

Application

Part *II*

OPERATORS, LEASEHOLDERS AND SURFACE OWNERS WITHIN 2 MILES -RADIUS

DATA EXTRACTED FROM TABLES 1, 2A, 2B AND 2C

New Mexico State Land Office Mays State SWD #1 310 Old Santa Fe Trail Santa Fe, NM 87501	Bureau of Land Management Mays State SWD #1 620 E. Greene Street Carlsbad, NM 88220-6292	LIMESTONE BASIN PROP RANCH LLC Mays State SWD #1 18 DESTA DRIVE MIDLAND, TX 79705
MERCHANT LIVESTOCK Mays State SWD #1 PO BOX 1105 EUNICE, NM 88231	PHILIP L WHITE Mays State SWD #1 PO BOX 25968 ALBUQUERQUE, NM 87125	EOG RESOURCES INC Mays State SWD #1 P.O. Box 2267 Midland, TX 79702
DEVON ENERGY PRODUCTION COMPANY, LP Mays State SWD #1 333 West Sheridan Ave. Oklahoma City, OK 73102	<div>Not a valid address per USPS</div> <div>CHEVRON USA INC Mays State SWD #1 AS WARREN PETROLEUM COMPANY P O BOX 1589 TULSA, OK 74102</div>	OCCIDENTAL PERMIAN LTD Mays State SWD #1 PO BOX 4294 HOUSTON, TX 77210
APACHE CORPORATION Mays State SWD #1 303 VETERANS AIRPARK LN #1000 MIDLAND, TX 79705	CHEVRON U S A INC Mays State SWD #1 6301 DEAUVILLE BLVD MIDLAND, TX 79706	CAZA PETROLEUM, LLC. Mays State SWD #1 4 GREENSPPOINT PLACE 16945 NORTHCHASE DR SUITE 1430 HOUSTON, TX 77060
EOG Y RESOURCES, INC. Mays State SWD #1 104 S 4TH ST ARTESIA, NM 88210	CENTENNIAL RESOURCE PRODUCTION, LLC Mays State SWD #1 1001 17th Street, Suite 1800 Denver, CO 80202	MRC PERMIAN COMPANY Mays State SWD #1 5400 LBJ FREEWAY SUITE 1500 DALLAS, TX 75240
ENERGEN RESOURCES CORP. Mays State SWD #1 605 RICHARD ARRINGTON JR. BLVD BIRMINGHAM, AL 35203	FEATHERSTONE DEVELOPMENT CORPORATION Mays State SWD #1 PO BOX 429 ROSWELL, NM 88202	FEDERAL ABSTRACT COMPANY Mays State SWD #1 P O BOX 2288 SANTA FE, NM 875042288
MRC DELAWARE RESOURCES, LLC Mays State SWD #1 P. O. BOX 1936 ROSWELL, NM 88202	EOG Y RESOURCES, INC. Mays State SWD #1 104 S 4TH ST ARTESIA, NM 88210	DEVON ENERGY PRODUCTION COMPANY, LP Mays State SWD #1 333 West Sheridan Ave. Oklahoma City, OK 73102
CHEVRON MIDCONTINENT, L.P. Mays State SWD #1 6301 DEAUVILLE BLVD MIDLAND, TX 79706	CAZA OPERATING, LLC Mays State SWD #1 200 N LORAIN STE 1550 MIDLAND, TX 79701	EOG RESOURCES INC Mays State SWD #1 P.O. Box 2267 Midland, TX 79702
MATADOR PRODUCTION COMPANY Mays State SWD #1 One Lincoln Centre 5400 LBJ Freeway, Ste 1500 Dallas, TX 75240	CENTENNIAL RESOURCE PRODUCTION, LLC Mays State SWD #1 1001 17th Street, Suite 1800 Denver, CO 80202	

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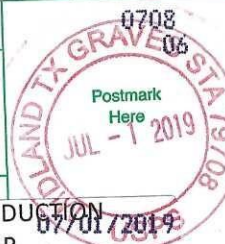
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310 Old Santa Fe Trail
Santa Fe, NM 87501



