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Technical Memorandum

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Subject: Review of Hydrogeologic Aspects of the December 2017 Oil and Gas Lease Sale, Ely District Office

This technical memorandum reviews hydrogeologic aspects of the Final Environmental Assessment DOI-BLM-NV-L030-2017-0021–EA (EA) for a December 2017 oil and gas lease sale. It is anticipated that any development would be unconventional, meaning that it would be necessary to use hydraulic fracturing (fracking) to open the target formation to release oil or gas. Although it is not limited to specific formations, the EA specifies that the target formations are the Chainman and Pilot Shale. The shale has very low permeability so that the oil or gas is not easily released unless the formation is broken apart by fracking.

The memorandum concludes that fracking development in the proposed lease area threatens the hydrogeology of the area, including regional springs and intermittent and perennial streams. The potential impacts include both contamination and depletion of flow. The following sections outline in detail the many issues the final EA failed to consider or adequately disclose. The first section considers the fracking fluids and brine possibly found in the targeted formation. The following sections consider how those fluids could affect surface water, groundwater, and other resources of the proposed lease area.

Chemistry of Fracking Fluid and Natural Brine

Unconventional O&G development potentially releases three fluids to the environment. These are fracking fluid, natural brine from the targeted formation, and natural gas (methane and higher chain hydrocarbons). Every operator has a formula that varies for every targeted formation rendering it impossible to know in advance the exact chemicals that will be injected into the formation, but the EA should consider the risks of releases of that fluid in a risk-based analysis and consider policies that would reduce the toxicity of the fluid. The analysis would include an assessment of chemical interactions of the fluids with the formations to be fracked and formations surrounding the targeted formation. This would include an assessment of daughter products caused by reactions between the fracking fluid and the formations.

The EA should also consider the contaminants in natural fluids, including high salinity and naturally occurring radioactive material. Brine contains extremely high concentrations of salt and naturally occurring radioactive materials. The injection of fracking fluid may displace brine into pathways that will start it flowing to the near surface. Increasing salt loads to pristine streams could ruin their water quality as a coldwater fishery. The EA should disclose the expected chemistry of the brine and assess the effects of that brine reaching streams or soils in the lease areas.

Methane is also a fluid released by well drilling and development in many ways. It is the most common gas in natural gas, which includes ethane, propane, and other gaseous hydrocarbons. Although not toxic itself, natural gas can accumulate and either explode or burn. It can also replace dissolved oxygen in surface water, thereby causing problems for aquatic life. The EA fails to consider the potential for gas to reach surface water or the effect that gas could have on aquatic life.

Effects on Surface Water

The EA's analysis of surface water effects (p 35) related simply to disturbance related effects, which are similar to other types of land disturbing activity. The analysis neglected to consider the potential for spills of contaminants, such as fracking fluid or spilled flowback. The EA analysis should relate the risks of contamination to the distance a wellpad, the site of most spills, would be from drainages.

The EA fails also to consider the potential for contaminated shallow groundwater to reach surface water, and the effects it could have. The transport of fracking fluid or produced water through the groundwater to shallow aquifers is discussed below, but the EA fails to relate the risks to surface to the proximity that surface water has to potentially contaminated groundwater.

The environmental analysis for a lease sale should include:

- An assessment of the distance a well pad is to surface water. This would be a GIS exercise of buffering the drainages and determine the areas greater than certain distances from the drainage.
- An assessment of stream reaches dependent on discharge of groundwater from shallow aquifers, so that placement of wells could minimize the risk to the surface waters. Stream channels connected to shallow groundwater occur in Railroad Valley North,

White River Valley, and Pahranagat Valley. There could also be intermittent surface waters connected to shallow groundwater on the east side of the Diamond Range and in the Snake Range.

Effects on Groundwater

The target formations are Chainman Shale and Pilot Shale (EA, p 1). Stratigraphically, these shale formations are part of the uppersiliclastic rock unit, which separates the upper and lower carbonate rock units (Welch et al. 2008). Both carbonate rock units are essential aquifers, as acknowledged in the EA, and discussed in Welch et al. (2008) and Heilweil and Brooks (2011). The carbonate aquifer has been targeted by the Southern Nevada Water Authority (SNWA) for its groundwater development project, as well (FEIS for SNWA Groundwater Development).

Well-bore drilling would occur through the upper carbonate aquifer to reach the shale that lies between the carbonate units. The upper carbonate aquifer is thousands of feet thick, thus there is a long well bore intersecting the aquifer. Leaks would be directly into the aquifer. Fracking would occur in the layer between two highly productive and highly important aquifers. Out-of-formation-fracking, which is much more common than commonly acknowledged (see below), would allow fracking fluids to directly flow into carbonate aquifers.

