

Additional Information

Seismic Risk Analysis

December 6, 2022

PN 1703.T16.00

Mr. Phillip Goetze, P.G.
NM EMNRD – Oil Conservation Division
1220 South St. Francis Drive
Santa Fe, NM 87505

Subject: **Waterbridge Stateline, LLC**
Long Shot SWD #1 - Seismic Potential Letter

Dear Mr. Goetze,

At the request of Water Bridge Stateline, LLC (Waterbridge), ALL Consulting, LLC (ALL) has assessed the potential injection-induced seismicity risks in the vicinity of Waterbridge's Long Shot SWD #1 (Subject SWD), a proposed saltwater disposal (SWD) facility in Eddy County, New Mexico, and summarized the findings in this letter. This assessment used publicly available data to identify the proximity and characteristics of seismic events and known faults to evaluate the potential for operation of the Long Shot SWD #1 to contribute to seismic activity in the area.

Geologic Evaluation

The Subject SWD is requesting a permit to inject into the Pennsylvania Cisco Formation at a depth of 8,320-8,995 feet below ground surface (bgs). The Cisco consists of various Pennsylvanian-age carbonates and is overlain by approximately 40 feet of shale beds with low porosity and permeability development that prevent the upward migration of injection fluid and serve as the upper confining layer (see **Attachment 1**). Additionally, approximately 80 feet of interbedded low porosity and low permeability shales and other carbonate rocks lie in the lower Cisco Formation and upper Strawn Formation and act as a lower confining zone by prohibiting downward migration of injected fluids into the underlying Strawn Formation (see **Attachment 1**). A stratigraphic chart depicting the geologic setting is included as **Figure 1**.¹

Seismic Events and Fault Data

A review of United States Geological Survey (USGS) and New Mexico Tech Seismological Observatory (NMTSO) earthquake catalogs determined that two seismic events have been recorded within a 100 square mile area [9.08-kilometer (km) radius] around the Subject SWD. The closest recorded seismic event was a M1.76 that occurred on December 29, 2021 and was located approximately 2.86 miles north of the Subject SWD (see **Attachment 2**).

¹ Ball, Mahlon M. 1995. "Permian Basin Province (044)." In *National Assessment of United States Oil and Gas Resources—Results, Methodology, and Supporting Data*. U.S. Geological Survey.
<https://certmapper.cr.usgs.gov/data/noga95/prov44/text/prov44.pdf> (accessed June 18, 2018).

Fault data from USGS and the Texas Bureau of Economic Geology (BEG) indicates that the closest known fault is located approximately 2.57 miles southeast of the Subject Well (See **Attachment 2**). This identified fault is within the Precambrian basement, which is approximately 7,000 feet below the injection interval². A map of the seismic events and faults within 9.08 km of the Subject SWD is included as **Attachment 2**.

