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DATE March 31, 2020

RE Geologic Review of Proposed Disposal Well
Penneco Environmental Solutions – Sedat #3A Well
Plum Borough, Allegheny County

Introduction

This technical review assesses the suitability of the geologic structure and setting for waste disposal via injection in the vicinity of the Sedat 3A gas well in Plum Borough, Allegheny County, Pennsylvania, owned and operated by Penneco Environmental Solutions (Penneco). The conclusions of this report are based on a review of all documents submitted by Penneco, published maps and reports from the DCNR and others, and my experience as a licensed professional geologist.

Background

The Sedat 3A (API #003-21223) was originally drilled and constructed as a gas well targeting the Bradford Formation. The Sedat 3A was drilled from January 25, 1989 to February 1, 1989 to a total

vertical depth (TVD) of 4,320 feet below grade (fbg). The Sedat 3A produced gas until 2015, when Penneco plugged it back to 1,940 fbg, targeting the Murrysville Formation as a disposal stratum. Currently, the Sedat 3A has 13 3/8 in diameter casing set from 0-16 fbg and sanded in, 9 5/8 in casing set from 0-643 fbg and cemented, 7 in diameter casing set from 0-1,948 fbg, and a 4 ½ in injection string set from 0-1,796 fbg, held in place with a Parmaco Tension Packer. A bridge plug is set in the Sedat 3A at 1,940 fbg, and the 7 in casing is perforated from 1,896-1,936 fbg.

On March 13, 2018, the Department received a permit application from Penneco to change the designation of the Sedat 3A from a gas well to an injection disposal well. Attached was an EPA permit and approved EPA permit application and required related documentation submitted for the disposal well to the EPA.

Geologic Setting

The Sedat 3A is located in the Pittsburgh Low Plateau Section of the Allegheny Plateau Physiographic Province, which is characterized by high local relief, deep valleys, and relatively flat-lying strata relative to other areas of the state. The surface is characterized by rocks of Pennsylvanian age, mostly the Monongahela Group, the Casselman Formation, and the Glenshaw Formation (Figure 1). The Sedat 3A is sited approximately 630 ft northwest of the mapped axis of the Duquesne Syncline, and locally beds dip towards the southeast. There are no local mapped faults, although faults are inferred approximately 5 miles to the southeast and 8 miles to the northwest. The Blairsville-Broadtop Lineament is located approximately 6 miles to the northeast.

The Murrysville Formation is the target stratum for the injection well. Also referred to as the Cussewago Sandstone, the Murrysville is characterized by a coarse-grained, poorly cemented sandstone, fining upward and interbedded with siltstone. The basal portion of the Murrysville has high permeability, while the finer-grained tightly cemented sand at the top of the Murrysville has low porosity and permeability. The Murrysville grades upwards into the Riddlesburg Shale. The Riddlesburg Shale is composed of interbedded shales, siltstones and scour-based fine-grained sandstones (Bjerstedt and Kammer, 1988). Gamma logs submitted by Penneco appear to show a distinctly lower porosity in the Riddlesburg as compared to the Murrysville; however, the locations of where the gamma logs were collected were not shown on the map, and an examination of the metadata indicate they may be located several miles outside of the area of review (AOR). Isopach maps submitted by Penneco indicate that the Riddlesburg has an approximate thickness in the area of the Sedat 3A of approximately 50 ft. The thickness and low porosity of the Riddlesburg in this area indicate that it is an effective upper confining layer.

Water and Groundwater Resources

Penneco's application identified no streams or wetlands within the quarter mile AOR. This is consistent with the Department's records.

The Department has no record of public water supplies within the AOR. Penneco conducted a survey of property owners within 1 mile of the Sedat 3A to identify owners of private water supplies. Five wells and two springs were identified as being within the quarter mile AOR. The sources of the springs are likely shallow water bearing zones in the Casselman Formation. The identified wells and springs are situated on the edge of the quarter mile AOR.

In the permit application, Penneco identified underground sources of drinking water (USDWs) as the Monongahela Group, the Conemaugh Group, and the Allegheny Group, a section which can be as thick as 1,300 ft. According to the Pennsylvania Groundwater Information System (PAGWIS), wells for domestic and industrial use in Plum Borough and Upper Burrell Township have depths ranging from 18 fbg to 500 fbg, but the median depths appear to be between 125 fbg and 150 fbg. The Pennsylvania Geologic Survey identifies formations below the bottommost member of the Allegheny Group (Worthington Formation) as producing water too high in salt to be considered adequate drinking water sources.

