STATE OF NEW MEXICO
DEPARTMENT OF ENERGY, MINERALS AND NATURAL RESOURCES
OIL CONSERVATION DIVISION

APPLICATION OF FAE II OPERATING, LLC TO CONVERT PRODUCING WELLS TO INJECTION WELLS FOR WATERFLOOD OPERATIONS, LEA COUNTY, NEW MEXICO.

CASE NO. 22593

NOTICE OF SUPPLEMENTAL EXHIBITS

In accordance with the Oil Conservation Division's request at the March 3, 2022 hearing in this matter, FAE II Operating, LLC ("FAE") provides the following supplemental exhibits:

1. McKee Waterflood Project Proposed Plan of Operation (Exh. D);
2. McKee Waterflood Proposed Secondary Recovery Project Induced Seismicity Analysis (Exh. E);
3. CE LaMunyon 76 Well Log (Exh. F);
4. CE LaMunyon 76 Type Log (Exh. G); and
5. Water Sample Laboratory Reports (Exh. H).

Respectfully submitted,

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Proposed Plan of Operation

Initial development of the McKee Waterflood Project is based on creating 40ac 5-spot patterns within the project area. Eight infill producers that were drilled in the late 1990's through the early 2000's will be converted to injection (CTI) with perforations added in the McKee A, B, and C sands as needed. The majority of these injectors are positioned at the edge of the project area which will protect correlative rights by preventing lease reserves from escaping the project boundaries. In areas where an injector is not on the edge of the project area, a producer will be reactivated to act as a low pressure sink and capture reserves before they can be pushed beyond the project boundary. The initial planned development patterns of the waterflood area can be seen in **Fig 1**.

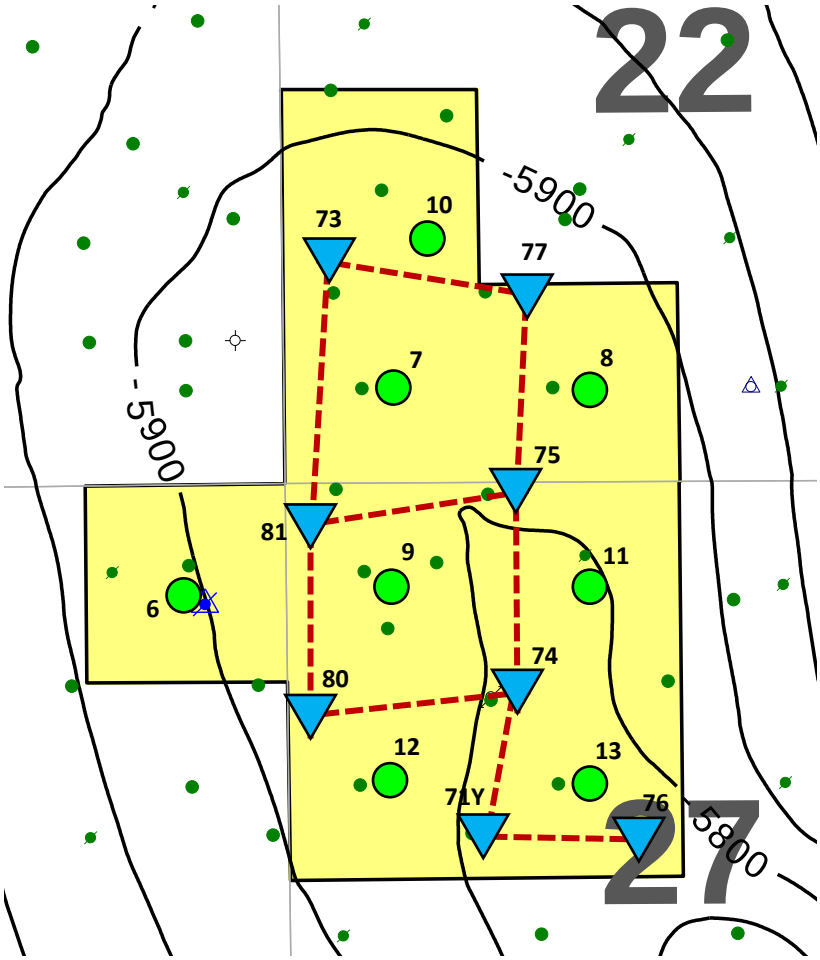

Fig 1 – The McKee Waterflood Project area is shown atop a McKee structure map with the proposed initial development plan. CTIs are shown as blue inverse triangles; producer recompletions and re-entries are shown as bright green circles.

Proposed Plan of Operation

Two complete normal 40ac 5-spot patterns and two partial normal 40ac 5-spot patterns to the south will be formed under initial development. Later pattern expansion within the project area would provide the opportunitiy to complete partial patterns and add injection to the rest of the project area boundaries. The central producers of the two complete 5-spot patterns are C. E. LaMunyon Wells Nos. 7 and 9 which are both currently producing from the ABO formation; these wells will be recompleted to the McKee sand. The remaining producers outside the completed patterns are all curently P&A'd wells; these include C. E. LaMunyon Wells Nos. 6, 8, 10, 11, 12 and 13. Plugged wells will be re-entered and returned to production in the McKee sand. Conformance work to ensure the producers are completed in the zones supported by surrounding injection will be done at the time of the re-entries, recompletions, workovers and conversions to injection. Producers will be artificially lifted using rod pump; lift will be upgraded as needed.

Injection water will be sourced from the surrounding area's produced water. Lab analysis compared samples of produced water from the C. E. LaMunyon lease central tank battery (CTB) to wells currently producing from the McKee sand to ensure compatibility. Both salinity and solids content were similar, therefore compatibility issues are not expected. FAE II Operating LLC intends to utilize the Teague Injection Station for this project; the station is located approximately 4,700 feet to the southeast of the project area. Injection flowlines as seen in **Fig 2** will be laid upon right of way (ROW) approval.

Assuming development is performed using a single workover rig, initial development is expected to take approximately six months to complete. Water injection will commence once injection flowlines are laid and CTIs are complete. Total investment for the McKee waterflood project is estimated to be $6.8 million for 2.448 mmbo in incremental secondary reserves.

Proposed Plan of Operation

Fig 2 – FAE II Operating LLC intends to utilize an existing injection station to the southeast of the project area. An injection flowline will be lain between the injection facilities and the proposed CTIs.

fae II operating

McKee Waterflood

Proposed Secondary Recovery Project

Induced Seismicity Assessment

07 April 2022

FAE Operating, LLC
Case No. 22593
Exhibit E

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Induced Seismicity Assessment

McKee Waterflood Project, Lea Co., New Mexico

Purpose

The purpose of this assessment is to determine the risk of induced seismicity from reactivating injection in the McKee formation within the C E Lamunyon lease, Lea County, New Mexico, and to gain approval for the proposed secondary recovery project, i.e. waterflooding project.

Conclusions

1. Induced earthquakes can be caused by over-injection (without withdrawal) and intensified if large enough fault(s) and stresses are present and flowpaths exist between the point(s) of injection and fault(s). Naturally fractured rock can create super-pathways between injection points and fault(s), inducing earthquakes with large volumes of injection.
2. The recent increase in disposal well (SWDs) volumes strongly correlate with the recent increase in seismic activity in southeast New Mexico.
    a. Disposal wells often inject into water-filled reservoirs without nearby production (withdrawal) from the same reservoir; this builds pressure in the reservoir significantly above the original reservoir pressure at a rate proportional to the disposal rate.
    b. Disposal wells dispose up to tens of thousands of barrels per day per well. When compared to the volume of the reservoirs they are injecting into, the large disposal volumes have to physically affect large areas.
3. Waterfloods generally maintain reservoir pressure close its original state, ultimately producing one barrel of fluid for every one barrel of injection. Waterfloods have been active in southeast New Mexico over the last 70+ years without significantly influencing seismic activity.
    a. Pressure does not continue to increase over time, but remains fairly constant after the reservoir achieves fill-up and the waterflood reaches a steady-state of operation. At fill-up the reservoir is around its original pressure.
    b. Injectors within waterfloods typically inject in the range of hundreds of barrels per day per well, instead of thousands of barrels per day per disposal well, with offsetting producers withdrawing fluids out of the reservoir at a similar rate as the injection rate.

c. Injection volumes within a waterflood are generally contained by offset producers and stay within established waterflood patterns. Standard patterns generally cover an area of 20 to 40 acres on the Central Basin Platform of southeast New Mexico. Since injected fluid is drawn to offset producers, the volumes do not affect large areas. This reduces the risk of water traveling to faults further away than 1,320 feet, the typical distance from injectors to producers in a 40-acre pattern.

4. Recent seismic activity within a 10-mile radius to the proposed McKee Waterflood Project appears local to the West Dollarhide area. Assuming this is induced seismicity, it is more likely to have been triggered by surrounding disposal wells than the West Dollarhide waterfloods.
   a. As localized areas within West Dollarhide's waterfloods reached fill-up, injection rates stabilized at a 1:1 ratio with production; i.e. one barrel injected for every one barrel produced. Each injector only averaged 100-300 bwipd over its life. Since 1990, the waterfloods have produced more volume than injected, reducing pressure in the formations. Without pressure build-up, the waterfloods could not have induced seismicity in the surrounding area.
   b. Of the active disposal wells surrounding the West Dollarhide area, only the wells injecting into the San Andres lacked offset producers to mitigate pressure build-up. With no San Andres production in the area, injection most likely started in a virgin pressure system. The Justis SWD #012B, has injected 1,000-4,000 bwipd since 1994, more than doubling in rate in the last few years and disposing over 15 million barrels cumulatively. It the SWD of highest risk to inducing seismicity in the area.
5. The proposed McKee Waterflood Project poses low risk for inducing earthquakes.
   a. The McKee sand is currently depleted and millions of bbls of injection will be required to bring the reservoir back to original pressure.
   b. Once the reservoir is repressured, pressure will remain fairly constant as the volume of injected and produced fluid will be very similar.
   c. Surveillance plots can be used to mitigate risk of induced earthquakes by monitoring injection and taking corrective actions if water is going outside targeted area/zones.
   d. The injected water from the waterflood will be contained within the waterflood patterns and very unlikely to ever reach the closest faults. The closest faults' slip potential was evaluated at <10% per Snee and Zoback.