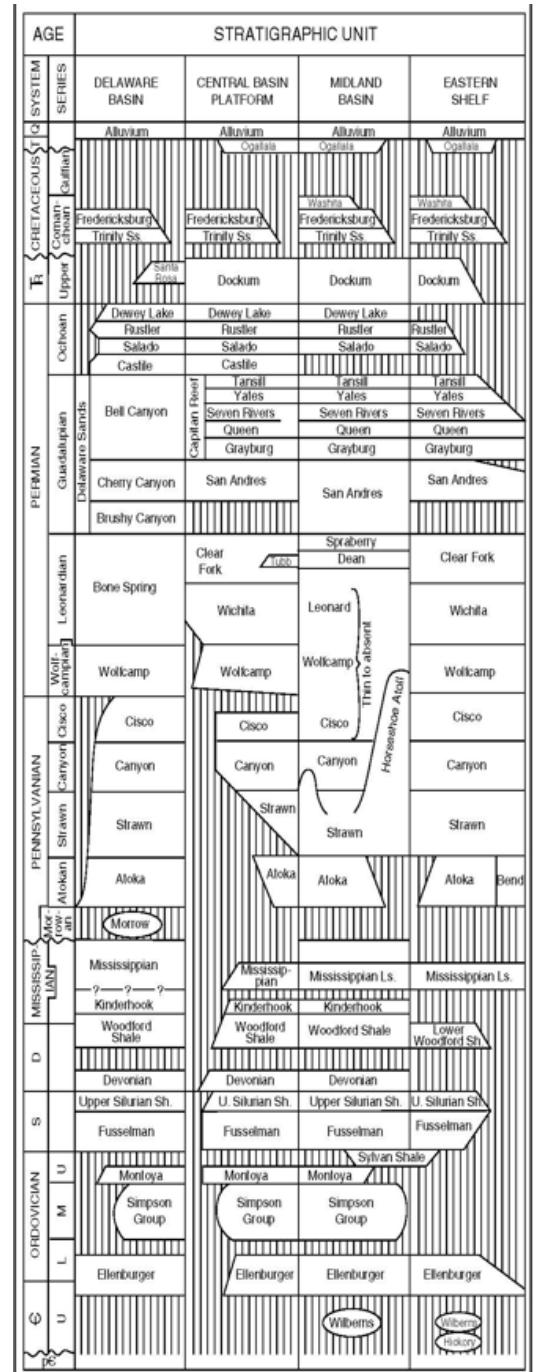
Seismic Potential Evaluation

Experience in evaluating induced seismic events indicates that most injection-induced seismicity throughout the U.S. (e.g., Oklahoma, Ohio, Texas, and Colorado) occurs as a result of injection into Precambrian basement rock or into overlying formations that are in hydraulic communication with the Precambrian basement rock, or as a result of injection near critically stressed and optimally oriented faults. Seismicity at basement depths occurs because critically stressed faults generally originate in crystalline basement rock and may also extend into overlying sedimentary formations.³

Injection into either the Precambrian basement rock or its overlying formations that are hydraulically connected to the basement rock through faulting or fracture networks can increase the pore pressure and may cause the fault to slip, resulting a seismic event.⁴ Because of this, the vertical distance between the injection formation and Precambrian basement rock as well as the presence or lack of faulting within the injection interval are major considerations when determining the risk of injection-induced seismicity. Geophysical logs from nearby well records show at least 7,000 feet of vertical separation between the injection interval and the Precambrian basement.¹ Injection-induced seismicity is not typically associated with shallow disposal wells, such as the Long Shot SWD #1.

For injection into the Cisco Formation to contribute to seismic activity, one of two hypothetical geologic scenarios must exist:⁴

Figure 1 – Delaware Basin Stratigraphic Chart (Ball 1995)



² G. Randy Keller, J. M. Hills & Rabah Djeddi, A regional geological and geophysical study of the Delaware Basin, New Mexico and West Texas, Trans Pecos Region (West Texas) (1980).

³ Ground Water Protection Council and Interstate Oil and Gas Compact Commission. *Potential Injection-Induced Seismicity Associated with Oil & Gas Development: A Primer on Technical and Regulatory Considerations Informing Risk Management and Mitigation*. 2015. 141 pages.

⁴ Skoumal, Robert J., et al. "Induced Seismicity in the Delaware Basin, Texas." *Journal of Geophysical Research: Solid Earth*, vol. 125, no. 1, 2020, doi:10.1029/2019jb018558.

1. Earthquake hypocenters would need to be significantly shallower (several kilometers) than initially identified by the USGS and NMTSO seismic monitoring networks, and thus placing seismic activity high in the sedimentary column, rather than in the Precambrian basement.
2. High permeability and transmissive conduits from fault-damaged zones would need to be present below the Cisco Formation, allowing fluid to migrate through the Strawn Formation shale and carbonate units and through significantly deeper confining intervals, and eventually into the Precambrian basement. Additionally, this hypothesis would need to assume that the injection fluids and bottom hole pressures in the Cisco Formation would need to exceed existing hydrostatic pressures within the deeper geologic formation in order for injection fluids to migrate downward.

There are no publications or data that suggest either of these scenarios to be true for the area around the Subject SWD.

Fault Slip Potential Modeling

A Fault Slip Potential (FSP) model was prepared to indicate the likelihood that operation of the Subject SWD would result in a seismic event based on the proximity and characteristics of known injection rates, fault, and subsurface pressures. The model parameters and SWDs, an FSP area map, and model run screenshots are included as **Attachment 3**.

The FSP modeling results through 25 years, with injection rates that are likely overestimated, resulted in FSP values of 0.00 on all known faults within 100 square miles of the Subject SWD indicating the area presents little to no risk for injection induced seismicity.

Conclusion

As an expert on the issue of induced seismicity, seismic monitoring and mitigation, it is my opinion that the potential for the Subject SWD to cause injection-induced seismicity is expected to be minimal, at best. This conclusion is based on (1) the presence of numerous confining layers above and below the injection interval, (2) the significant vertical distance between the injection zone and Precambrian basement rock in which the nearest fault is located, and (3) FSP modeling results which indicate no risk of induced seismicity potential.

