Water
Fracking Process

Typical volumes of water:
- 4 - 5,000,000 gallons for horizontal wells
- 670,000 gallons for vertical wells
Flowback Storage
Typical volumes of water:
Average in N. America, 8 barrels of produced water for every barrel of oil
In CA, 15 barrels of produced water for every barrel of oil
~80% of wells for enhanced oil recovery (EOR)
~20% of wells for waste water disposal
Spills and leaks of waste water

Nearly 3 Million Gallons Of Drilling Waste Spill From North Dakota Pipeline

BY KATIE VALENTINE JAN 22, 2015 9:28AM

In this Dec. 17, 2014 photo, workers tend to oil pump jacks behind a natural gas flare near Williston, N.D.

Almost 3 million gallons of saltwater drilling waste spilled from a North Dakota pipeline earlier this month, a spill that's now being called the state's largest since the North Dakota oil boom began.

The brine, which leaked from a ruptured pipeline about 15 miles from the city of Williston, has affected two creeks, but it doesn't currently pose a threat to drinking water or public health. The pipeline's operator — Summit Midstream Partners — discovered the spill on Jan. 6, but officials didn't find out about the true size of the spill until this week.

The pipeline company has been trying to clean up the spill by vacuuming water from the creek, but in doing so, they're also capturing a lot of fresh water.
Spills and leaks of waste water

Nearly 3 Million Gallons Of Drilling Ill From North Dakota Pipeline

Published November 18, 2013, 10:19 AM

Saltwater spills can cause lasting damage

BISMARCK - More than 65,000 barrels of saltwater — about 2.3 million gallons — produced by the oil and gas industry have been spilled on North Dakota land in the past 22 months, posing an environmental risk to soil, plants and freshwater resources in dozens of cases, a Forum News Service review of incident reports found.

State regulators highlight that most of the saltwater was contained and cleaned up on well sites.

Reports show 81 percent of the 1,090 releases of saltwater — some of it mixed with oil, diesel fuel or other liquids — were contained on site or within the leaking pipeline’s right-of-way.

And nearly 70 percent of the saltwater was reported as recovered, usually by vacuuming up the briny liquid or hauling the contaminated soil to the landfill, or both, according to incident reports filed with the state Department of Health from Jan. 1, 2012, to Oct. 29 of this year.

Still, at least 15 percent of the spills — more than 13,000 barrels — weren’t contained, and the issue is considered a high-enough priority that the department is trying to assemble a task force of industry experts, industry representatives, state regulators and others to keep the winter at bay.

"Are there new, better approaches to remediating this saltwater? Because that’s actually harder to clean up than the oil," he said.

The amount of saltwater spilled in the state since 2012 would fill nearly four Olympic-size swimming pools. By comparison, during roughly the same time frame, 705 oil spills were reported in North Dakota, spilling a total of about 4,225 barrels of oil, the Associated Press reported last month. Those figures don’t include a 20,600-barrel oil spill discovered near Tioga in September.

With state-mandated North Dakota landowners have become more organized and vocal in their concerns about saltwater spills. Last month, landowners and a lawyer led a tour of so-called "salted lands" in Bottineau County, where pockets of farmland sterilized by spills and pipeline leaks dot the landscape.

"Saltwater is far more devastating to our environment than oil is," said Galen Peterson, who farms near Mandaree in Bottineau County and is secretary of the North Dakota Landowners Association.

Public notice in works

Incident reports show about four-fifths of the saltwater spills since 2012 were 50 barrels or fewer, and almost half involved five barrels or fewer. A barrel is 42 gallons.
Spills and leaks of waste water

Oil drillers' brine spills blight land

ADVANCE FOR USE TUESDAY, SEPT. 8, 2015 AND THEREAFTER — in this April 24, 2015 photo, Carl Johnson, left, and his son, Justin, walk across a stretch of pasture surrounded by an oilfield waste water spill on their ranch near Carlsbad, N.M. The ranchers have been fighting oil companies for decades over spills of brine, polluted water.

“We lose our water,” Justin Johnson said, “that ruins our ranch.”

Their plight illustrates a side effect of oil and gas production that has worsened with the past decade’s drilling boom: spills of wastewater that foul the land, kill wildlife and threaten freshwater supplies.

An Associated Press analysis of data from leading oil- and gas-producing states found more than 180 million gallons of wastewater spilled from 2009 to 2014 in incidents involving ruptured pipelines, overflowing storage tanks and even deliberate dumping. There were some 21,601 individual spills. The numbers are incomplete because many releases go unreported.

Though spills get more attention, wastewater spills can be more damaging. Microbes in soil eventually degrade spilled oil. Not so with wastewater — also known as brine, produced water or saltwater. Unless thoroughly cleansed, saltwater can’t be reused.