1.0 Induced Seismicity Overview

1.1 Introduction

Since 2009, the central US has seen an increase in earthquakes that has led to significant research into determining the cause and risk mitigation. Through this research and historical case studies, many of the earthquakes have been identified as *induced earthquakes*. Induced earthquakes are generally defined as earthquakes caused by human activities. While there are numerous ways that humans can induce earthquakes, over-injection has been identified as the cause of the recent increase of earthquake activity in the central US.

Per the EPA UIC Program, a Class II water injection well includes wells used to dispose of oil and gas production wastes and/or enhanced recovery of oil and gas (EOR); typically injecting salt water, fresh water, CO2, acid gas, or mixtures of any of these. For the purposes of this assessment, waste-water wells and salt water disposal wells (SWDs) will be referred to as *disposal wells* and injection wells associated with EOR will be referred to as *injectors*.

1.2 Factors of Earthquakes

A natural earthquake occurs by a sudden slip of a fault. Per the USGS "A fault is a fracture or zone of fractures between two blocks of rock. Faults allow the blocks to move relative to each other. This movement may occur rapidly, in the form of an earthquake - or may occur slowly, in the form of creep…" For injection to induce an earthquake, enough fluid has to be injected to increase the pressure in the reservoir. Assuming the increasing pressure is transmitted to a fault, then the increase in pore pressure within the fault directly opposes the stresses holding the fault closed. As the difference between these two pressures lessens, the frictional resistance to slip decreases and increases the chances of an earthquake.

Not all injection is capable of inducing earthquakes. There are a variety of factors that have to be present for injection to induce earthquakes. First, the area must meet the conditions required for a natural earthquake to occur, i.e. there must be fault(s) and stresses large enough to produce felt earthquakes. Next, fluid pathways, i.e. flowpaths, must exist between the place(s) of injection and the fault(s). Lastly, the volume of injection has to be large enough to increase the reservoir pressure high enough to overcome the frictional resistance and induce earthquakes.

1.3 Recent Earthquake Activity

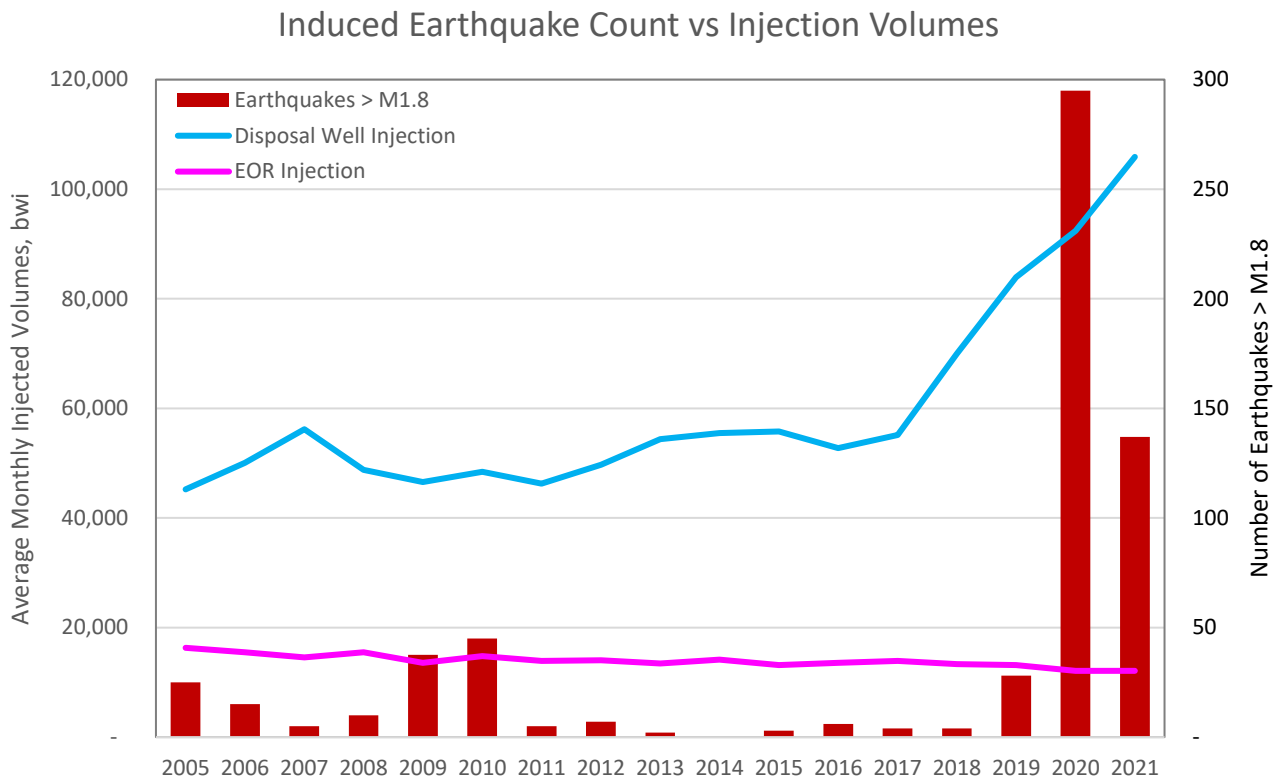
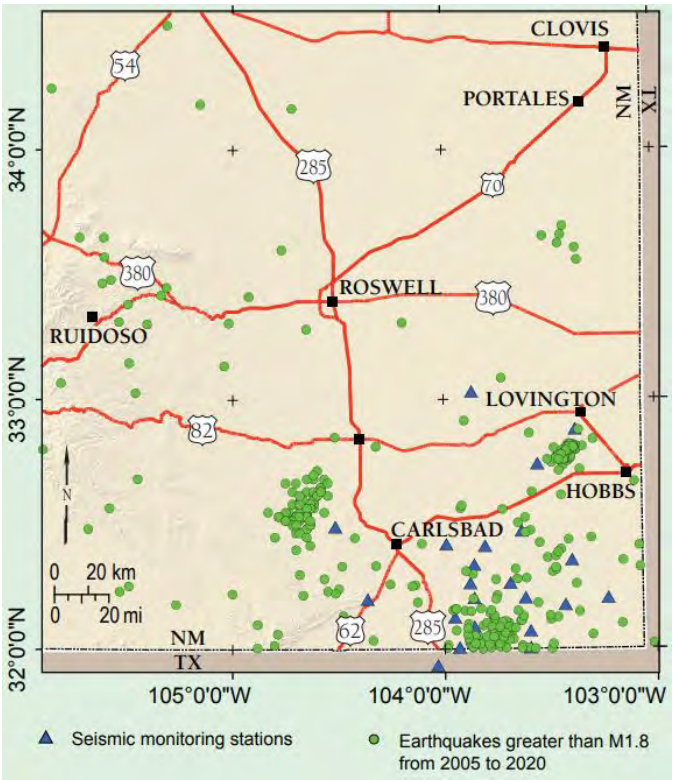


Fig 1A (above) — Bar graph showing the number of earthquakes in southeastern New Mexico over time plotted against the average monthly injection from disposal wells and EOR injectors in the same geographical area. SOURCE: Litherland and Glasgow (2021)

Fig 1B (right) —Map of southeastern New Mexico showing earthquake with magnitudes greater than M1.8 that occurred between 2005 and 2020. SOURCE: Litherland and Glasgow (2021)



New Mexico has seen a rapid increase in earthquakes in the last few years. Similar to the rest of the central U.S. this coincides with oil and gas activity, but more specifically with increased water disposal volumes. **Fig 1A** shows the number of earthquakes and injection volumes of both disposal and EOR injectors in the mapped area shown in **Fig 1B**. Fig 1B also pinpoints the

earthquake epicenters and seismic monitoring stations. For the last 15 years, injection in waterflooding projects has steadily decreased while SWD volumes have ramped up rapidly in the last few years. The delay between the ramp up in disposal volumes and earthquakes is most likely due to the time it takes for fluid volumes to reach stressed faults and for pressure to build-up high enough to cause the faults to slip. EOR injection is much less likely to cause fault slippage as water is contained within producer-injector patterns and unlikely to reach relatively far away faults. Well-managed mature waterfloods producer the equivalent volume injected which would prevent pressure build-up.

1.4 Historical Example: Rocky Mountain Arsenal (RMA) Disposal Well

The first documented and possibly most referenced case of induced seismicity is the Rocky Mountain Arsenal (RMA) disposal well. This well was drilled by the U.S. Army in 1961 near Denver, Colorado for the purpose of disposing chemical waste. The well was drilled to a total depth (TD) of 12,045 feet into a Precambrian crystalline rock whose original pressure was found to be approximately 3915 psi. Injection began in March 1962 at high rates and pressures, 4300 bbls/day at 1450 psi over virgin pressure, and was maintained through September 1963 when the well was shut-in. This injection induced hundreds of observed earthquakes starting only a few months after injection.

