GEOLOGIC STUDY
QUEEN LAKE FEDERAL 19 #1

The proposed SWD Conversion Well is the Queen Lake Federal 19, #1 (API #: 015-24292) located in Section 19, T24S, R29E, in Eddy County, New Mexico approximately 19 miles southeast of Carlsbad, New Mexico (Figure 1). The well was originally drilled in 1982 to a total depth of 13,500 feet and was plugged in 2013. Key Energy Services, LLC plans to sidetrack the well and convert it to a commercial Class II salt water disposal well (SWD), completed in the undivided Silurian-Devonian section between the approximate depths of 14,500 to 16,000 ft. total vertical depth (TVD) relative to Kelly bushing (KB). The expected formation tops and lithologies are summarized in the following table.

Tops From Well Completion Report Received by NMOCD on 1/14/83.

Stratigraphic Unit	Geological System	Formation Tops (Log Depth ft. RKB)	Lithology
Base Lowermost USDW – Permian Redbeds	Permian	~500	Clastics
Delaware Mtn. Group (Guadalupian)	Permian	2,735	Clastics
Cherry Canyon Formation (Guadalupian)	Permian	3,638	Clastics
Brushy Canyon Formation (Guadalupian)	Permian	4,400	Clastics
Bone Spring Formation (Leonardian)	Permian	6,473	Carbonates and Clastics
Wolfcamp (Wolfcampian)	Permian	9,698	Carbonates and Shale
Strawn Group	Pennsylvanian	11,852	Carbonates and Shale
Atoka Group	Pennsylvanian	12,038	Carbonates and Shale
Morrow Group	Pennsylvanian	12,657	Carbonates and Shale
Undivided Mississippian	Mississippian	13,600 ((Estimate)	Carbonates and Shale
Woodford Formation –Upper Devonian (Proposed Confining Zone)	Devonian	14,300 (Estimate)	Shale
Undivided Devonian/Silurian (Proposed Injection Zone)	Devonian/Silurian	14,500 (Estimate)	Carbonates
Ellenburger Fm.	Ordovician	16,500 (Estimate)	Carbonates
Basement	Precambrian	17,000 (Estimate)	Crystalline Rock

The base of the lowermost underground source of drinking water (USDW) is expected to occur at relatively shallow depth based on a review of water well information for the area (Hendrickson and Jones, 1952) and records from the National Water Information System (USGS, 2019a). The base of the USDW is expected at a maximum depth of 500 feet below ground surface as usable groundwater in the area is associated with the Pecos River alluvium and the upper Permian redbeds (Hendrickson and Jones, 1952). Below these strata are evaporite deposits containing bedded salt, gypsum, and anhydrite associated with

the lower part of the Permian Ochoan Series. The expected depth to the proposed injection zone is approximately 14,500 feet. As such, approximately 14,000 feet of sediment is present providing containment between the expected base of the USDW and the proposed injection zone.

Based on a review of commercial structure maps from Geomap® Company (2019), there are no faults located in the vicinity of the proposed injection well. Maps reviewed include Horizon A – Delaware Lime, Horizon B – Strawn Lime, and Horizon C – Siluro-Devonian. The maps reviewed are current as of February 19, 2019. Based on this review, there is no evidence of faults, including open faults, or any other hydrologic connection between the proposed disposal zone and any USDW.

The proposed injection zone consists of the undivided Silurian-Devonian age strata, which primarily consists of carbonates (limestone and dolomite) and possibly chert conglomerates. Porosity in the unit is expected to range from 3 to 15% and consists of both intergranular primary porosity and secondary dissolution porosity. The top of the injection zone will be below the base of the Upper Devonian Woodford Formation, which will be the upper confining zone and is expected to be encountered at a depth of approximately 14,300 ft. KB (TVD). The top of the injection zone is expected at a depth of approximately 14,500 ft. KB (TVD). The thickness of the injection zone is proposed to be 1,500 feet, which will allow selective perforation of zones indicating good porosity and additional rathole for full open-hole log data acquisition. Depths and thicknesses will be finalized upon evaluation of the logs.

The injection zone formation water is expected to be sodium chloride brine having a total dissolved solids (TDS) concentration ranging from approximately 50,000 to 230,000 mg/l based on data obtained from the USGS produced water database (2012). Water samples from the Devonian strata are summarized below.

County	Formation	Depth (ft.)	TDS (mg/l)	Sample Source	Location	USGS Record No.	Proximity
Eddy	Devonian	11,748	229,706	Drill Stem Test	T24S, R25E, S24	30000642	20 miles west
Eddy	Devonian	12,820	48,954	Drill Stem Test	T17S, R31E, s17	30000528	40 miles NNE
Eddy	Devonian	11,748	203,100	Unknown	T24S, R25E, s24	30000549	20 miles west
Eddy	Devonian	16,578	120,326	Drill Stem Test	T24S, R31E, s28	30000310	14 miles East
Eddy	Devonian	15,060	56,922	SWAB	T23S, R29E, s24	30900416	7.7 miles East
Eddy	Devonian	15,500	96,171	Flowline	T22S, R30E, s36	30900462	14 miles NE

Source: USGS, 2012

Analysis of the closest sample of Devonian formation fluid from USGS record number 30900416 indicated additional constituents consisting of calcium, magnesium and sulfate with approximately 85% of the total solids attributed to sodium and chloride.

In addition, TDS values for the Devonian strata taken from a separate USGS database (2019) are shown on Figure 1. These data indicate a range in TDS values from approximately 21,000 mg/L to 203,000 mg/L and indicate that the formation fluid is sodium chloride brine. Since this will be a produced water disposal well, no issues with injectate and formation fluid compatibility are apparent.

The proposed upper confining zone consists of the Upper Devonian Woodford Formation also known as the Woodford Shale. The Woodford Shale consists of low permeability black shale and siltstone containing abundant pyrite and organic carbon (Comer, 1991). The Woodford Formation is laterally continuous throughout the Permian Basin (Comer, 1991). In the site vicinity the Woodford Formation is expected to be 200 to 300 feet thick.

REFERENCES:

Comer, J.B., 1991, Stratigraphic Anaysis of the Upper Devonian Woodford Formation, Permian Basin, West Texas and Southeastern New Mexico, The University of Texas at Austin, Bureau of Economic Geology, Report of Investigations No. 201, 66 pp.

Hendrickson, G.E, and Jones, R.S., 1952, Geology and Ground-Water Resources of Eddy County, New Mexico, Ground-Water Report 3, prepared cooperatively by the United States Geological Survey, New Mexico Bureau of Mines & Mineral Resources, and the State Engineer of New Mexico, 179 pp.

Geomap® Company, 2019, Structure Map Plats for Horizon B – Delaware Lime, Horizon B – Strawn Lime, and Horizon C – Siluro-Devonian. Maps current as of February 19, 2019.

United States Geological Survey, 2012, Produced Water Database (Revised) from original database compiled by DOE Fossil Energy Research Center that was located in Bartlesville, Oklahoma. Downloaded at http://energy.cr.usgs.gov/prov/prodwat/data2.htm

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United States Geological Survey, 2019b, Energy Resources Program, Produced Water Geochemical Database v.2.3. Viewed on 3/24/19 at https://energy.usgs.gov/EnvironmentalAspects/EnvironmentalAspectsofEnergyProductionandUse/ProducedWaters.aspx#3822349-data