The Monongahela Group (to a small extent) and the top two members of the Conemaugh Group (the Casselman Formation and Glenshaw Formation), are mapped at the surface. This indicates that the total thickness of the USDWs is approximately 710 ft. With the thickness of the Riddlesburg Shale of 50 ft with its base at 1,822 fbg, this provides sufficient separation between any USDWs and the Murrysville Sand.

Given the distances and depths, and absent any mechanical integrity issues of the Sedat 3A, the private water supplies are unlikely to be affected by UIC activities at the Sedat 3A. However, because domestic use water wells and springs are within the quarter mile AOR, additional monitoring beyond the EPA permit is warranted. The proposed Sedat 1A is located approximately 1,010 ft to the southwest and was proposed as a monitoring well for the injection formation. This distance is closer to the injection well than any identified or suspected water supply well. Monitoring of water levels at this well would provide an early warning if fluid injected into the Murrysville Formation could migrate via unidentified abandoned wells or fractures into an area where it would pose a risk to USDWs. Suggested special permit conditions are included as Appendix B.

Mining

Mining, particularly of coal, is common in Allegheny County. Three abandoned underground mines are present within 1 mi of the Sedat 3A. The boundary of the Renton No. 5, targeting the Pittsburgh Coal Seam, is approximately 3,500 ft to the southwest of the Sedat 3A. The Springdale Mine, formerly operated by the Allegheny Pittsburgh Coal Company and targeting the Upper Freeport, is located approximately 1,500 ft to the northwest. The Sedat 3A was drilled through the former Renton Mine, operated by Villa Coal Company, also targeting the Upper Freeport Formation. All three mines have been sealed, and no active mining permits currently exist in the 1 mi area of review. All other coal seams are either absent or inferred.

Abandoned underground coal mines may provide pathways for groundwater flow, including from injection and disposal wells. However, the top of the injection zone is located at approximately 720 ft below mean sea level. The elevation of the mined-out area is at 560 ft above mean sea level, separating it from the injection zone by 1,280 ft, at least 50 ft of which is the Riddlesburg Shale confining layer. Absent mechanical integrity issues with the cementing and casing, fluid migration into the mined-out area is unlikely due to the distance of separation.

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Oil and Gas

In this geologic review, two major areas of concern are storage field locations and other oil and gas wells within the area of review. The Murrysville has been identified as a candidate for oil and gas storage, and operation of a disposal well in this formation could interfere with the operation of a storage field. Other oil and gas wells in the area of review could also interfere with the operation of the disposal well, possibly presenting a pathway for disposed fluids to return to the surface.

The nearest active gas storage field to the Sedat 3A is the Murrysville Storage field, approximately 4 mi south. The Murrysville Storage Field targets the Venango Group. The Venango group is below the Murrysville stratigraphically, and should not be affected by activities at the Sedat 3A. The nearest active storage field that targets the Murrysville formation is the Oakford Storage Field, approximately 11.5 miles to the southeast. The distance between the Sedat 3A and the Oakford Storage Field likely prohibits any interaction between the storage field and the disposal well.

DEP records identify sixteen oil & gas wells within a half mile of the Sedat #3A. One well is in DEP records as being Operator Reported Not Drilled (ORND), and one is recorded as Plugged. Of the remaining wells, four are located in the quarter mile AOR- the Sedat 1, the Sedat 5H, the Sedat 4A, and the Sedat 2A, all owned by Penneco. The Sedat 1 will be converted into the Sedat 1A monitoring point. The status, depth, depth of casing, and locations of all sixteen wells were all verified by a DEP Oil and Gas Inspector. The Inspector also found that the active wells had adequate mechanical integrity and were unlikely to provide a pathway for injected fluid to reach USDWs.

Penneco's application also correctly identified 66 oil & gas wells within a mile radius of the Sedat 3A. However, a number of wells from sources other than eFACTS are unaccounted for. Such wells can be located on EQT and People's Natural Gas Company historic farm maps, as well as on the mine maps from the former Renton Mine, and in the original Sedat 3A permit file. On May 31, 2018, Penneco submitted a summary of findings in response to the PADEP notice of deficiency dated April 17, 2018, stating that they had investigated the site with metal detecting equipment in search of these wells, and were unable to locate them.