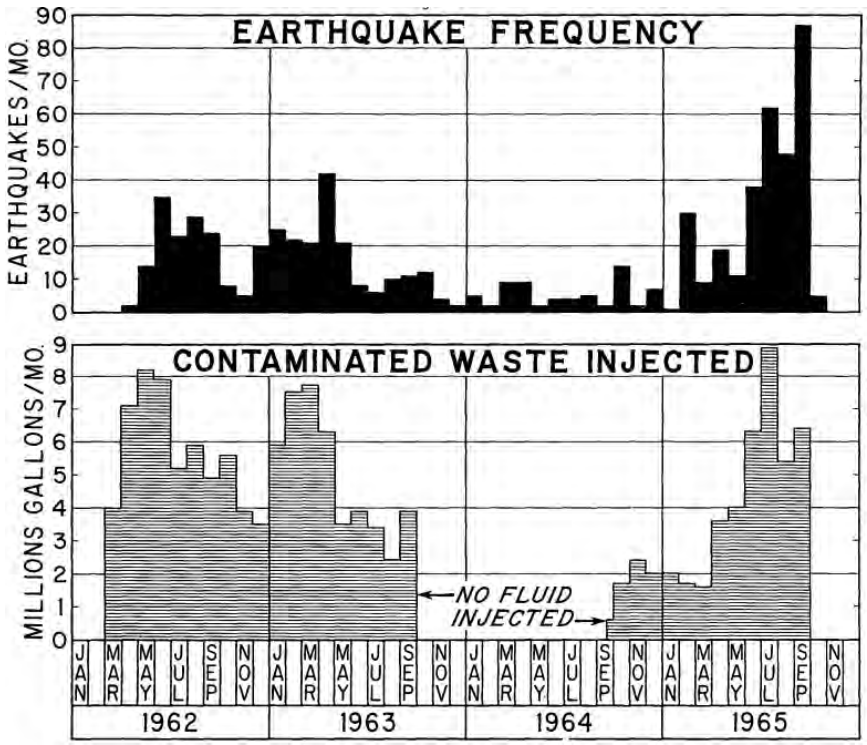


Fig 2 — Correlation of RMA injection rates and earthquake frequency from mid-1960s research.

SOURCE: Evans (1966)

Research performed in the mid-1960s correlated the number of earthquakes to the volume of fluid injected, seen in **Fig 2**. This is really an indirect correlation of the pressure, with the volume of fluid acting as the intermediary. The delay between the start of injection and the first observed earthquake is a result of the time it took for the fluid to travel from the injection site to the faults and build-up pressure high enough to cause the faults to slip. Earthquakes continue even after injection stops because pressure remains built-up within the faults and fracture network. Each earthquake acts as a pressure valve, allowing energy to escape in the form of an earthquake and reducing the built-up pressure. If no additional pressure is added, eventually the pressure will fall below the normal stress and the earthquakes would cease.

Additionally, the research found that while the depths of the earthquakes varied, they were all within the same Precambrian crystalline rock in which the disposal well was drilled. From a geologic standpoint, crystalline rock is not an ideal formation for injection. As an igneous rock, granite has very low matrix porosity and permeability, leaving only the vast network of natural fractures to store the volume of injected chemical waste. By injecting at high rates and high pressure, the disposal well was essentially hydraulically fractured every day for over a year, connecting and opening natural fractures in the area. This open fracture network created multiple flowpaths to the faults which could hold larger volumes of injected fluid and would become the earthquake epicenters. As the fractures and faults spanned the depths of the Precambrian rock, so did the earthquake epicenters. Similarly, the epicenters aligned along the network of natural fractures found in the Precambrian rocks in the area.

Ultimately, the RMA disposal well is an example of how a lack of understanding in geology and reservoir mechanics combined with over-injection can result in induced earthquakes. Completing this well in a highly porous and permeable formation would have allowed the fluid and pressure to dissipate over a larger area, instead it increased quickly within the limited space of the fracture network. Injecting into a virgin pressure system reduced the differential pressure needed to reach the rock's critical pressure and cause fracturing. Injecting into a depleted reservoir would have allowed for larger volumes of injection before reaching the rock's critical pressure. As a lone disposal well, there was no other pressure outlet in the formation; a waterflood (though not applicable with chemical disposal) would have allowed equal volumes to be produced, creating a stable reservoir pressure and avoiding the pressure build-up that led to the induced earthquakes.

2.0 Secondary Recovery Injection (Waterfloods)

2.1 Purpose of a Waterflood

Waterflooding is a type of secondary recovery where water is pumped into an injector with the purpose of sweeping oil from injectors to producers. Secondary recovery, or enhanced oil recovery (EOR), is needed when the primary drive mechanism of a reservoir is depleted, resulting in a low-pressure system with minimal movement within the reservoir. The injection of fluid under secondary recovery is the introduction of energy, via pressure, into the stagnant system. Fluid naturally flows from high pressure to low pressure; injectors create high pressure points and producers create low pressure points, allowing for the control and direction of fluid flow within the reservoir. This leads to water physically displacing oil and water to the offset producers, where the fluid is produced (withdrawn) from the reservoir. The pressure relationship between injectors and producers mostly confines fluid flow to within the waterflood patterns. While limited travel outside of the patterns may occur, the undepleted areas beyond a field's development act as a high-pressure fence and the fluids are drawn back to the low pressure at active producers.

2.2 Injection Overview

While disposal wells are prized for high-rate injection to eliminate production waste water, waterflood injectors are focused on efficiently sweeping oil to producers. Sweep efficiency can be optimized in a variety of ways. Standardized patterns of injectors and producers can improve the sweep efficiency by utilizing the pressure boundaries created between injectors to control the flow of fluid within the reservoir. **Fig 3** shows the fluid flowpaths, i.e. streamlines, associated with injector-producer pairs and how the introduction of injectors can control where fluid flows and sweep efficiency. The placement of wells in specific patterns takes advantage of the no-flow pressure boundary created between injectors where the pressure from each injector is equal. This effectively creates fences within the reservoir, the fluid is forced to flow towards the low pressure point within its fenced area, i.e. the producer.

These pressure boundaries, i.e. fences, can be created at any reservoir pressure so there is no need for injection to increase reservoir pressure to high levels. Ideally, pressure maintenance is used to keep the reservoir pressure above bubble point; when the reservoir pressure falls below bubble point, saturated gas comes out of solution and makes the oil less mobile. Often pressure is built until it approaches the reservoir's initial pressure which is usually above bubble point; this causes free gas to dissolve back into the oil and raises oil mobility as much as possible. After fill-up, the reservoir pressure is maintained by producing a volume equal to that injected until all economic oil reserves are recovered.

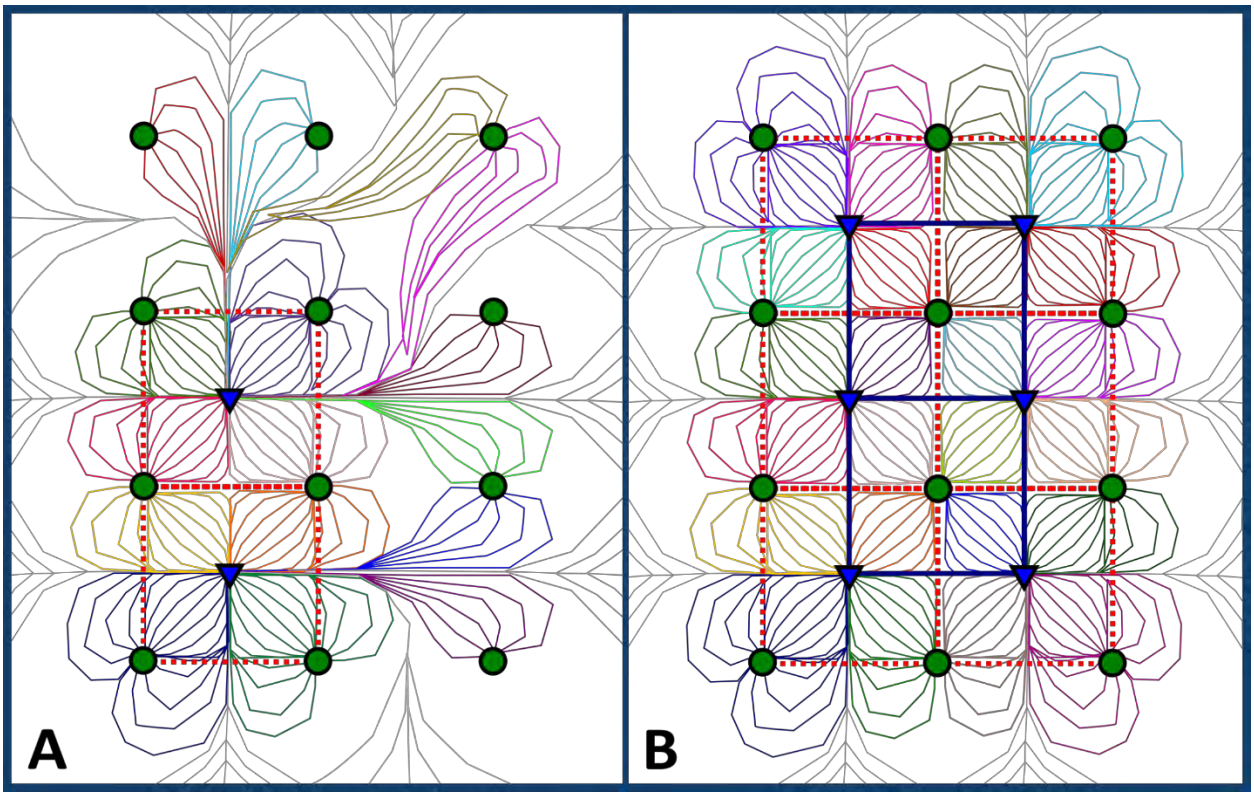


Fig 3 — Streamlines indicate the fluid flowpaths from injector (blue triangle) to producer (green circle). The above streamlines are colored by injector-producer pairs. The addition of injector in Fig 3B restricts the flow that was previously shown in Fig 3A. This restriction is a result of the no-flow pressure boundary created between two injectors where the pressure from each injector is equal. SOURCE: Neal (2021)

2.3 Surveillance Plots

Operators use surveillance plots to monitor a waterflood's efficiency at both a fieldwide view and within specific patterns. Some of the more common surveillance plots used include production history (production and injection rates over time), voidage replacement ratio (VRR), and material balance plots. The VRR and material balance plots have the unique ability to determine if an area is over-injecting and if the fluid/pressure is staying within the target area, respectively. This makes these two plots ideal for evaluating induced seismicity risk at real time.