Sincerely,
ALL Consulting

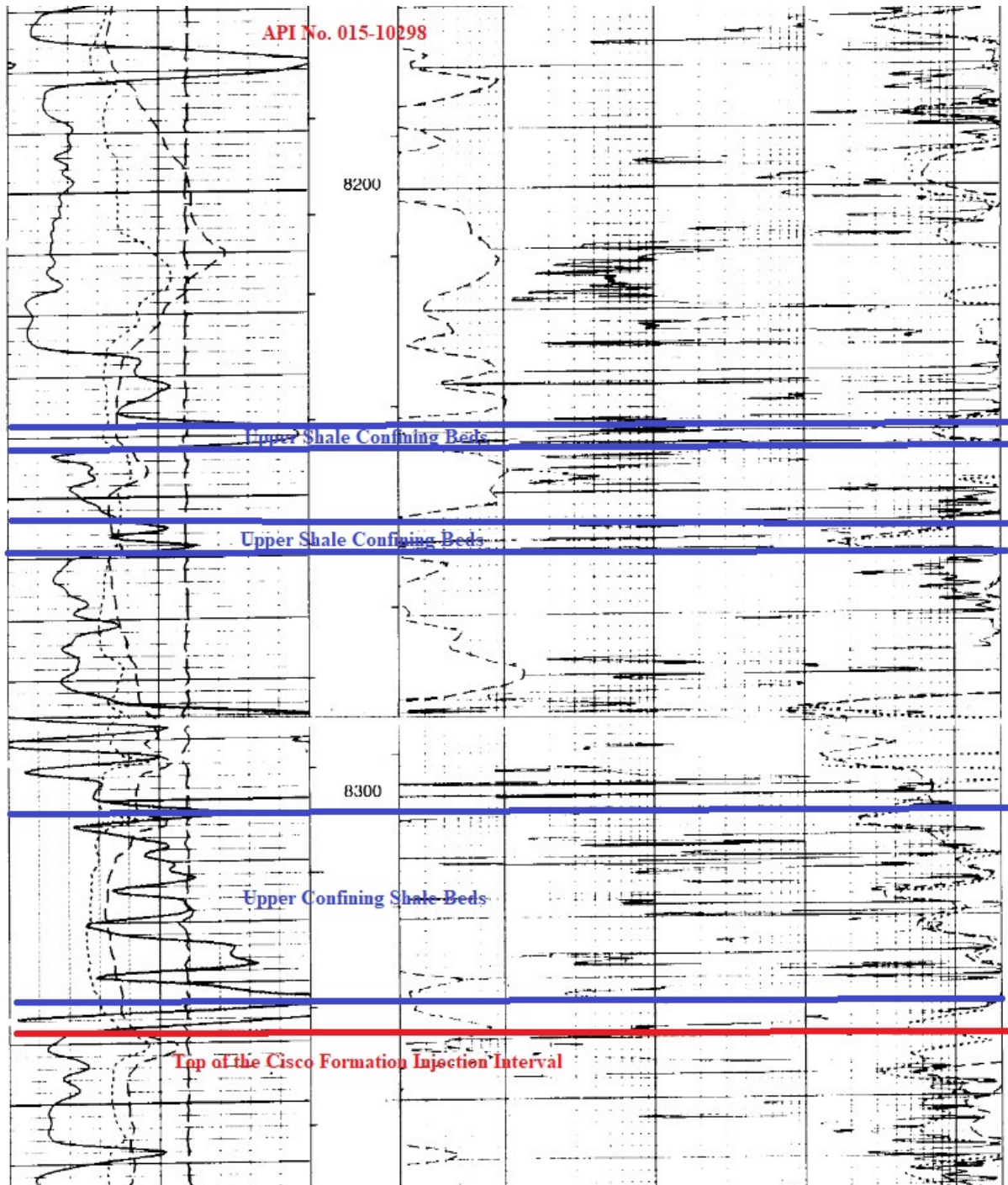


Dan Arthur, P.E., SPEC
President/Chief Engineer

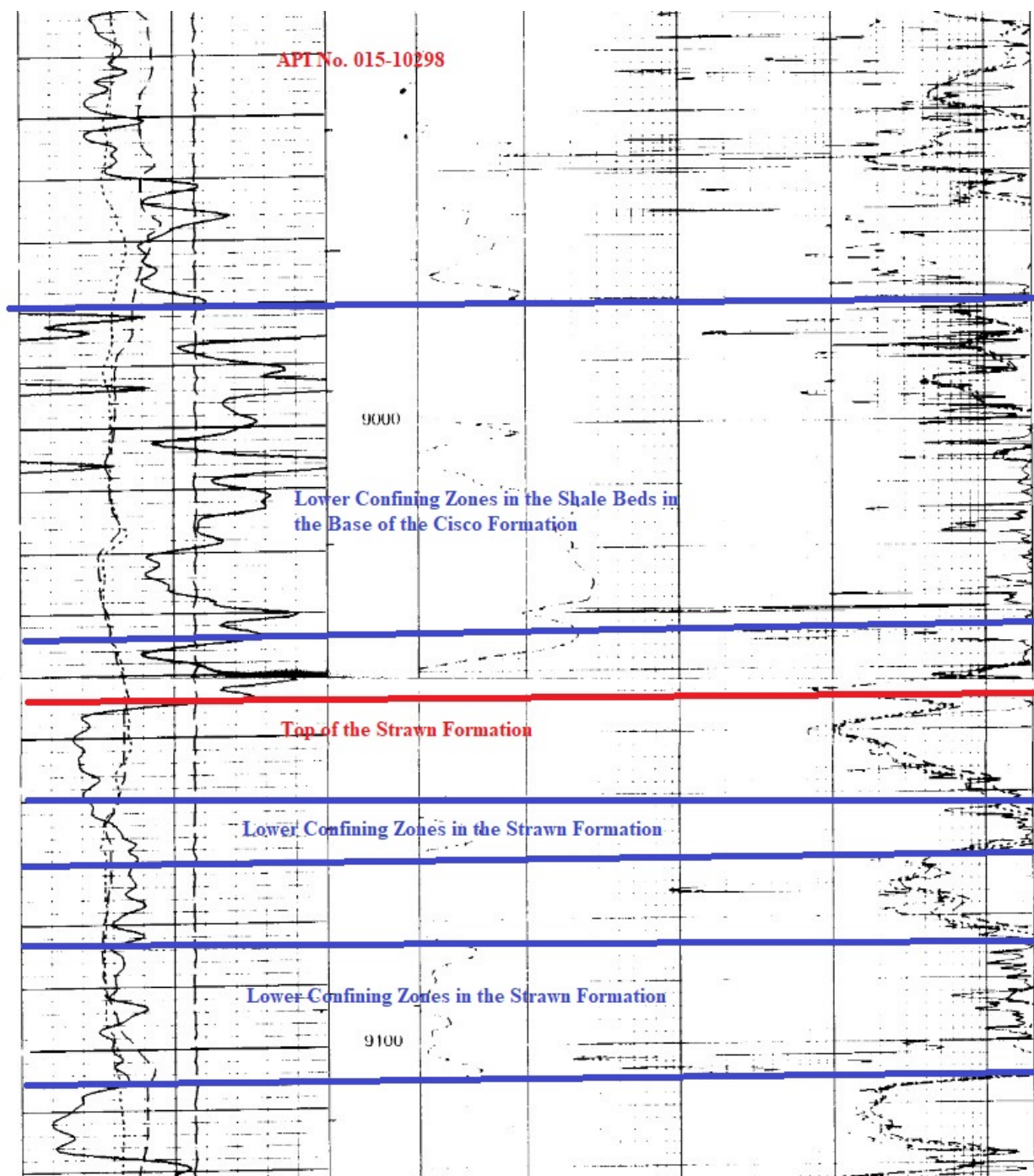
Waterbridge Stateline, LLC
Long Shot SWD #1 Seismic Information
December 6, 2022