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July 3, 2019

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

RE: AWR Disposal, LLC Mays State SWD #1
UL I, Section 4 T23S R35E, Lea County

Dear Mr. Goetze:

On behalf of AWR Disposal LLC, R.T. Hicks Consultants is providing data and an opinion regarding the probability that injection of wastewater in the above referenced well at the proposed rates will cause seismic events of sufficient magnitude to create damage. It is our understanding that OCD is interested in such an opinion as part of the SWD approval process. We elected to provide this opinion as a separate submission as the C-108 does not specifically require such an opinion.

We relied upon the following data to develop our opinion

- State of stress in the Permian Basin, Texas and New Mexico: Implications for induced seismicity, Jens-Erik Lund Snee and Mark D. Zoback, The Leading Edge, February 2018¹
- Plate 5, which is reproduced from the Snee and Zoback publication, which uses the following references
 - Crone, A. J., and R. L. Wheeler, 2000, Data for Quaternary faults, liquefaction features, and possible tectonic features in the Central and Eastern United States, east of the Rocky Mountain front; U.S. Geological Survey Open-File Report.
 - Ewing, T. E., R. T. Budnik, J. T. Ames, and D. M. Ridner, 1990, Tectonic map of Texas: Bureau of Economic Geology, University of Texas at Austin.
 - Green, G. N., and G. E. Jones, 1997, a digital geologic map of New Mexico in ARC/INFO format: U.S. Geological Survey Open-File Report.
 - Ruppel, S. C., R. H. Jones, C. L. Breton, and J. A. Kane, 2005, Preparation of maps depicting geothermal gradient and Precambrian structure in the Permian Basin: USGS Order no. 04CRSA0834 and Requisition no. 04CRPR01474.
 - NMOCD database of oil and gas wells
- Plate 5, which shows the distribution of active and new SWD wells in the area of the proposed AWR Disposal SWD well
- Stratigraphic and lithologic information from two deep wells in the Delaware Basin
- Data on the thickness and lithology of the Simpson Group from the Texas Bureau of Economic Geology²

¹ https://scits.stanford.edu/sites/default/files/3702_tss_lundsnee_v2.pdf

² http://www.beg.utexas.edu/resprog/permianbasin/PBGSP_members/writ_synth/Simpson.pdf

Plate 5 reproduces Figure 3 of the 2018 publication of Snee and Zoback and shows

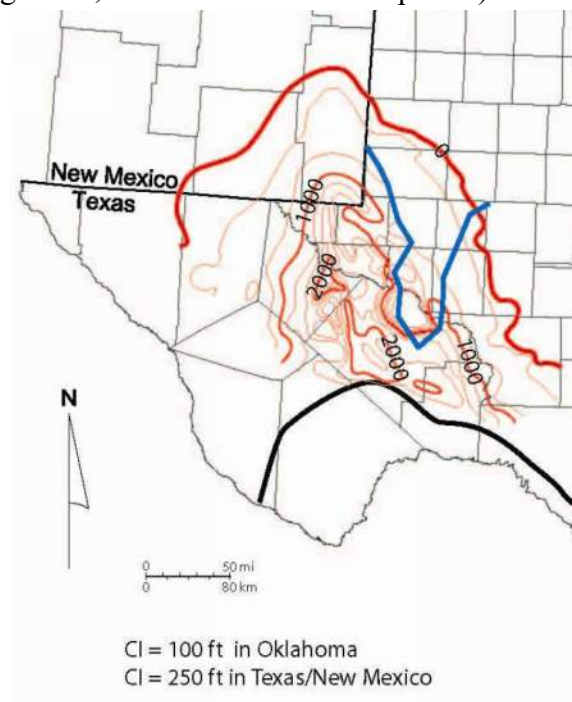
1. Fault traces based upon the references provided above for which Dr. Snee and Dr. Zoback provide a value of the fault slip potential (FSP)
2. Areas of documented seismic activity, and a magnitude 4.0+ earthquake that occurred between 1970-2004 about 16 miles east of the proposed Mays State SWD #1. A larger magnitude and more recent seismic event is reported about 30 miles west of the Mays State SWD #1 well location.
3. Although Plate 5 does not show faults that may be identified in confidential seismic data owned by oil and gas operators, the mapped fault that is closest to the Mays State SWD #1 (about 4.5 miles to the east) exhibits a low FSP (less than 5%) based upon the modeling and analysis of Snee and Zoback referenced above
4. Other mapped faults in southern Lea County shown on Plate 5 also show a low FSP, except for part of northwest-southeast trending fault about 32 miles north-northwest of the Mays State SWD #1 well that has a FSP of about 25 – 33% in the central portion of this fault trace.