The carbonate aquifers also support many springs in the area. Most egregiously, Group D is upgradient of Big and Little Warm Spring in Duckwater Valley. Group B lies along the White River Flow System path from White River Valley to Pahranagat Valley, so drilling would occur upgradient of the springs in Pahranagat Valley. Group E is in the northern portion of White River Valley, near many carbonate-based springs. Group H is in the central to southern portion of White River Valley, also near carbonate-based springs. However, spills at these areas would contaminate surficial aquifer and perched aquifer that support cold-water springs. Group F would be in a recharge zone for both Spring and Snake Valleys, so spills could contaminate recharge to both basin fill and carbonate aquifers. White River Valley and Pahranagat Valley are hydrologic basins of concern because of the presence of threatened fish dependent on the springs. The EA failed to consider the risks to these springs or specify management practices that could minimize the risks.

The cursory discussion of hydrogeology in the EA (p 32-35) does not pass for an analysis. The EA is wrong with regard to interbasin flow from the Death Valley Flow System (DVFS) (EA, p 32); although some have suggested flow moved from DVFS to the White River Flow System (WRFS), the broader consensus is that flow goes in the other direction, from WRFS to DVFS. The cited reference, Harrill and Prudic (1998),is out of date and has been superseded by Heilweil and Brooks and studies of the DVFS. It is not relevant to the consideration of impacts of leasing, and should not be part of the EA.

The EA lists groundwater basins in Table 3.3. It is incorrect in two respects. The total appropriations have not been adjusted for supplemental water rights, meaning some uses are limited in the total amount of water that can be used, but the water could be obtained from more than one source. Each source may have a water right equal to total amount, but not all sources could be used fully in one year; they are limited to the total amount that can be used. Second, the total appropriations include amounts awarded to SNWA in 2011, but those awards have been set aside by the courts.

Pathways for Contaminants to Reach the Surface

Natural gas released by unconventional O&G development has been found to contaminate shallow aquifers, wells, and springs near gas developments. However, the EA for this lease sale has not considered this potential in any way.

Natural gas can discharge from three different sources -the deep shale, a natural gas well bore, or shallow microbial sources - to shallow groundwater or to streams and springs. Fracking can mobilize gas from either source which can cause short-term or long-term methane contamination on streams and springs. Simply drilling through formations with natural gas can provide a pathway for the gas in that formation to move vertically toward the surface; the pathway can be along the annulus between the casing and the hole wall; the formation can be sandstone or other conventional type gas formation that is not extensive enough to be developed conventionally. The well does not have to provide the entire pathway to the shallow groundwater but could simply connect the source with a shallow fault or fracture which could link the well to shallow groundwater.

Fracking releases both fracking fluid injected into the formation and brine which can follow natural or artificial pathways to shallow groundwater. The high pressure required for fracking can cause fracking fluid to leak from the well bores into surrounding formations, if the well bore leaks. From those sources, the fluid can follow natural pathways to shallow groundwater, streams and springs. The natural pathways include faults and fractures.

The first is that the industry assumes that most fracking operations do not cause fractures to leave the target formation. Based on observed experience in the Marcellus shale, that is not correct because many operations have been documented to cause fractures that leave the formation. Much fracking fluid leaves the shale during fracking through out-of-formation fractures which extend as much as 1500 feet above the Marcellus shale (Hammock et al. 2014; Fisher and Warpinski 2011). Hammock et al. (2014) documented 10,286 microseismic events as much as 1900 feet above the shale from 56 HF stages for six Marcellus wells, including many events that extended above the Tully limestone, which had been considered a barrier to fracturing. These fractures did not extend to shallow groundwater, but they provided a pathway from the shale to much more permeable formations closer to shallow groundwater. The new fractures also potentially connect with natural fractures and faults.

The permeability of the target formation also changes due to fracking. Pre-fracking, the rate of flow through the shale can be measured in inches per millenia due to the shale's extremely low permeability. Hydraulic fracturing increases the permeability of the formation. This allows the oil/gas to flow with the natural groundwater (brine which becomes produced water) to the well more easily. If the fractures contact the edge of the shale, the increased permeability allows the fluids to contact more naturally permeable formations above or below the formation more easily. In this sale, these formations are carbonate aquifers.

The siliclastic formation which contains the shale is extensively folded and faulted. If fracking pressures or fractures contact these natural fractures, the natural fractures could provide a pathway for fluids to flow upward out of the shale (Caine et al 1996). If a target formation is close to a natural pathway, fracking fluids or natural brine could flow to the near surface. The fracking pressures could reactivate old faults that have been sealed, so faults that previously did not transmit fluid could begin to if the fracking pressures reactivated the fractures. The risks due to potential reactivation of existing pathways could be minimized if the setbacks were established. As part of this NEPA process, the BLM should establish setbacks from existing faults, and establish standards for determining the existence of faults, so that potential lease purchasers could understand their requirements. The required setbacks are not simply from the surface but also from the well, wherever it is located below the ground surface. This is important especially if the wells are directionally drilled.