The VRR is a measure of injection volume to produced volume. Though it is mostly used to determine if fill-up has been achieved in a reservoir, it can also be used to determine if over-injection is occurring. Fill-up occurs when the cumulative VRR equals 1.0; this means that every barrel of fluid produced has been replaced with an injected barrel of fluid. Many operators set a target VRR of 1.2 to maintain fill-up, under the assumption that 20% of injection will be lost out of the target formation or lease area. If the cumulative VRR > 1.2, there are two likely scenarios: 1) fluid is moving outside of the defined target area; or, 2) over-injection is occurring.

The material balance plot is most useful after fill-up has occurred; it plots cumulative fluid production vs cumulative injection. An efficient waterflood maintains the material balance from this point forward; every injected barrel should result in a produced barrel, but keeping the material balance at a 1:1 ratio (slope = 1) is only possible in a closed system. If the slope of the curve begins to increase, then more production is occurring than injection. This indicates that there is an influx of fluid; most often this is seen where a strong aquifer is present. If the slope of the curve decreases, then fluid leak-off is occurring.

If evidence indicates injection is going out of the targeted interval, operations can intervene and perform workovers on injectors to plug-off unwanted flowpaths, e.g. cement squeeze leak-off intervals. If cumulative VRR indicates the reservoir is becoming over-pressured, operations can reduce injection rates. These surveillance plots can be used in EOR/waterflood projects to monitor injection, give early warning signs, and allow operators to take corrective actions to control injection and mitigate the risk of induced earthquakes.

3.0 Risk of Induced Seismicity

3.1 Recent Seismicity of Surrounding Project Area (10-mile radius)

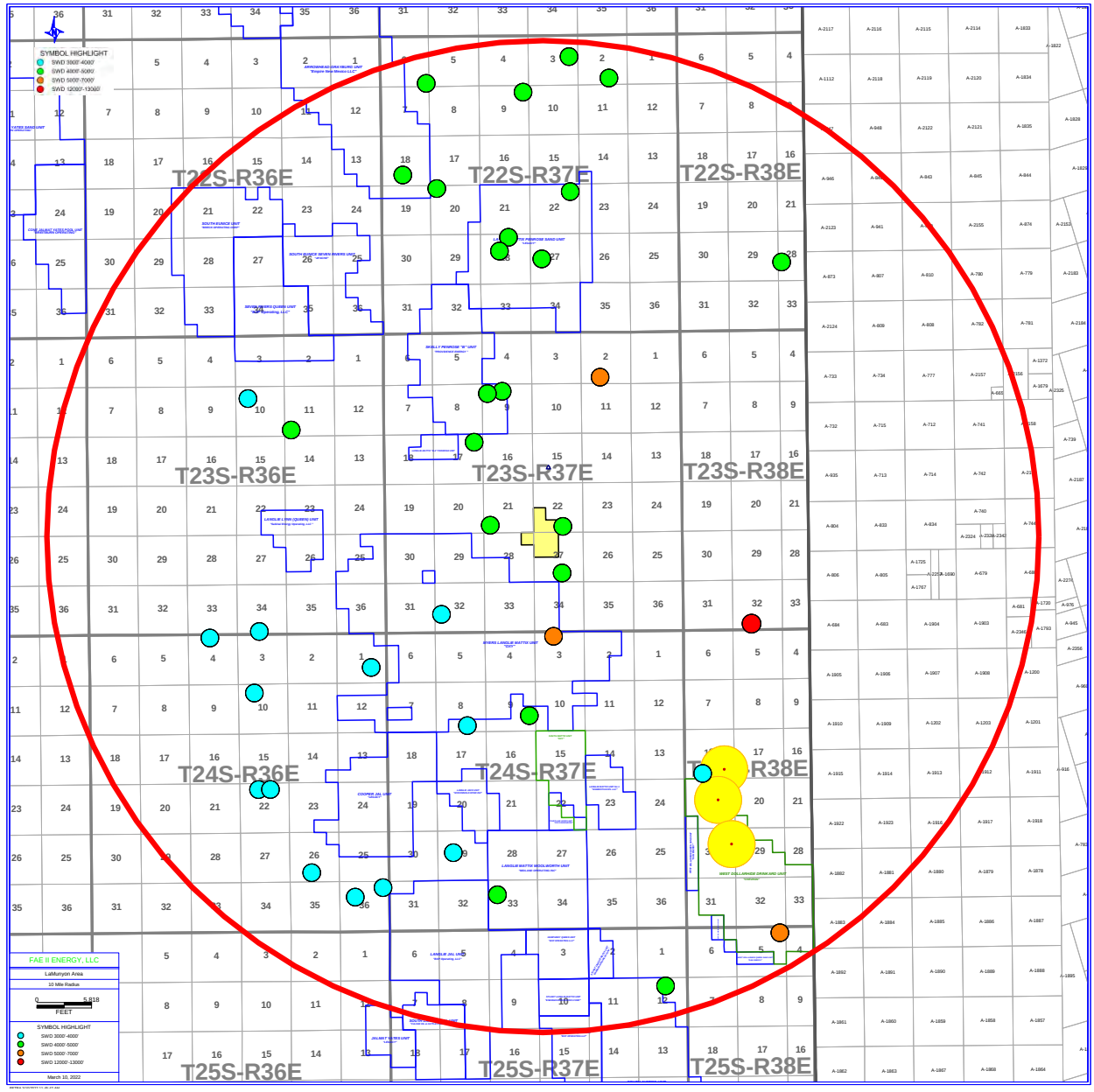


Fig 4 — Base map showing the proposed McKee Waterflood Project with disposal wells, color coded by injection depth, and seismic activity within a 10-mile radius. Since 2021 there have been three 2.5-2.9 earthquakes within a 10-mile radius. All three earthquakes are within or directly offsetting the West Dollarhide Drinkard Unit (WDDU) and several disposal wells.

3.2 Injection Analysis of Surrounding Project Area (10-mile radius)

From **Fig 4**, there are numerous secondary recovery units (blue outlines) found in the surrounding project area; many units are actively injecting or have historically injected as waterfloods. Additionally, injection has occurred through 39 disposal wells in the area. An analysis of production and injection volumes from oil-bearing formations was performed to determine if any over-injection has taken place; see **Table 1** for cumulative volumes by formation. Little of the volume produced from the McKee sand has been replaced with injection; this reservoir should be classified as depleted.

Formation(s) Listed from Shallow to Deep	*Cumulative Total Fluids Prod, mbbls*	*Cumulative Water Inj, mbwi*	*Oil Cut, %*	*Cumulative VRR, decimal*
SANTA ROSA	30	-	100%	-
YATES / SEVEN RIVERS / QUEEN	1,755,185,159	1,303,737,087	12%	0.74
GRAYBURG	309,525,863	255,591,726	10%	0.83
SAN ANDRES	130,388,521	514,835,670	3%	3.95
GLORIETA	7,785,326	-	33%	-
PADDOCK	34,869,870	59,378	57%	0.00
BLINEBRY	160,385,056	38,532,176	30%	0.24
TUBB	125,926,515	114,687,921	33%	0.91
DRINKARD	40,936,804	-	56%	-
ABO	24,933,364	643,337	57%	0.03
WOLFCAMP	5,142	-	96%	-
PENNSYLVANIAN	3,923	-	100%	-
STRAWN GRANITE WASH	12,331,867	-	74%	-
MORROW	146,693	-	17%	-
DEVONIAN	73,908,467	17,094,378	24%	0.23
SILURIAN	2,166,241	-	55%	-
FUSSELMAN	56,713,135	17,042,367	23%	0.30
MONTOYA	1,759,033	-	48%	-
SIMPSON (McKEE)	12,256,507	1,132,599	62%	0.09
ELLENBURGER	74,575,762	1,160,341	58%	0.02

Table 1 — Cumulative production and injection of oil-bearing formations within a 10-mile radius of the proposed McKee Waterflood Project pulled from IHS. From an area perspective, only the San Andres formation stands out as having a significant volume of injection over production. Cumulative numbers will vary by lease and should be evaluated locally.

3.3 West Dollarhide Area Study

The West Dollarhide area has three active waterfloods in the Queen, Tubb, and Devonian formations and a productive pool in the Fusselman. The combined production history of these is displayed in **Fig 5**. Starting around 1990, the volume of injection was roughly equal to the volume of produced water. Since the units also produced oil, the reservoir pressure was decreasing as the volume produced was larger than the volume injected. Starting in 2014, the injection volumes began steadily declining as the number of injectors declined. Over the life of the waterfloods, injectors have typically injected between 100-300 bwipd. The relationship between injection and production volumes in seen in the VRR plot displayed in **Fig 6**. This plot shows there was not enough injected volume to re-pressurize the formations to their initial reservoir pressures, i.e. the reservoirs remained depleted, compared to their original pressures. It is highly unlikely these injectors could have pressurized a fault and induced earthquakes.