“We can’t clean that up,” said Kerry Sutcliffe, a University of Tulsa environmental engineer. “Brine spills are much more difficult.”

In addition to extreme salinity, the fluids often contain heavy metals such as arsenic and mercury. Some ranchers said they have lost cattle that lapped up the liquids or ate limited grass.

“They get real thin. It messes them up,” said Melvin Reed of Strider, Oklahoma. “Sometimes you just have to shoot the hell out of them.”

Nearly 3 Million Gallons Of Drilling Ill From North Dakota Pipeline

A company working with an oil and gas drilling company is cleaning up a spill of wastewater in North Dakota.

Oil companies are being criticized for not doing more to clean up spills.

View all 15 images in gallery...
Traditional solutions

ft to 100’s of ft
Traditional solutions
### Produced water characteristics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Blended</th>
<th>Flowback/Produced</th>
<th>Groundwater (Freshwater)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Dissolved Solids (TDS) mg/L</td>
<td>11,100</td>
<td>35,600</td>
<td>233</td>
</tr>
<tr>
<td>Conductivity (μmhos/cm at 25°C)</td>
<td>30,400</td>
<td>139,000</td>
<td>449</td>
</tr>
<tr>
<td>pH</td>
<td>6.36</td>
<td>6.57</td>
<td>7.74</td>
</tr>
<tr>
<td>Chloride (mg/L)</td>
<td>6,300</td>
<td>22,900</td>
<td>18.1</td>
</tr>
<tr>
<td>Sodium (mg/L)</td>
<td>2,680</td>
<td>8,120</td>
<td>6.75</td>
</tr>
<tr>
<td>Calcium (mg/L)</td>
<td>811.0</td>
<td>2,610.0</td>
<td>81.6</td>
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<tr>
<td>Magnesium (mg/L)</td>
<td>55.7</td>
<td>183.0</td>
<td>19.9</td>
</tr>
<tr>
<td>Sulfate (mg/L)</td>
<td>4.62</td>
<td>3.3</td>
<td>36.2</td>
</tr>
</tbody>
</table>

![Total Dissolved Solids from the Produced Waters Database in the United States](image-url)
Principle

The voltage difference is a function of the injected current and the resistivity beneath the electrode array

Ohm’s Law: \( V = I R \)
Electrical resistivity imaging

Measurement response

Resistance
Electrical resistivity imaging

In reality
Case study

Release from a Saltwater Disposal Well
### Site and conditions

<table>
<thead>
<tr>
<th>Site</th>
<th>Chloride (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P-1</td>
<td>1,000</td>
</tr>
<tr>
<td>P-4</td>
<td>904</td>
</tr>
<tr>
<td>P-7</td>
<td>2,030</td>
</tr>
<tr>
<td>P-10</td>
<td>2,920</td>
</tr>
<tr>
<td>P-13</td>
<td>5,560</td>
</tr>
<tr>
<td>P-15</td>
<td>3,330</td>
</tr>
<tr>
<td>Farm Pond</td>
<td>2,820</td>
</tr>
<tr>
<td>Sump @ house</td>
<td>16,200</td>
</tr>
<tr>
<td>Sump @ T</td>
<td>17,100</td>
</tr>
<tr>
<td>Creek (north of sump @ T)</td>
<td>1,410</td>
</tr>
</tbody>
</table>
Survey Layout

Data collection

[Map showing survey layout with lines labeled SE-NW Line, S-N Line, and SW-NE Line. Images of fieldwork actions are also present.]
Resistivity results

![Resistivity results diagram](image-url)
Case study

Resistivity results

Archie’s Law:

$$S_w = \sqrt[n]{\frac{a R_w}{\phi R_t^m}}$$

- $S_w$: Water saturation, fraction
- $a$: Empirical constant (usually near unity)
- $R_w$: Resistivity of formation water, $\Omega \cdot m$
- $\phi$: Porosity, fraction
- $R_t$: Resistivity of uninvaded formation, $\Omega \cdot m$
- $m$: Saturation exponent (also usually near 2)
Ground truthing
Summary

- Electrical resistivity technique proved to be successful in delineating regions impacted by the brine spill.
- The plume in proximity to the injection well indicate the leak originated at depth, consistent with other leaking wells in area.
- Based on the subsurface geology in the area we were able to use Archie’s law to provide a resistivity range for the subsurface regions impacted by the brine for this reconnaissance survey.
- Geophysical results use to aid in placement of follow-up monitoring wells. The sampling results from these wells correlate well to the resistivity results.

  Unfortunately the drilling technique was unable to penetrate the shallow bedrock and so still awaiting further quantitative results.
Questions / Comments ?

Website Resources:
- General: hgiworld.com
- Mining: heapsolutions.com
- Leak Detection: hgileakdetection.com