Plate 6 reproduces the major elements of Plate 5 in the inset map and also shows that within an 6-mile radius around the proposed Mays State SWD #1, the OCD database shows about 2 active or new Devonian SWDs, which translates into an average density of about one SWD for every 56.5 square miles.

Figure 4 from the referenced Bureau of Economic Geology (The Middle-Upper Ordovician Simpson Group Of The Permian Basin: Deposition, Diagenesis, And Reservoir Development) is attached to this letter and the portion of that figure for the Delaware Basin is shown to the right. In southern Lea County the mapped thickness appears to be 500-1500 feet thick (note one contour line appears to be missing on the map). This unit, which is clay-rich carbonate interbedded with shale and sandstone, provides an excellent permeability/pressure barrier between the injection zone and the basement faults that were re-activated during Woodford time.

Data from the Amoco Federal CW Com 1 (3002528119) show that the thickness of the Simpson near the Mays State SWD #1 is about 450 feet thick with. This is consistent with Figure 4 of the BEG paper (probably because this well was used to produce the isopach map).

We contend that the data permit conclusion that unmapped faults (which may be located by confidential seismic data that AWR Disposal not possess) near the Mays State SWD #1 would be dominantly north-south normal faults, as is



common in Lea County. The data on Plate 6 permit a conclusion that faults near the Mays State SWD #1 are also most likely to exhibit a low FSP, like the mapped faults shown on Plate 5.

Given the density of Devonian SWDs (planned/new and active) near the proposed Mays State SWD #1 well and the high likelihood that any unmapped faults in the area would exhibit a low FSP, the probability that injection into the Mays State SWD #1 would cause an increase in pore pressure to trigger a seismic event of sufficient magnitude to cause damage is very low.

The users of this letter should recognize the uncertainties of using seismic maps of the Permian Basin to determine probability that injection of wastewater into a single SWD well could cause seismic events of sufficient magnitude to cause damage. However, on a regional basis injection by numerous wells into the Devonian/Fusselman/Montoya interval will raise the hydrostatic pressure. If pressure increases sufficiently, fluid could migrate from the injection zone along fault planes, up and down. Downward fluid migration will be intercepted first by the sandstone units of the Simpson Group. After fluid pressure increases in these sandstones, fluid would migrate downward into the Ellenburger Formation, which lies beneath the Simpson Group. This downward migration will next enter the permeable units of the Ellenburger and, over time, increase the fluid pressure. After fluid pressure in the Ellenburger is sufficiently large to cause downward migration along fault planes or other conduits, the migrating fluid will, in some areas, enter a thinner horizon of granite wash. Downward migrating fluids from the injection zone could then enter basement fault planes if the pressure in the granite wash horizon is sufficient, and reduce the frictional resistance (lubricate the faults). Reduction in the frictional force in faults due to fluid invasion can and has caused seismic events.