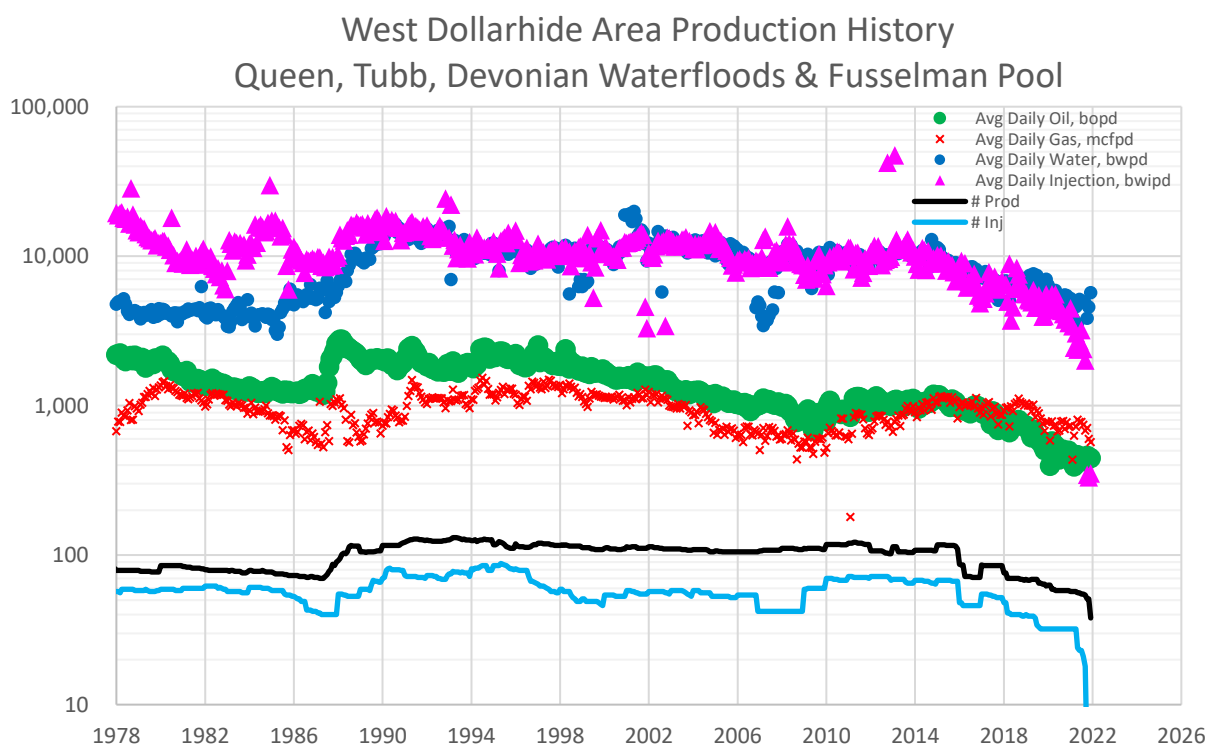


Fig 5 — Production history of the West Dollarhide area over time. Since the 1990s, injection volumes have equaled produced water volumes, meaning that pressure could not rise in the area as more volume was produced than injected.

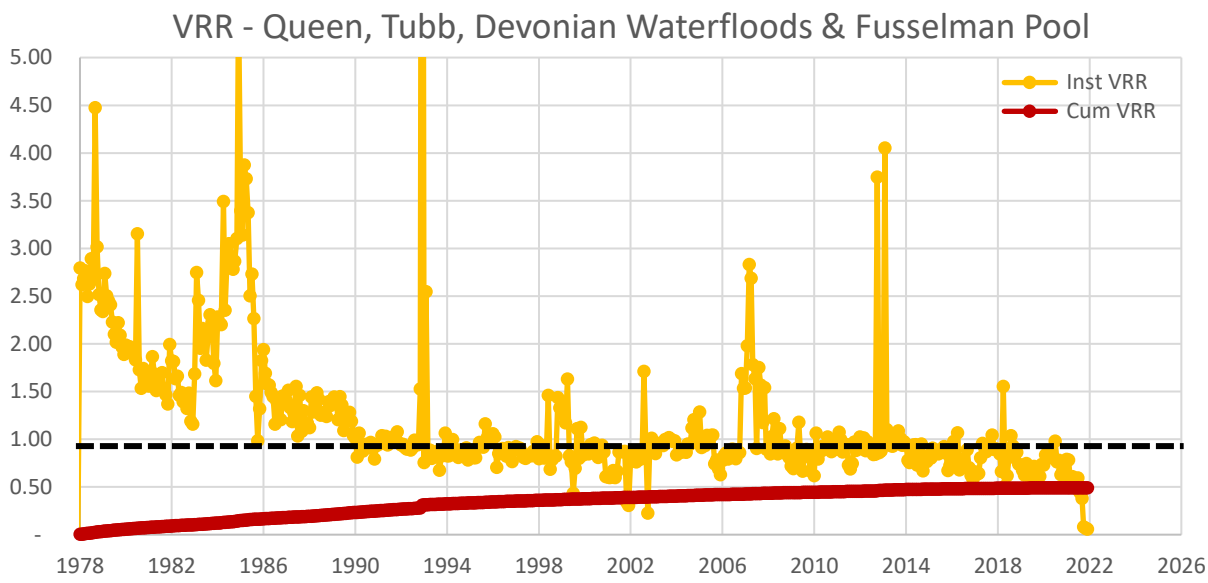


Fig 6 — The VRR plot indicates production volumes remained higher than injection volumes, resulting in the voidage never being fully replaced. With the formations being pressure depleted compared to their initial reservoir pressures, it is unlikely that the West Dollarhide area induced seismicity.

Surrounding the West Dollarhide area are a number of SWD wells whose over-injection could have pressurized a local fault and caused induced earthquakes in the area. Even though these SWDs are not all adjacent to the seismic activity, if they connect with a fault, the injected volume will travel and build pressure, both vertically and horizontally, along the fault plane. This is why earthquake epicenters can be significantly deeper than disposal formations. **Table 2** shows the closest disposal wells to the West Dollarhide area.

Well Name	*API*	*Location*	*Disposal Formation*	*Last Injection*	*Cumulative Inj, bwi*
JUSTIS SWD #012B	30-025-24761	25S 37E 12B	SAN ANDRES	Feb 2022	15,868,724
FOWLER SWD SYSTEM #001	30-025-11074	24S 37E 09I	SAN ANDRES	Dec 2021	5,295,648
MEXICO L #001	30-025-12365	25S 38E 05A	FUSSELMAN	Sep 2021	7,168,825
G H MATTIX B FEDERAL #001	30-025-31770	24S 37E 03C	PADDOCK-BLINEBRY	Jan 2022	809,131
STATE 32 #001	30-025-21476	23S 38E 32N	ELLENBURGER	Feb 2017	1,160,341
J H MCCLURE B COI #022	30-025-27176	24S 38E 19I	QUEEN	Sep 2014	344,253
BUCKSKIN FED #002	30-025-27024	24S 38E 18N	QUEEN	Feb 2012	259,368
WOOLWORTH ESTATE #001	30-025-27081	24S 37E 33E	SEVEN RIVERS	Jan 2009	12,378,439

Table 2 — Well information of disposal wells surrounding the West Dollarhide area and closest to induced seismicity in southeastern New Mexico.

Only about half of the surrounding disposal wells were active injectors leading up to the induced earthquakes in 2021, the G H Mattix B Federal #001, Mexico L #001, Fowler SWD System #001 and Justis SWD #012B. A comparison of the average daily rate of injection between these four disposal wells is shown in **Fig 7**. From this plot, the highest disposal rates correlate with the highest cumulative injection volumes reported in Table 2. Disposal wells at the highest risk for inducing seismicity would have high rates over time and possibly show an increase in disposal rates a few years prior to the seismic activity. The Justis SWD #012B and Mexico L #001 have the highest disposal rates over time while the Justis SWD #012B and Fowler SWD System #001 show increasing rates in the last few years prior to 2021. This puts the Justis SWD #012B at the highest risk for inducing seismicity with the Mexico L #001 and Fowler SWD System #001 at moderate risk and the G H Mattix B Federal #001 at the lowest risk.