Attachment 1
Upper and Lower Confining Zones

Upper Shale Confining Zones from API No. 015-10298

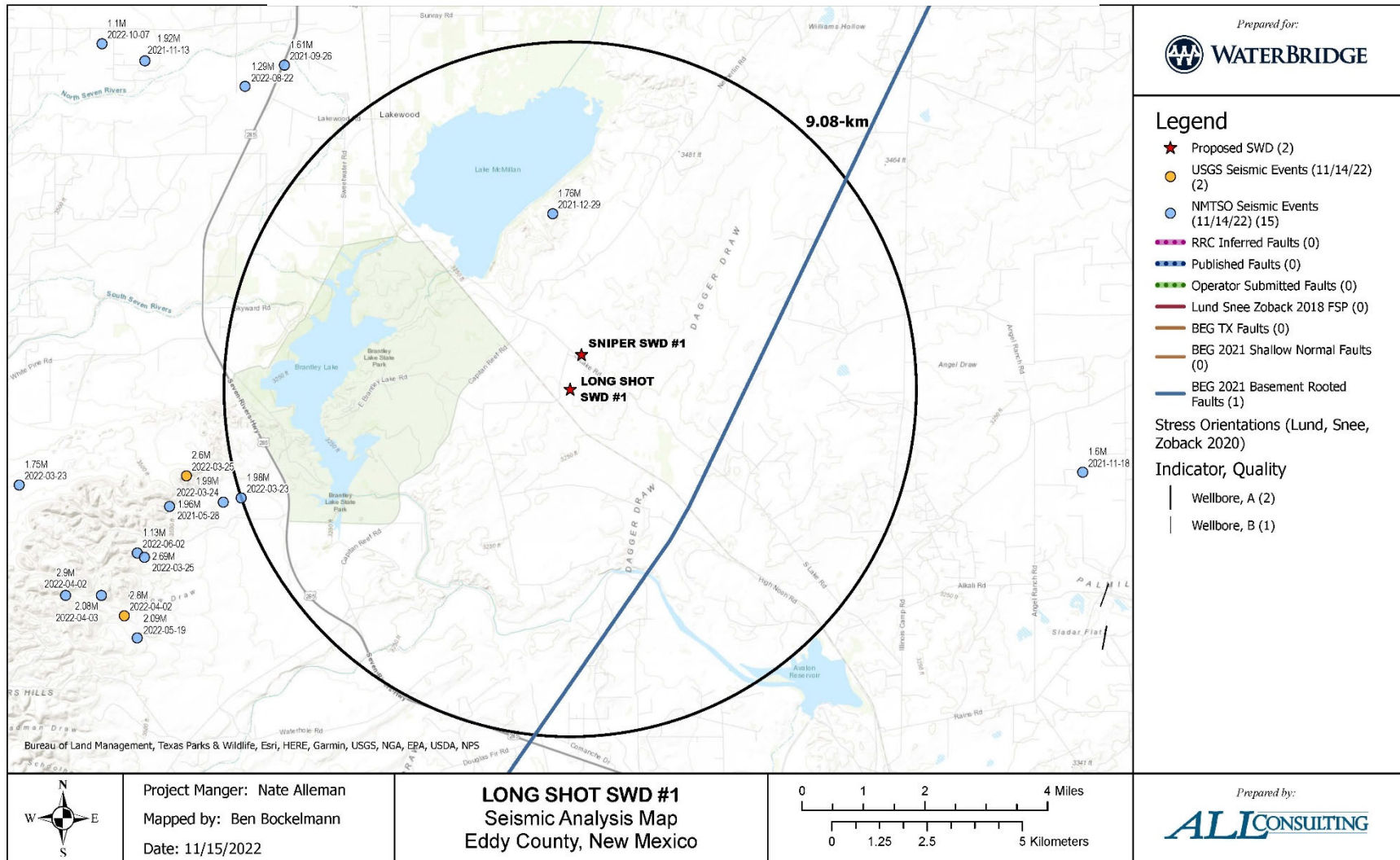


