr}$  is assumed to represent or least contaminated end member
- Mixing zone is bounded by mixing lines between brine and values on evaporation line
- $^{87}\text{Sr}/^{86}\text{Sr}$  of Goose Lake Brine is identical to mean value for Weyburn brines (Quattrocchi et al, 2006)

# Sensitivity of $^{87}\text{Sr}/^{86}\text{Sr}$ to Mixing

- Sample 264Y shows sensitivity of Sr isotopes for detecting small amounts of produced water
- In this binary system, as little as 0.005% could be detected given the analytical uncertainty in  $^{87}\text{Sr}/^{86}\text{Sr}$



# Conclusions

- **Strontium isotopes**
  - Sensitive indicators of small amounts of produced water contamination
  - Ratios do not change with evaporation
  - Mixing systematics allow calculation of degree of contamination
- Regional baseline data from other wetland areas in Williston basin are needed in anticipation of increased oil production from tight rocks that require hydrofracturing