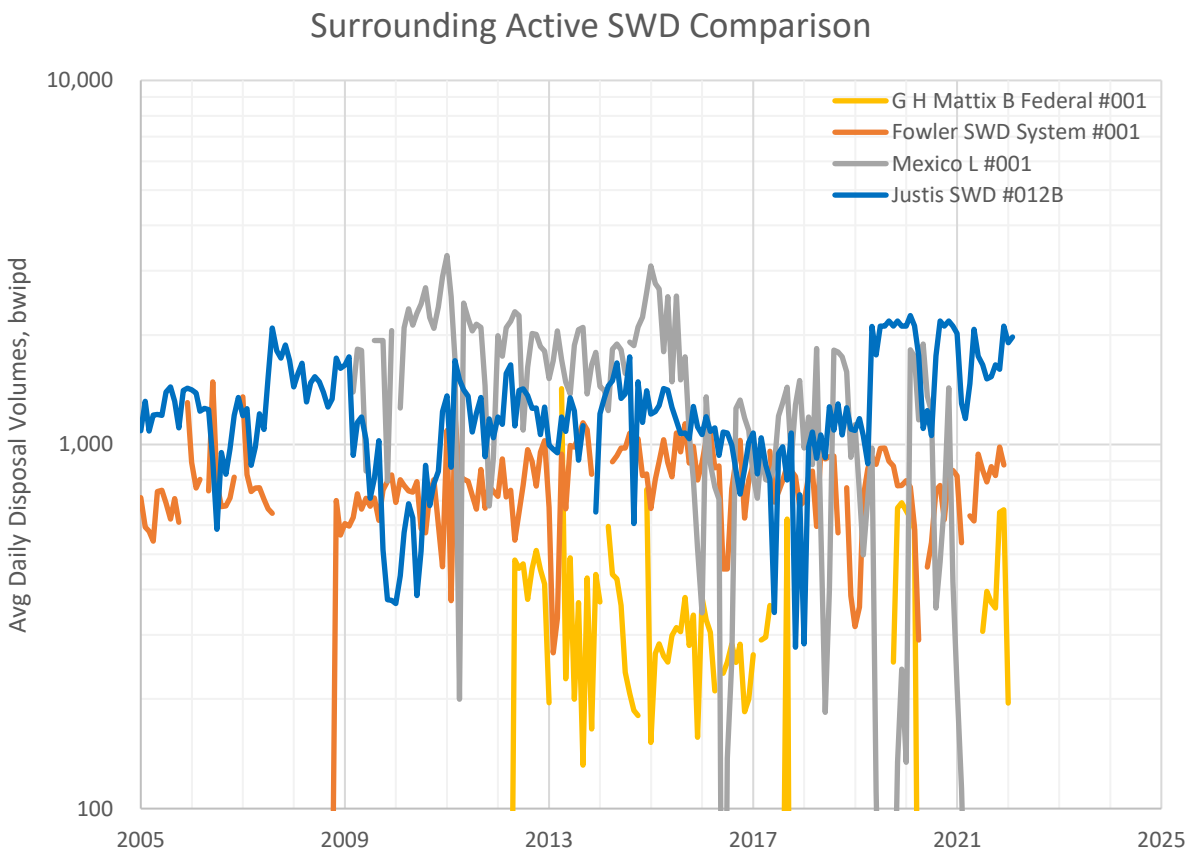


Fig 7 — Comparison of the average daily disposal rates of the four active SWDs surrounding the West Dollarhide area.

Of the three disposal wells rated moderate to high risk of inducing seismicity, the Mexico L #001 is the closest, falling within the boundaries of several of the waterflooding units. This well injected over 7 million barrels of waste water over a 12-year period, staring in 2009. The production and injection in the area, see **Fig 8**, shows that the disposal well is injecting into a depleted zone that cumulatively produced 23 million barrels of oil and water prior to injection. This should reduce the Mexico L #001's risk of induced seismicity to low.

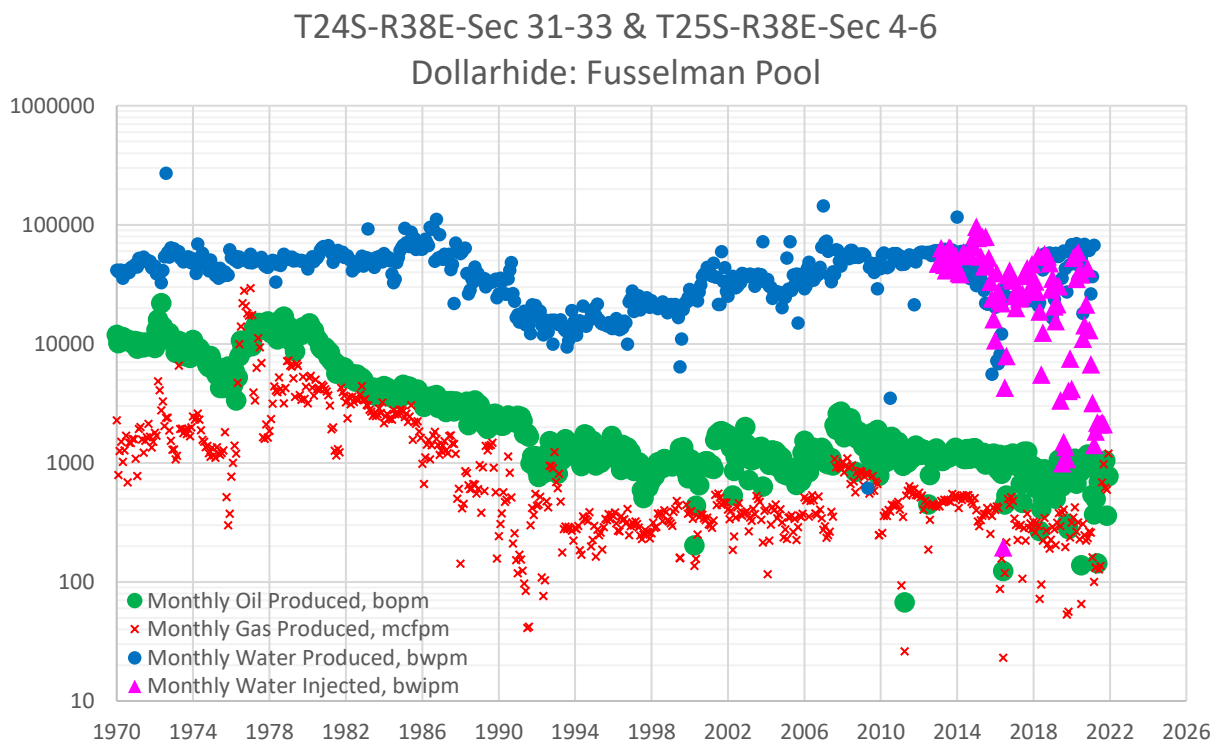


Fig 8 — Reported production and disposal history of the Dollarhide: Fusselman pool located in the West Dollarhide area.

The remaining two moderate and high-risk disposal wells, the Fowler SWD System #001 and the Justis SWD #012B, respectively, both inject into the San Andres formation. Neither well is surrounded by producers of the same formation, nor is there record of the San Andres being produced in the area. This implies these SWDs started injecting into a system at virgin pressure. The Justis SWD #012B is the closest to the West Dollarhide area and the highest risk disposal well in the area for inducing seismicity.

3.4 Fault Slip Potential (FSP) of McKee Waterflood Project

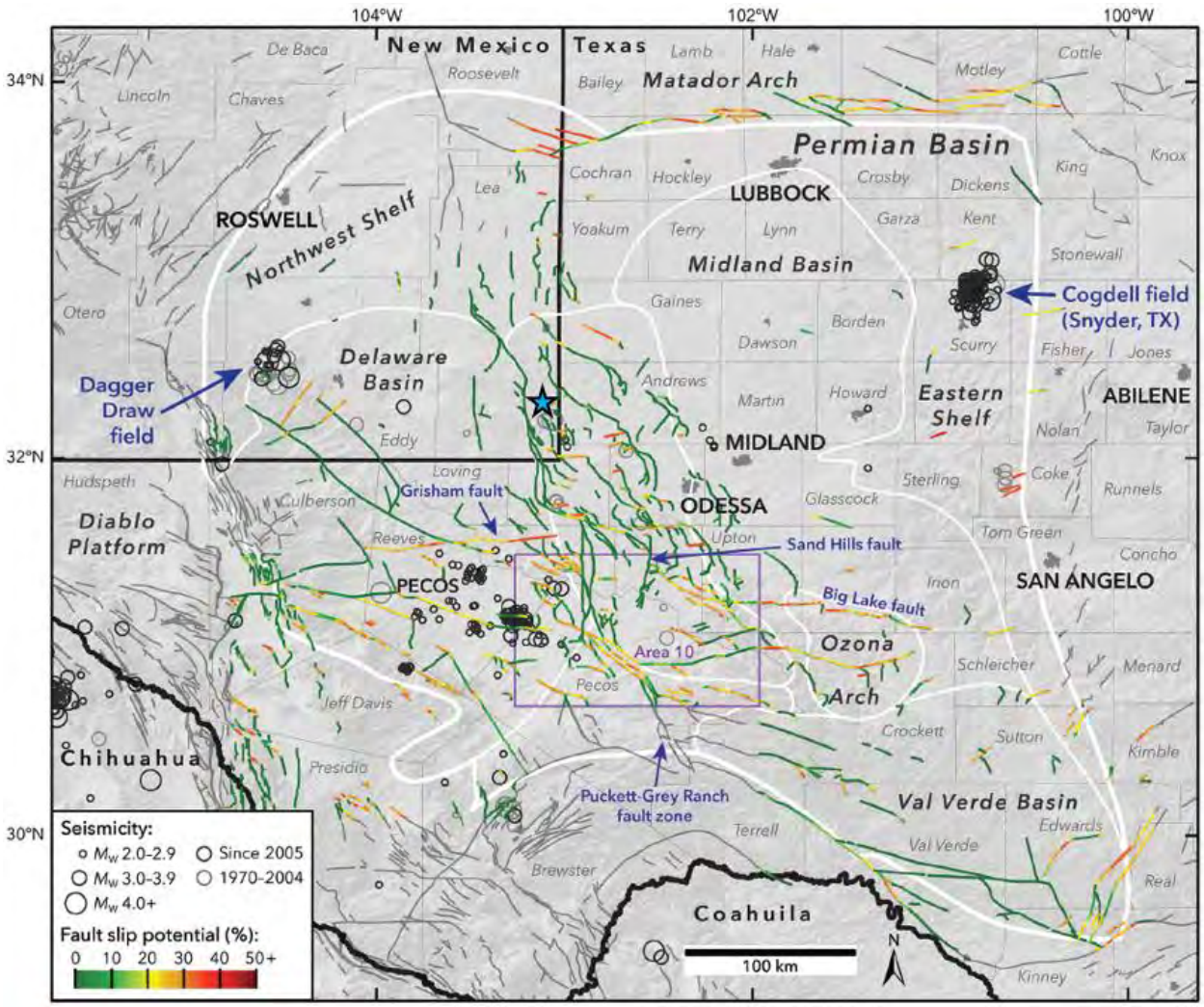


Fig 9 — Results of Snee and Zoback's probabilistic fault slip potential (FSP) analysis of the Permian Basin. The McKee Waterflood Project is marked with a blue star. This location falls between several faults with <10% FSP. With proper monitoring and avoiding over-injection, the minor risk these faults present for induced earthquakes can be mitigated.