Lower Shale Confining Zones from API No. 015-10298



Attachment 2
Seismic Event Map

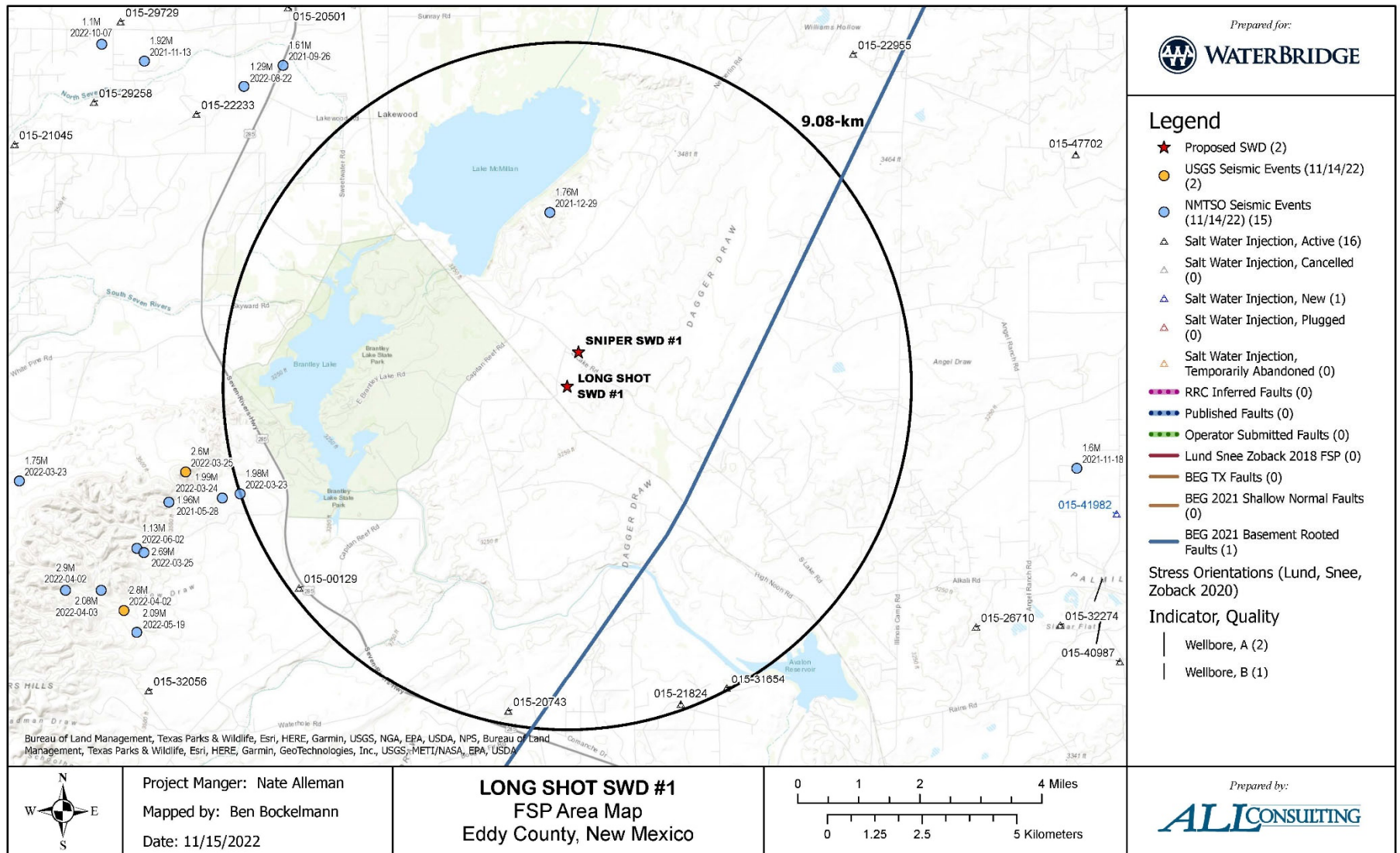
Long Shot SWD #1 Nearby Seismic Events and Faults