Seismic events (prepared by Harry Wise, P.G.):

The Department's review indicates there are no historical seismic events within the quarter mile radius area of review. There are no historical earthquakes (since 1970) of magnitude two (2M) or greater within Allegheny County.

In EPA's Response to Comments for The Issuance of an Underground Injection Control (UIC) Permit for Penneco Environmental Solutions, LLC Question 10 notes "Injection wells may increase seismic activity which could cause fluid migration and USDW contamination and mine subsidence. One commentator specifically referenced the proximity of the injection well to the Blairsville-Broadtop (Mahoning River) Lineament" as problematic. In response to this statement, EPA discusses how induced seismic events associated with injection wells in Ohio were created by disposal in Precambrian basement rock. These rocks are often cross-cut by blind faults or are crystalline in nature. Additional studies by the State of Oklahoma (http://earthquakes.ok.gov/) and within the geologic community appear to corroborate the belief that injecting fluid into brittle, crystalline basement rock can induce seismicity. The EPA comment response document noted that the "Blairsville-Broadtop (Mahoning River) Lineament is part of this deep

Precambrian fault system approximately 7,000 feet below the Murrysville Sand injection zone and thus will not allow fluid movement into USDWs." The Department's review of the basement rock (depths of approximately 18,000 to 19,000 feet below land surface) confirmed a separation distance of thousands of feet, in this case of approximately 17,000 feet.

The Department also reviewed the maps from "Topographic and Geologic Atlas of Pennsylvania, No. 36, Freeport Quadrangle", 1933, prepared by H. Herbert Hughes, for the Commonwealth of Pennsylvania, Department of Internal Affairs and the Topographic and Geologic Survey. This review indicates the site is located on the northwestern side of the axis of the Duquesne-Fairmount Syncline. No other structural geologic features were noted around the proposed well with the closest structure being an inferred fault located approximately 4.8 miles to the southeast of the site. Based on this review, the Department concurs with EPA's statement in their comment response document that injection will not occur within, or should not flow into, the deeper Precambrian crystalline rocks.

Induced seismicity relating to the operation of injection wells results from the interrelationship of factors such as depth to basement rock, distance to existing faults, fault plane orientation and pore pressure regimes. This geologic analysis has not revealed indicators suggestive of a heightened potential for induced seismicity; however, there are some reported structural geologic anomalies that have been noted within the area surrounding the well. Based upon the review of all available information, it is my professional opinion that injection activities at this well pose a very low risk with regards to induced seismicity. It is recommended that to better understand the response of the Murrysville sandstone to injection fluids and to best manage any seismic risk, the application of the specific permit conditions addressing seismic monitoring and mitigation listed in Appendix A should be implemented.

Conclusions

The Sedat 3A is completed in the Murrysville Formation, which is approximately 17,000 ft above basement rock, and is not located within a mile of any known or inferred faults. Seismic risk of injection into the Murrysville Formation is therefore low. The Murrysville formation has an upper confining layer of Riddlesburg Shale approximately 50 ft thick, and is separated from known USDWs by approximately 1,800 ft. There are no known faults or lineaments within the quarter mile AOR. The risk of injected fluid migrating from the Murrysville through natural pathways is therefore low.

Sixteen oil & gas wells were identified within a half mile of the Sedat 3A. Of these, one was ORND, and another was in DEP records as Plugged. The remaining wells were found to have mechanical integrity. The risk of fluid migration through known oil and gas wells to USDWs is therefore low.

The deepest underground mining in the area is located approximately 1,280 ft above the injection zone, which includes 50 ft of the Riddlesburg Shale. The risk of fluid migration from the Murrysville Formation to USDWs mediated by underground mining is low.

Due to the low risk of fluid migration to USDWs and induced seismicity, operation of the Sedat 3A as a Class III disposal well is unlikely to be prejudicial to the public interest. However, to mitigate risks, I recommend the special conditions outlined in Appendix A and B to be included on the permit. I hold these opinions with a reasonable degree of scientific certainty.

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Appendix A. (Prepared by Harry Wise, P.G.)