SOURCE: Snee and Zoback (2018)

3.5 Project Risk Assessment

	Question	NO APPARENT RISK	CLEAR RISK	Denver RMA, Colorado	McKee Waterflood Project
	Background Seismicity				
1	Are large earthquakes (M ≥ 5.5) known in the region (within 200 miles)?	NO	YES	YES	NO
2	Are earthquakes known near the injection site (within 10 miles)	NO	YES	YES	YES
3	Is rate of activity near the injection site (within 10 miles) high?	NO	YES	YES	NO
	Local Geology				
4	Are faults mapped within 10 miles of the site?	NO	YES	NO	YES
5	If so, are these faults known to be active?	NO	YES	NO	NO
6	Is the site near (within 200 miles of) tectonically active features?	NO	YES	YES	NO
	State of Stress				
7	Do stress measurements in the region suggest rock is close to failure?	NO	YES	YES	NO
	Injection Practices				
8	Are (proposed) injection practices sufficient for failure?	NO	YES	YES	NO
9	If injection has been ongoing at the site, is injection correlated with the occurrence of earthquakes?	NO	YES	YES	NO
10	Are nearby injection wells associated with earthquakes?	NO	YES	YES	NO
	TOTAL "YES" ANSWERS	**0**	**10**	**8**	**2**

Table 3 — Criteria to determine if injection provides 'no apparent risk' or 'clear risk' of induced seismicity; developed by S. D. Davis and C. Frohlich. Induced seismicity risk assessment was performed on the two historical cases in addition to the proposed McKee Waterflood Project. While the two historical cases show 'clear risk' for inducing earthquakes, the McKee Project assessment appears to be at low risk for inducing earthquakes.

SOURCE: Davis and Frohlich (1993)

3.6 Summary

The RMA disposal well provides a clear case history establishing a relationship between SWD volumes and seismic activity. Multiple actions could have been taken to mitigate the risk of inducing earthquakes. It is important to understand the geology of the reservoir, specifically the porosity, permeability, and natural fractures, in which you plan to inject, as well as continually monitor the wells for signs of over-injection or leak-off. Faults do not induce earthquakes from a small volume of injected fluids; it is the build-up of high volumes of fluids and pressure that cause a fault to slip. Awareness of local faults and reservoir dynamics are paramount to mitigating the risk of inducing earthquakes.

The proposed McKee Waterflood Project poses low risk for inducing earthquakes. The project is intended as a secondary recovery/waterflood project and will be focused on sweeping oil from injectors to producers. To efficiently and cost effectively accomplish this, FAE II Operating LLC plans to utilize waterflood surveillance to ensure injection stays within the targeted McKee sand and the injector-producer patterns, where the producers will be 500'-1,000' from the injectors. If evidence indicates injection is going out of the targeted interval, operations can intervene and perform workovers on injectors to plug-off unwanted flowpaths, e.g. cement squeeze leak-off intervals.

Since injected volumes should stay with the established waterflood patterns, it is highly unlikely for the injection to reach any of the faults shown in **Fig 9**. Per Snee and Zoback's FSP evaluation, the faults closest to the project area all appear to be low risk of induced seismicity. The closest fault(s) run North-South and were evaluated as having <10% FSP. These faults would have to be exposed to a significant build-up of fluid and pressure in order to induce an earthquake. Currently, the McKee sand is pressure depleted, requiring millions of barrels of injection before achieving fill-up and restoring the reservoir back to its original state. After fill-up is achieved, waterflood operations targeting a 1.0-1.2 cumulative VRR will prevent unintentional over-injection and avoid pressure build-up. The proposed McKee Waterflood Project poses low risk for inducing earthquakes.

4.0 References

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CARDINAL Laboratories

PHONE (575) 393-2326 ° 101 E. MARLAND ° HOBBS, NM 88240

January 12, 2022

JAMES MARTINEZ

FORTY ACRES ENERGY

11777 KATY FREEWAY STE. 305 B

HOUSTON, TX 77079

RE: WATER SAMPLES

Enclosed are the results of analyses for samples received by the laboratory on 01/10/22 13:10.

Cardinal Laboratories is accredited through Texas NELAP under certificate number T104704398-21-14. Accreditation applies to drinking water, non-potable water and solid and chemical materials. All accredited analytes are denoted by an asterisk (*). For a complete list of accredited analytes and matrices visit the TCEQ website at www.tceq.texas.gov/field/qa/lab_accred_certif.html.

Cardinal Laboratories is accreditated through the State of Colorado Department of Public Health and Environment for:

Method EPA 552.2	Total Haloacetic Acids (HAA-5)
Method EPA 524.2	Total Trihalomethanes (TTHM)
Method EPA 524.4	Regulated VOCs (V1, V2, V3)

Cardinal Laboratories is accredited through the State of New Mexico Environment Department for:

Method SM 9223-B	Total Coliform and E. coli (Colilert MMO-MUG)
Method EPA 524.2	Regulated VOCs and Total Trihalomethanes (TTHM)
Method EPA 552.2	Total Haloacetic Acids (HAA-5)

Accreditation applies to public drinking water matrices for State of Colorado and New Mexico.

This report meets NELAP requirements and is made up of a cover page, analytical results, and a copy of the original chain-of-custody. If you have any questions concerning this report, please feel free to contact me.

Sincerely,

Celey D. Keene

Celey D. Keene

Lab Director/Quality Manager

CARDINAL Laboratories

PHONE (575) 393-2326 ° 101 E. MARLAND ° HOBBS, NM 88240

Analytical Results For:

FORTY ACRES ENERGY 11777 KATY FREEWAY STE. 305 B HOUSTON TX, 77079	Project: WATER SAMPLES Project Number: NONE GIVEN Project Manager: JAMES MARTINEZ Fax To:	Reported: 12-Jan-22 14:51

Sample ID	Laboratory ID	Matrix	Date Sampled	Date Received
FORTH ACRES WELL 32.26537-103.	H220086-01	Water	10-Jan-22 10:00	10-Jan-22 13:10
EAST OF PIPE YARD 32.27167-103.:	H220086-02	Water	10-Jan-22 10:15	10-Jan-22 13:10
SEETON BATTERY 32.29308-103.16	H220086-03	Water	10-Jan-22 10:30	10-Jan-22 13:10
LAMUNYON CTB 32.27994-103.163:	H220086-04	Water	10-Jan-22 10:45	10-Jan-22 13:10

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FORTH ACRES WELL 32.26537-103.14128

H220086-01 (Water)

Analyte	Result	MDL	Reporting Limit	Units	Dilution	Batch	Analyst	Analyzed	Method	Notes
Cardinal Laboratories										
Inorganic Compounds										
Chloride*	**364**		4.00	mg/L	1	2010711	GM	10-Jan-22	4500-Cl-B	
TDS*	**2450**		5.00	mg/L	1	2010607	GM	12-Jan-22	160.1	

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FORTY ACRES ENERGY 11777 KATY FREEWAY STE. 305 B HOUSTON TX, 77079	Project: WATER SAMPLES Project Number: NONE GIVEN Project Manager: JAMES MARTINEZ Fax To:	Reported: 12-Jan-22 14:51

EAST OF PIPE YARD 32.27167-103.14762

H220086-02 (Water)

Analyte	Result	MDL	Reporting Limit	Units	Dilution	Batch	Analyst	Analyzed	Method	Notes
Cardinal Laboratories										
Inorganic Compounds										
Chloride*	**96.0**		4.00	mg/L	1	2010711	GM	10-Jan-22	4500-Cl-B	
TDS*	**696**		5.00	mg/L	1	2010607	GM	12-Jan-22	160.1	

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SEETON BATTERY 32.29308-103.16597

H220086-03 (Water)

Analyte	Result	MDL	Reporting Limit	Units	Dilution	Batch	Analyst	Analyzed	Method	Notes
Cardinal Laboratories										
Inorganic Compounds										
Chloride*	**54000**		4.00	mg/L	1	2010711	GM	10-Jan-22	4500-Cl-B	
TDS*	**94800**		5.00	mg/L	1	2010607	AC	11-Jan-22	160.1	

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FORTY ACRES ENERGY 11777 KATY FREEWAY STE. 305 B HOUSTON TX, 77079	Project: WATER SAMPLES Project Number: NONE GIVEN Project Manager: JAMES MARTINEZ Fax To:	Reported: 12-Jan-22 14:51

LAMUNYON CTB 32.27994-103.16338

H220086-04 (Water)

Analyte	Result	MDL	Reporting Limit	Units	Dilution	Batch	Analyst	Analyzed	Method	Notes
Cardinal Laboratories										
Inorganic Compounds										
Chloride*	**26000**		4.00	mg/L	1	2010711	GM	10-Jan-22	4500-Cl-B	
TDS*	**48800**		5.00	mg/L	1	2010607	AC	11-Jan-22	160.1	

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Inorganic Compounds - Quality Control

Cardinal Laboratories

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch 2010607 - Filtration										
Blank (2010607-BLK1)				Prepared: 06-Jan-22 Analyzed: 07-Jan-22						
TDS	ND	5.00	mg/L							
LCS (2010607-BS1)				Prepared: 06-Jan-22 Analyzed: 07-Jan-22						
TDS	535		mg/L	500		107	80-120			
Duplicate (2010607-DUP1)		**Source: H220016-02**		Prepared: 06-Jan-22 Analyzed: 07-Jan-22						
TDS	1260	5.00	mg/L		1240			2.00	20	
Batch 2010711 - General Prep - Wet Chem										
Blank (2010711-BLK1)				Prepared & Analyzed: 07-Jan-22						
Chloride	ND	4.00	mg/L							
LCS (2010711-BS1)				Prepared & Analyzed: 07-Jan-22						
Chloride	100	4.00	mg/L	100		100	80-120			
LCS Dup (2010711-BSD1)				Prepared & Analyzed: 07-Jan-22						
Chloride	100	4.00	mg/L	100		100	80-120	0.00	20	