Waterbridge Stateline, LLC
Long Shot SWD #1 Seismic Information
December 6, 2022

Attachment 3
FSP Area Map, Parameters, and Results

Long Shot SWD #1 FSP Area Map



Long Shot SWD #1 FSP Parameters

Parameter	Value	Source
Vertical Stress Gradient (psi/ft)	1.05	ALL Research (2022)
Horizontal Stress Direction (degrees azimuth)	20	Lund Snee (2020)
Reference Depth (ft)	8,995	Nearby Geophysical Logs (2022)
Initial Reservoir Pressure Gradient (psi/ft)	0.43	ALL Research (2022)
A-Phi Parameter	0.65	Lund Snee (2020)
Friction Coefficient	0.6	Lund Snee (2020)
Injection Interval Thickness (ft)	7000	Nearby Geophysical Logs (2022)
Porosity (%)	5	ALL Research (2022)
Permeability (mD)	35	ALL Research (2022)
Fault Strike (degrees)	Varies	BEG Fault Data (2022)
Fault Dip	80	Lund Snee (2020)
Fluid Density (kg/m ³)	1000	ALL Research and Reynolds (2022)
Dynamic Viscosity (Pa*s)	0.0003	ALL Research and Reynolds (2022)
Fluid Compressibility (Pa ⁻¹)	4.70E-10	ALL Research and Reynolds (2022)
Rock Compressibility (Pa ⁻¹)	8.70E-10	ALL Research and Reynolds (2022)

Long Shot SWD #1 FSP Parameters Continued

1. All known faults within 100 square miles of the Subject SWD, broken into 3-kilometer segments.
2. All active & pending SWDs within 100 square miles of the Subject SWD, assumed to inject at their maximum permitted rate for 25 years, or at their single highest reported monthly injection volume in the well's history when permitted rate was not available.
3. Injection interval thickness of 7,000 feet to account for the vertical separation between the base of the Cisco injection interval and top of the Precambrian Basement where known faults are located. Limiting the injection interval to only the proposed Cisco Formation would eliminate known faults from the model.

Long Shot SWD #1 FSP Parameters Continued

SWD Name (API)	SWD Status	Injection Rate (BWPD)	Modeled Time Period
Long Shot #1	Pending	30,000	2022 - 2047
Sniper #1	Pending	30,000	2022 - 2047
Spring SWD #001 (015-00129)	Active	4,579	2022 - 2047
Avalon State SWD #001 (015-20743)	Active	186	2022 - 2047
State L SWD #001 (015-21824)	Active	767	2022 - 2047
Avalon 10 Federal SWD #042 (015-31654)	Active	319	2022 - 2047

Long Shot SWD #1 FSP Results

Fault Slip Potential

Fault Selector:

All Faults
Fault #1, 0.00 FSP
Fault #2, 0.00 FSP
Fault #3, 0.00 FSP
Fault #4, 0.00 FSP
Fault #5, 0.00 FSP
Fault #6, 0.00 FSP
Fault #7, 0.00 FSP
Fault #8, 0.00 FSP

FSP = 0.00 on all
fault segments.