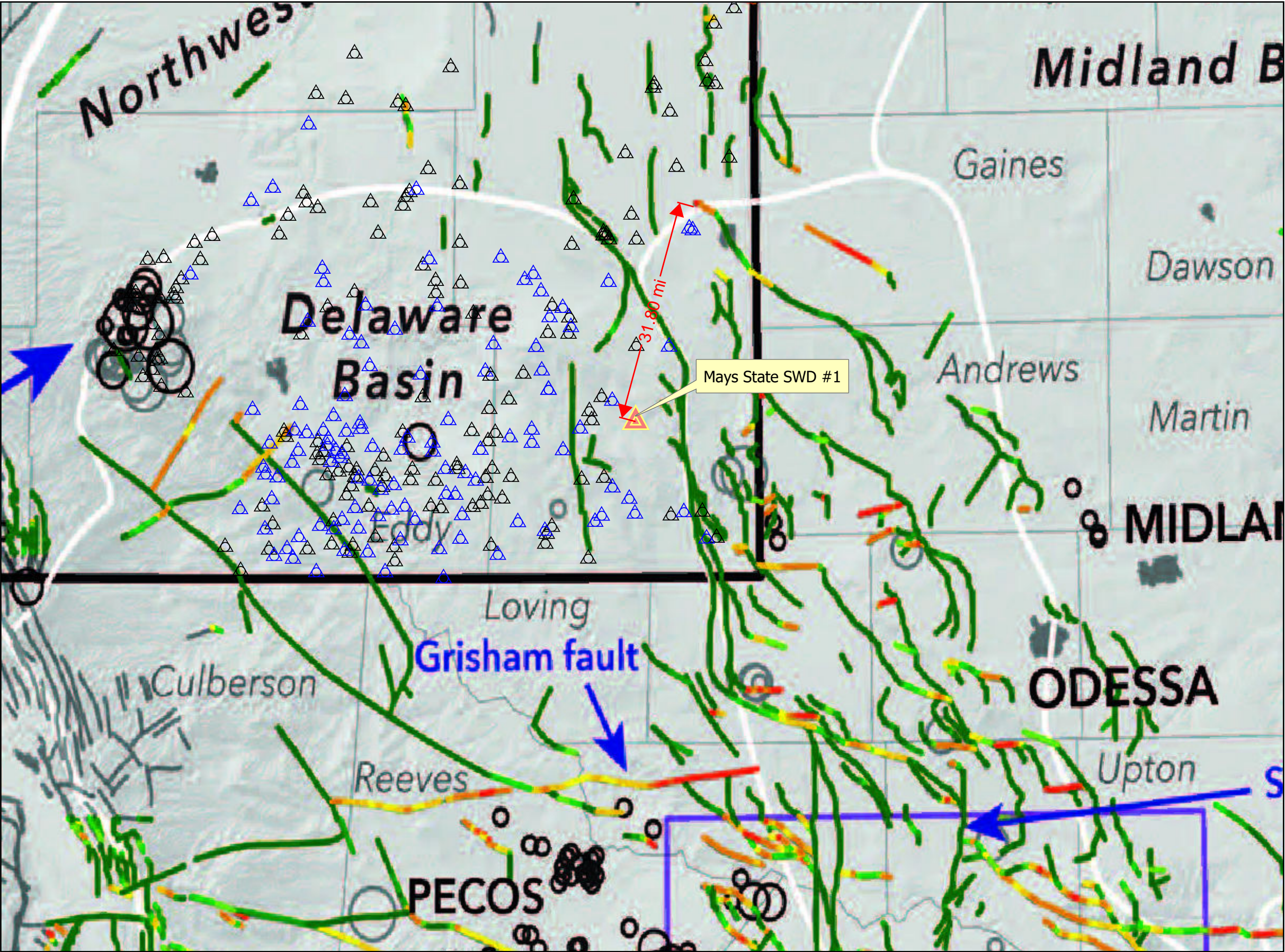
In my opinion, the probability that injection into the Mays State SWD #1 will measurably contribute to the events described above, although the probability of causing a seismic event resulting in damage is so low as to be nil.

Sincerely,
R.T. Hicks Consultants

A handwritten signature in black ink, appearing to read "Randall T. Hicks".