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Notes and Definitions

ND	Analyte NOT DETECTED at or above the reporting limit
RPD	Relative Percent Difference
**	Samples not received at proper temperature of 6°C or below.
***	Insufficient time to reach temperature.
-	Chloride by SM4500Cl-B does not require samples be received at or below 6°C
	Samples reported on an as received basis (wet) unless otherwise noted on report

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CARDINAL Laboratories

101 East Marland, Hobbs, NM 88240
(575) 393-2326 FAX (575) 393-2476

RUSH

CHAIN-OF-CUSTODY AND ANALYSIS REQUEST

Company Name: Forty Acres Energy
Project Manager: James Morrez
Address: 11757 Houston Tx
City: Houston State: Tx Zip:
Phone #: 806-420-8278 Fax #:
Project #: Project Owner:
Project Name:
Project Location:
Sampler Name:

BILL TO
P.O. #:
Company:
Attn:
Address:
City:
State: Zip:
Phone #:
Fax #:

ANALYSIS REQUEST

FOR LAB USE ONLY Lab I.D.	Sample I.D.	(G)RAB OR (C)OMP.	# CONTAINERS	MATRIX: GROUNDWATER	WASTEWATER	SOIL	OIL	SLUDGE	OTHER:	PRESERV.: ACID/BASE:	ICE / COOL	OTHER:	SAMPLING DATE	TIME	Scale	TDS	Cl
H220086 1	Forty Acres Well 32.26537 - 103.14128		1	X									1/10	10:A.m	✓	✓	✓
2	East of Pipe Yard 32.27167 - 103.14762		2	X									1/10	10:15Am	✓	✓	✓
3	Seeton Battery 32.29308 - 103.16597		3	X									1/10	10:30Am	✓	✓	✓
4	Lamunyon CTB 32.27994 - 103.16338		4		X								1/10	10:45Am	✓	✓	✓

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Relinquished By: Date: 1/10/22 Time: 1:10 P.m. Received By: Tamara Oldaker
Relinquished By: Date: Time: Received By:

Verbal Result: ☐ Yes ☐ No Add'l Phone #:
All Results are emailed. Please provide Email address:
James@fgenergyus.com
REMARKS:

Delivered By: (Circle One)
Sampler - UPS - Bus - Other:
Observed Temp. °C 19.6
Corrected Temp. °C 19.1
Sample Condition: Cool ☐ Yes ☑ No; Intact ☑ Yes ☐ No
CHECKED BY: (Initials) TO.

Turnaround Time: Standard ☑ Rush ☑ Due 1/13
Thermometer ID #113
Correction Factor -0.5°C
Bacteria (only) Sample Condition: Cool ☐ Yes ☐ No; Intact ☐ Yes ☐ No
Observed Temp. °C
Corrected Temp. °C

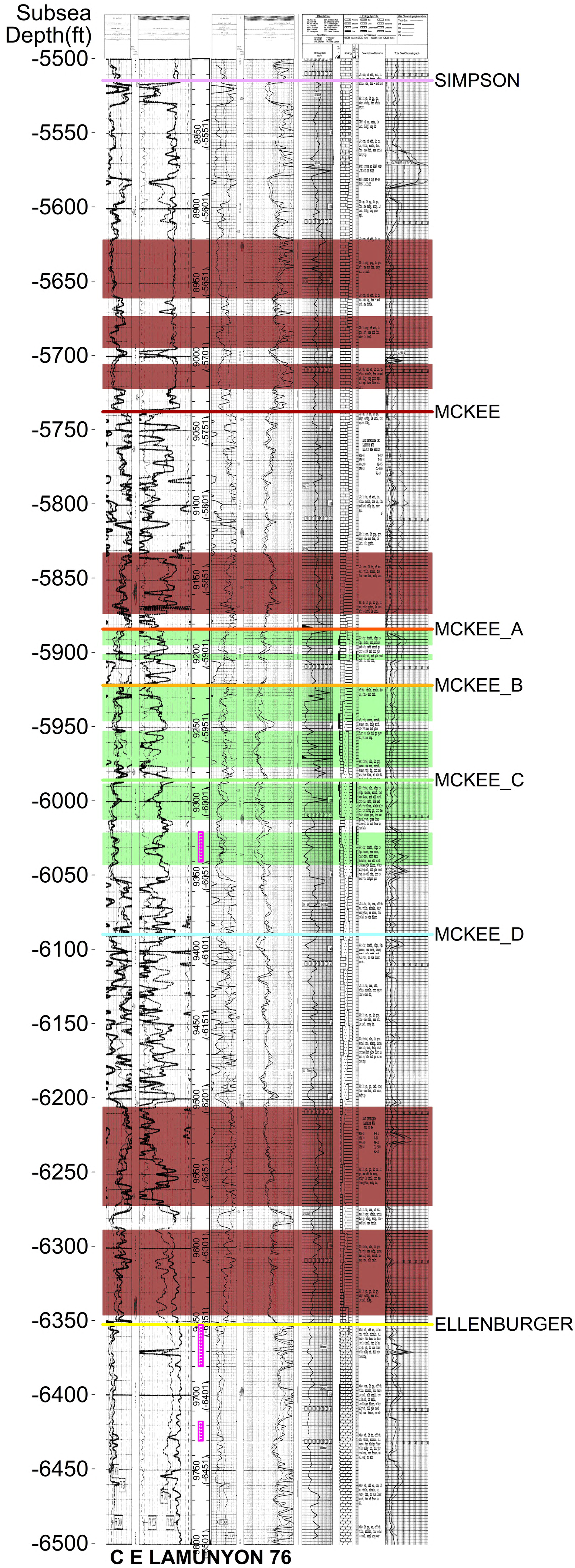
FORM-006 R 3.2 10/07/21

† Cardinal cannot accept verbal changes. Please email changes to celey.keene@cardinallabsnm.com

Received by OCD: 4/11/2022 2:02:04 PM

Released to Imaging: 4/11/2022 2:15:53 PM

30025350740000
FAE
C E LAMUNYON 76
SPUD_DATE : 9/17/2000
T23S R37E S27



Seal Rock - impermeable rock confining native and injected reservoir fluids/gas to a specific reservoir/interval

Net Pay - reservoir-quality rock bearing hydrocarbons

C E LAMUNYON 76
TD : 9,800
ELEV_KB : 3,299

FAE Operating, LLC
Case No. 22593
Exhibit F

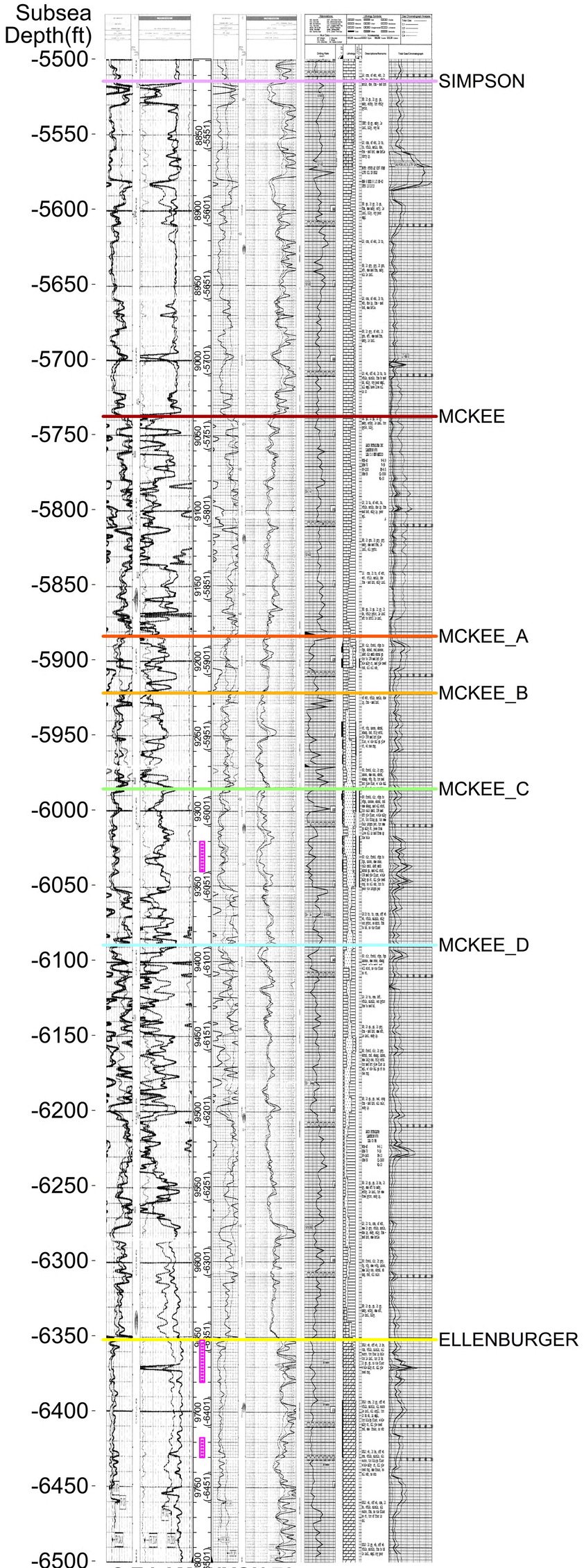
30025350740000

FAE

C E LAMUNYON 76

SPUD_DATE : 9/17/2000

T23S R37E S27



C E LAMUNYON 76

TD : 9,800

ELEV_KB : 3,299

FAE Operating, LLC
Case No. 22593
Exhibit G