Out-of-formation fracking, when the fractures leave the target formation, occurs frequently. The pressure forces fracking fluid to flow outside of the shale, whether through out-of-formation fractures or through just making a contact with more permeable formations above the shale, and start the movement of fluid to shallow groundwater through natural pathways. Travel time for contaminants to reach the surface could vary from tens to thousands of years, depending on the conductivity of the connections (Myers 2012).

The coincidence of fracking between two carbonate aquifers magnifies the potential for contaminants from the fracking to reach aquifers, and pathways to shallow aquifers, as compared to fracking development in other areas such as the Marcellus shale. The depth to the shale in this sale area does not protect water resources due to the connectivity of the carbonate aquifer. It is at the lease sale phase that analysis of the connectivity between the shale and carbonate aquifers would be most appropriate, both to the protect the environment and to inform potential lease buyers of the development risks they would face.

Water Use

Fracking requires millions of gallons of water, some of which remains underground, and the remainder is too contaminated for use. The EA (Appendix E) indicated that up to 10,000,000 gallons could be used, per well, depending on whether the well is vertical or horizontal. This water is effectively consumptively used because it either remains bound in the shale or it is so contaminated it would be disposed through an injection well. The EA (Appendix E) lists various potential sources of water for fracking, but they are all speculative. A NEPA analysis should consider the amounts of water that would be required, on average and at the upper end if prices allow for rapid development, to develop each of the eight lease areas. Although the potential sources may not be identifiable, it is reasonable to conclude it would be from a nearby source due to the costs of trucking tanks trucks full of water. The NEPA analysis should consider the potential effects on nearby water sources, such as springs, if all of the water was sourced locally. The NEPA analysis would then establish limits on the development, which the lease purchaser would have to work within or would have to truck water from outside the area.

The EA (Appendix E) discusses water use from a prior appropriations' perspective. However, the BLM must expand its consideration to include protecting the environment from water use decisions. The Nevada State Engineer (NSE) could grant a temporary water right without considering the impact on the environment if it would not harm senior water rights. Unless it can be shown that obtaining groundwater for fracking would affect a senior water right, the NSE would grant it. The BLM has the authority to limit fracking based on whether the water use would affect environmental resources associated with the streams. As part of analysis of potential leasing, the BLM should consider the potential impacts to water quantity in the basins that could be used to provide the water. The BLM should also determine water sources that could be off limits for large diversions necessary to frack a well.

Neither the EA nor Appendix E discuss in any detail the fact that water used for fracking is consumptively used, except possibly flowback that is treated for use in other ways. Fracking fluid either remains bound in the formation or that collected as flowback is reinjected for disposal. Either way, it is effectively lost. Produced water may be new water, but it is usually highly contaminated brine.

Flowback and Spills

Flowback is the fluid that flows back up the well from the formation after the pressure induced to cause fracturing is released. Flowback is a natural result of most fracking operations. Flowback can be either fracking fluid or natural fluids occurring in the targeted formation. The operator must be prepared to capture the flow, or a spill will result.

Drill pads should be sufficiently far from surface water that flowback will not contaminate the surface water if the operator is unable to contain it. The drill pad must also have sufficient

BMPs to contain spills on site. Most flowing streams in Nevada are very small, and contamination could devastate them due to their small size. As part of an analysis of potential leasing, the BLM should consider the potential contaminants in flowback and risks to surface water from spills. The analysis should include an assessment of risks as a function of distance from the well pad to the resource, so that setbacks can be established.

Cumulative Impacts

The EA cumulative effects analysis (EA, Chapter 4) does not include reference to the SNWA Groundwater Development Project (FEIS, Clark, White Pine, and Lincoln County Groundwater Development Project), even though it would affect water resources with both groundwater depletion and impact of surface disturbance, in some of the proposed lease sale areas.

Conclusion and Recommendations

This memorandum has detailed multiple risks that unconventional oil and gas development could cause to groundwater and surface water resources in the proposed lease sale area. The NEPA analysis should include much improved assessments of the existing hydrogeology and potential connections among the target formations and shallow aquifers. This should be done separately for all lease areas. The site-specifc analysis should include a detailed consideration of the hydrogeology at the site, including stratigraphy, fault mapping, and baseline hydrogeology data, such as groundwater levels and chemistry. A conceptual flow model for groundwater flow through the area and to downgradient water sources, as outlined in this memorandum, should be completed.

The analysis should be completed in a new draft environmental assessment or in a full Environmental Impact Statement (EIS). Alternatives should be considered, in addition to the no action alternative, based on the risks to water resources determined from the environmental assessment.

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