Calculate

MODEL INPUTS

GEOMECHANICS

PROB. GEOMECH

HYDROLOGY

PROB. HYDRO

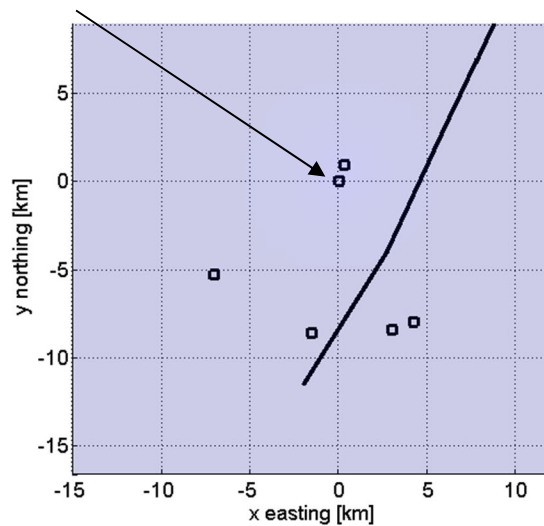
INTEGRATED

Export

Choose Plot Labels

Summary Plots

Long Shot SWD #1



0.00

0.2

0.4

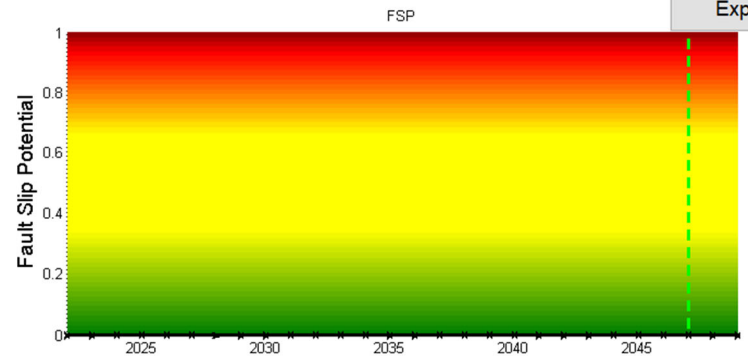
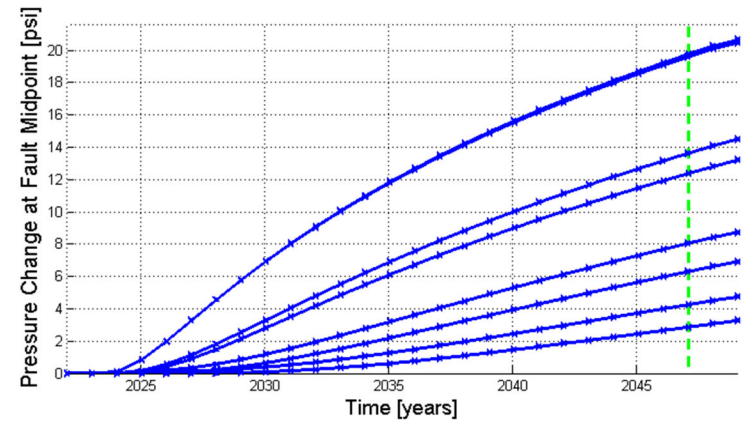
0.6

0.8

1

Year:

2047



Export

Rose-Coss, Dylan, EMNRD

From: Rose-Coss, Dylan, EMNRD
Sent: Thursday, December 8, 2022 9:07 AM
To: Nathan Alleman
Subject: RE: [EXTERNAL] RE: The Oil Conservation Division (OCD) has accepted the application, Application ID: 120276

Hey Nate,

Thanks for putting those together. The way they were submitted was fine. Going forward though I believe application additions can be uploaded directly to the document packet in E-Permitting. If that isn't straight forward let me know and I can help to figure it out. Then you can just let us know they are in there and under what action ID.

Anyway, I've got a few things on my plate before I can get back to these seismic reviews, but they are in the queue. I'll reach out if I have any questions.

Regards,

Dylan Rose-Coss

Petroleum Specialist
Oil Conservation Division
1220 South St. Francis Drive
Santa Fe, New Mexico 87505

C: (505) 372-8687



From: Nathan Alleman <nalleman@all-llc.com>
Sent: Wednesday, December 7, 2022 12:32 PM
To: Rose-Coss, Dylan, EMNRD <DylanH.Rose-Coss@emnrd.nm.gov>
Subject: RE: [EXTERNAL] RE: The Oil Conservation Division (OCD) has accepted the application, Application ID: 120276

Dylan,

We've got the seismic information available for WaterBridge's Sniper and Long Shot SWDs and wondered who we should send that to? Should we send to you and cc Phil or should we send to the UIC email address?

Nate Alleman

ALL Consulting
Office: 918-382-7581
Cell: 918-237-0559

From: Rose-Coss, Dylan, EMNRD <DylanH.Rose-Coss@emnrd.nm.gov>
Sent: Wednesday, November 2, 2022 3:59 PM
To: Nathan Alleman <nalleman@all-llc.com>
Subject: RE: [EXTERNAL] RE: The Oil Conservation Division (OCD) has accepted the application, Application ID: 120276

So I ran it by Phil and Brandon.

They asked that I ask for additional information; i.e., a seismic risk assessment which includes: – an earthquake analysis within in a 10 mi x 10 mi area of the proposed well, the reason the wells will not be a potential source of contribution for the ongoing events, and a statement that addresses the proximity with a signature by a qualified expert. The question of “deep” should also be addressed, as the BEG in Texas has been lumping pre-wolfcamp into the “deep” category for their modeling, so “not Devonian” in and of itself isn't a pass necessarily.

I've attached the contact list. It'll have Tiffany and Brandon's email on it.

Hope that helps, it was good timing on the conversation as we had our Engineering team meeting this morning.