Seismic Monitoring and Mitigation

The permittee shall prepare and implement a seismic Monitoring and Mitigation Plan. The seismic Monitoring and Mitigation Plan shall be submitted to the Department of Environmental Protection ("Department") at least 30 days prior to the anticipated start date of disposal activities in an existing well. This plan, or the plan as modified by the Department, shall be fully implemented at the time disposal activities begin and thereafter and shall include the following components:

(1) Installation of a seismometer that, at minimum, includes the following:
   a. One 3-component velocity sensor (X, Y, and Z axes), high-frequency seismometer **or** a local network consisting of a **minimum** of four high-frequency seismometers that have 3-component velocity sensors.
   b. For purposes of this seismic Monitoring and Mitigation Plan, a "seismic event" shall mean circumstances which reflect tectonic seismic activity above the thresholds and within the distances set forth in Paragraphs (11) or (12) below.
   c. For purposes of this seismic Monitoring and Mitigation Plan, an "Injection-Induced Seismic Event" shall mean circumstances which reflect seismic activity that may be directly attributable to the permitted injection activities. Raw seismic data gathered by the seismometer(s) described in (1) a. will be processed to calculate event location (epicenter/hypocenter) and magnitude. Events attributable to surface activities (such as, but not limited to, mining or blasting) or system noise will not be considered potential Injection-Induced Seismic Events.
   d. If the one sensor option is chosen, and an Injection-Induced Seismic Event occurs at or above the thresholds specified in (11) c and d below, the operator will mobilize a local network consisting of a minimum of four (4) high-frequency seismometers that have 3-component velocity sensors within 48 hours of the event.
   e. All seismometers shall be installed in accordance with the manufacturer's instructions prior to operation of the disposal well.

(2) A description of and specification sheet for the seismometer installed at the disposal well site.

(3) The installation of a recorder that, at a minimum, continuously records 100 samples per second using a data logger with 24-bit digitizer and Global Positioning System (GPS) timing, in accordance with the manufacturer's instructions prior to operation of the disposal well.

(4) A description of and specification sheet for the seismic recorder installed at the disposal well site.

(5) A description of the protocol for operating and completing calibration of the seismometer and seismic recorder installed at the disposal well site demonstrating that it conforms with the standards employed by the Pennsylvania State Seismic Network (PASEIS) and the manufacturer's instructions.

(6) A description of the routine maintenance and service checks that will be implemented to monitor the operability or running condition of the seismometer and seismic recorder installed at the disposal well site. The description should detail how the checks satisfy the manufacturer's instructions.

(7) Verification that tectonic seismic event data will be captured at the disposal well site electronically and in a manner that is suitable for tectonic seismic event recordation and analysis.

(8) Verification that seismic data will be provided to the Incorporated Research Institutions for Seismology (IRIS) Network in real time and that the continuous, real time data conforms to the data format required by IRIS for archiving under PASEIS' network code (PE) and open distribution. If data transmission is interrupted, notification will be provided to the Department verbally within 24 hours and in writing within seven (7) days.

(9) A description of measures that will be taken to install the seismometer in a manner that will minimize interference from background sources and allow for optimal Seismic Event identification and location (epicenter and hypocenter). This shall include a plan view map of proposed seismometer location(s).

(10) Contact information for the responsible person in charge of conducting seismic monitoring activities at the disposal well site.

(11) If the one sensor option is chosen, a tectonic seismic event contingency plan that includes monitoring, reporting and mitigation provisions consistent with the following:

a. Immediate electronic notification to the Department and the Department of Conservation and Natural Resources' Bureau of Topographic and Geologic Survey (BTGS) of detection of any measurable event, within six (6) miles measured radially from the disposal well.

b. Notification within 10 minutes via email to the Department and 1 hour via telephone to the Department's statewide toll-free number in the case of seismic activity referenced in a. above will include filtering/processing of raw seismic data to identify and remove non-tectonic events (e.g. mine blasts or system noise).

c. Should an Injection-Induced Seismic Event occur (i.e., not a surface-related event or system noise), the Operator will reduce the well's operating injection rates. Reduction of the disposal well's operating injection rates in use at the time of the Injection-Induced Seismic Event by 50% within 48 hours of the occurrence of 3 or more consecutive Injection-Induced Seismic Events greater than 1.0 and less than 2.0 on the Richter Scale over a seven (7) day period occurring within three (3) miles measured radially from the disposal well. The seven (7) day period is defined as starting with the occurrence of any Injection-Induced Seismic Event of magnitude 1.0 or greater. Reduced operating injection rates shall be maintained until the Department provides written notice addressing injection rates.

d. Termination of all injection activities within 48 hours of the occurrence of an Injection-Induced Seismic Event of magnitude 2.0 or greater within three (3) miles measured radially from the disposal well until receipt of a written notice from the Department addressing continued well usage and operating conditions.