Randall T. Hicks
Principal

Copy: AWR Disposal LLC



Seismic and Fault Slip Potential: Ewing et al. (1990), Green and Jones (1997), Ruppel et al. (2005), and the USGS Quaternary Faults and Folds Database (Crone and Wheeler, 2000).

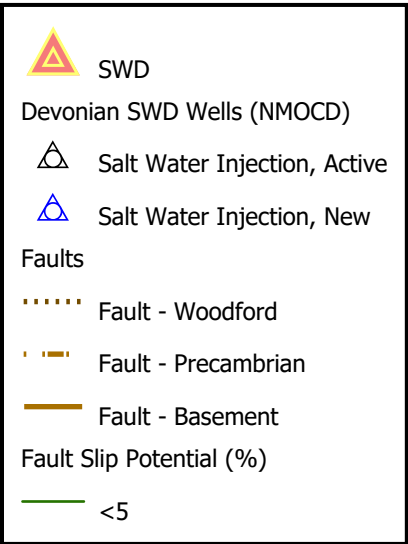
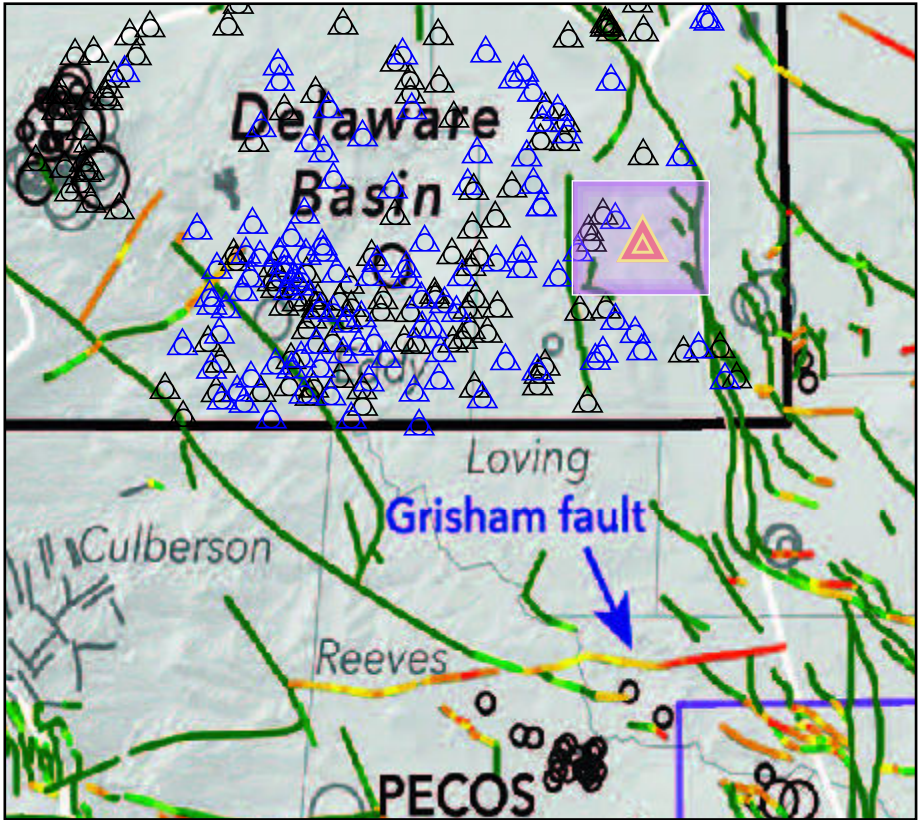
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Fault Slip Potential and Seismic Activity

AWR Disposal, LLC
Mays State SWD #1

Plate 5

April 2019



Seismic and Fault Slip Potential: Ewing et al. (1990), Green and Jones (1997), Ruppel et al. (2005), and the USGS Quaternary Faults and Folds Database (Crone and Wheeler, 2000).