Anyway, let me know what Y'all want to do.

Regards,

Dylan Rose-Coss

Petroleum Specialist
Oil Conservation Division
1220 South St. Francis Drive
Santa Fe, New Mexico 87505

C: (505) 372-8687



Dylan

From: Nathan Alleman <nalleman@all-llc.com>

Sent: Wednesday, November 2, 2022 10:28 AM

To: Rose-Coss, Dylan, EMNRD <DylanH.Rose-Coss@emnrd.nm.gov>

Subject: RE: [EXTERNAL] RE: The Oil Conservation Division (OCD) has accepted the application, Application ID: 120276

Thanks for the update Dylan. I thought you'd mentioned that SRA restrictions were only being applied to Deep SWDs? Based on that, we didn't figure there would be an issue with getting a shallow SWD permitted.

Do you have contact info for Tiffany and Brandon so I can follow up?

Nate Alleman

ALL Consulting

Office: 918-382-7581

Cell: 918-237-0559

From: Rose-Coss, Dylan, EMNRD <DylanH.Rose-Coss@emnrd.nm.gov>

Sent: Wednesday, November 2, 2022 11:26 AM

To: Nathan Alleman <nalleman@all-llc.com>

Subject: RE: [EXTERNAL] RE: The Oil Conservation Division (OCD) has accepted the application, Application ID: 120276

Nathan,

We'd been performing a tech review on the Waterbridge applications. The proposed locations fall within the general Dagger Draw SRA and we will no be able to move on them until there is further guidance on that SRA.

Tiffany and Brandon will be the contacts best to follow up with for more information on the status of the SRAs.

Regards,

Dylan Rose-Coss

Petroleum Specialist

Oil Conservation Division

1220 South St. Francis Drive

Santa Fe, New Mexico 87505

C: (505) 372-8687



From: Nathan Alleman <nalleman@all-llc.com>

Sent: Friday, October 28, 2022 3:32 PM

To: Rose-Coss, Dylan, EMNRD <DylanH.Rose-Coss@emnrd.nm.gov>

Subject: RE: [EXTERNAL] RE: The Oil Conservation Division (OCD) has accepted the application, Application ID: 120276

Yes, this progress in itself is helpful.

Thanks again!

Nate Alleman

ALL Consulting

Office: 918-382-7581

Cell: 918-237-0559

From: Rose-Coss, Dylan, EMNRD <DylanH.Rose-Coss@emnrd.nm.gov>

Sent: Friday, October 28, 2022 4:29 PM

To: Nathan Alleman <nalleman@all-llc.com>

Subject: RE: [EXTERNAL] RE: The Oil Conservation Division (OCD) has accepted the application, Application ID: 120276

We've only just recently been able to release apps from the initial submittal portal at the "Admin Complete" stage. There is a chance more apps will be sent out with these emails.

I did have Alana specifically look into these two though. No timeline on the tech review, we have roughly a dozen on the short list in front of them at the moment.

Hope that helps all the same though.

Cheers,

Dylan

From: Nathan Alleman <nalleman@all-llc.com>

Sent: Friday, October 28, 2022 1:54 PM

To: Rose-Coss, Dylan, EMNRD <DylanH.Rose-Coss@emnrd.nm.gov>

Subject: [EXTERNAL] RE: The Oil Conservation Division (OCD) has accepted the application, Application ID: 120276

CAUTION: This email originated outside of our organization. Exercise caution prior to clicking on links or opening attachments.

Not sure whether or not you were behind getting the Administrative Completeness reviews completed on WaterBridge's SWD applications, but if so, I certainly appreciate it!!

Take care!

Nate Alleman

ALL Consulting

Office: 918-382-7581
Cell: 918-237-0559

From: OCDOnline@state.nm.us <OCDOnline@state.nm.us>

Sent: Friday, October 28, 2022 2:42 PM

To: Nathan Alleman <nalleman@all-llc.com>

Subject: The Oil Conservation Division (OCD) has accepted the application, Application ID: 120276

To whom it may concern (c/o Nathan Alleman for WaterBridge Stateline LLC),

The OCD has determined the submitted *Application for a fluid injection well permit* (C-108) to be administratively complete.

The application has been assigned admin order ID (p#) pJZT2218739005 [SWD-2494] with the following conditions:

- **None**

The accepted C-108 can be found in the OCD Online: Imaging under the admin order ID (p#).

The OCD does not require any further documentation at this time; however, the OCD may request additional information during the technical review of the application.

Please note: This acceptance does not constitute an approved UIC permit (Salt Water Disposal order).

For application status, please contact the OCD Engineering Bureau UIC team.

Thank you,

Alana Schaefer

Petroleum Specialist-A

505-476-3441

Alana.Schaefer@emnrd.nm.gov

New Mexico Energy, Minerals and Natural Resources Department

1220 South St. Francis Drive

Santa Fe, NM 87505