The assessment of continued usage will include, but not limited to, the following criteria:

i. Magnitude and frequency of events detected;
ii. Operational history prior to the event and operating conditions at the time of the event (rates, volumes, pressures);
iii. Any mitigation/intervention attempts made prior to termination of activities;
iv. Ability of permittee to identify another potential source for the event based on data processing and analysis of conditions.

(12) If the network option is chosen, a tectonic seismic event contingency plan that includes monitoring, reporting and mitigation provisions consistent with the following:

a. Immediate electronic notification to the Department and the BTGS of detection of any measurable event, within three (3) miles measured radially from the disposal well.
b. Notification within 10 minutes via email to the Department and 1 hour via telephone to the Department's statewide toll-free number in the case of seismic activity referenced in a. above will include filtering/processing of raw seismic data to identify and remove non-tectonic events (e.g. mine blasts or system noise).
c. Should an Injection-Induced Seismic Event occur (i.e., not a surface-related event or system noise), the Operator will reduce the well's operating injection rates. Reduction of the disposal well's operating injection rates in use at the time of the Injection-Induced Seismic Event by 50% within 48 hours of the occurrence of 3 or more consecutive Injection-Induced Seismic Events greater than 1.0 and less than 2.0 on the Richter Scale over a seven (7) day period occurring within three (3) miles measured radially from the disposal well. The seven (7) day period is defined as starting with the occurrence of any Injection-Induced Seismic Event of magnitude 1.0 or greater. Reduced operating injection rates shall be maintained until the Department provides written notice addressing injection rates.
d. Termination of all injection activities within 48 hours of the occurrence of an Injection-Induced Seismic Event of magnitude 2.0 or greater within two (2) miles measured radially from the disposal well until receipt of a written notice from the Department addressing continued well usage and operating conditions. The assessment of continued usage will include, but not limited to, the following criteria:

i. Magnitude and frequency of events detected;
ii. Operational history prior to the event and operating conditions at the time of the event (rates, volumes, pressures);
iii. Any mitigation/intervention attempts made prior to termination of activities;
iv. Ability of permittee to identify another potential source for the event based on data processing and analysis of conditions.

(13) Provisions for submitting an updated seismic Monitoring and Mitigation Plan as needed or as may be required by the Department. Updates may be necessary in cases where the risk profile associated with injection activities changes. A signed and certified

statement by a qualified professional person responsible for preparing the seismic Monitoring Plan that the plan is true and accurate and includes the components outlined above. The certification shall provide: "I, (insert name), hereby certify, under penalty of law as provided in 18 Pa.C.S. § 4904 (relating to unsworn falsification to authorities) that I prepared the seismic Monitoring Plan for (insert facility name) and the information provided is true, accurate and complete to the best of my knowledge and belief."

(14) Upon commencement of disposal activities at the disposal well, the permittee shall record tectonic seismic event data electronically in an appropriate format for analysis (event location and magnitude) and maintain daily records of tectonic seismic event data electronically for review at the request of the Department. Tectonic seismic event records must be maintained for one (1) year.

(15) The permittee shall maintain all calibration, maintenance and repair records for the seismometer for at least five (5) years.

(16) The permittee shall maintain all calibration, maintenance and repair records for the seismic recorder for at least five (5) years.

(17) The operator may submit a summary report and plan for modification or discontinuation of the seismic Monitoring Plan two (2) years after injection activities commence. The Department's review will be completed as soon as practicable after receipt of the summary report and a written response will be provided to the operator. DEP's assessment of the report will be dependent on, but not limited to, the following criteria:

   a. Magnitude and frequency of any events during the monitoring period;
   b. Operational history during the monitoring period (rates, volumes, pressures);
   c. Planned operational conditions moving ahead (rates, volumes, pressures);
   d. Demonstration through pressure fall-off that system is at equilibrium and behaving in as a homogenous reservoir;
   e. Need for any mitigation/intervention during the monitoring period.

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Appendix B.

It is recommended that the permittee prepare and implement a monitoring plan for the Sedat #1 well as identified in the permit application. Monitoring of fluid levels at the monitoring point should occur at least monthly for the first year of operation, and then quarterly for the next two years. If at any point fluid levels at the monitoring point rise to within 100 feet of the deepest fresh groundwater, the permittee shall abide by conditions established in the EPA permit, and cease operations of the Sedat #3A.