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January 25, 2021

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By E-mail

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Re: Panoche Energy Center, LLC follow up December 18, 2020 meeting with EPA on UIC Permit No. R9UIC-CA1-FY17-2R

Dear Mr. Albright:

Panoche Energy Center, LLC, ("PEC") appreciated the opportunity to meet with the U.S. Environmental Protection Agency, Region 9 ("EPA") on December 18, 2020, to discuss our comments on the advance copy of the draft renewal Underground Injection Control permit: Class I Non-Hazardous Waste Injection Wells Permit No. R9UIC-CA1-FY17-2R ("Draft Permit"). As we discussed on the 18th, renewal of the Draft Permit is critical to PEC's ability to continue to operate its 400-megawatt power generation plant (the "Facility"), which is an essential part of California's energy infrastructure. We remain hopeful that PEC and EPA can reach agreement on the terms and conditions of the Draft Permit before it goes out for public comment. To that end, this letter responds to several topics we discussed on the 18th.

Regarding PEC's comments on the Draft Permit, Attachment A to this letter summarizes PEC's understanding of EPA's responses, as well as PEC's revised responses to the three questions EPA raised. Please let us know if you have further questions regarding our summary.

With regard to the overarching issue of corrective action, PEC very much appreciates and recognizes that EPA accounted for many of the matters raised and took notice of the details provided in our September 25, 2020 letter to you, and that EPA accordingly revised its scope of proposed corrective actions. We recognize that EPA has reduced the scope of corrective action to the following: "Install a monitoring well as described in the draft permit, near Silver Creek 18, to the USDW and conduct associated testing as described." However, PEC remains concerned that there is an inadequate basis for proposing such a monitoring requirement.

During our December 18th meeting, EPA noted that monitoring is required for two reasons: (a) because PEC has not provided any "empirical evidence" to conclude that there is no endangerment to the underground source of drinking water ("USDW") within the Area of Review ("AoR"); and (b) wells that lack cement plugs across the base of the USDW must be deemed "improperly plugged and abandoned." PEC respectfully disagrees with both assertions; and PEC hopes this letter provides additional empirical evidence to demonstrate to EPA that wells within the AoR were properly plugged and abandoned, and that empirical evidence exists to conclude there is no endangerment to the USDW. In addition, PEC is unable to understand what EPA seeks to accomplish with its revised corrective action proposal without additional details on how the condition will be implemented. Each of these topics is addressed below.

Empirical Basis for Non-Endangerment Finding

On January 17 and September 25, 2020,[1] PEC submitted to Region 9 a comprehensive review of its methodology and analysis to complete a corrective action evaluation. While PEC reviewed every artificial penetration within the AoR, per EPA direction, PEC focused its analysis on those specific wells within the AoR that do not have a cement plug at the base of the lowermost USDW.

To determine remaining wellbore conditions at the time of well plugging, the corrective action evaluation conservatively assumed a maximum initial reservoir fluid pressure gradient, a maximum modeled pressure buildup in the reservoir due to injection, and only relied on official well records and logs filed with and certified by California Geologic Energy Management Division ("CalGEM"). Because of the availability of certified well records for all of the wells, no assumptions had to be made to address inadequate well records. Applying this methodology and relying on empirical evidence available through CalGEM, PEC's analysis shows that ***all wells*** within the AoR have sufficient mud column weight to resist fluid entry without relying on mud gel strength. In fact, PEC's analysis shows that reservoir pressures would have to increase by 35% over their 2017 value to overcome the mud weight alone and by 125% to overcome the combination of gel strength and mud weight based on the 2017 reservoir buildup value.[2]

Furthermore, in its September 25, 2020 letter, PEC demonstrated through an empirical analysis that operation of its Enhanced Wastewater System ("EWS") reduced injection rates by up to 80 percent. As a result, Facility operations will not increase pressures within the injection zone as much as indicated in our January 17, 2020, analysis. The September 25th analysis shows that the minimum pressure level needed to cause the movement of fluids from the injection zone into

[1] Panoche Energy Center, January 17, 2020 (Attachment A, Response to USEPA Comment No. 1d from Letter Dated December 3, 2019); Panoche Energy Center, September 25, 2020.

[2] Panoche Energy Center, September 25, 2020, Panoche Energy Center, LLC comments on UIC Permit No. R9UIC-CA1-FY17-2R (Figure 3).

the USDW will not be reached at any of the wells located within the AoR, including those wells with no cement plug across the base of the USDW. To the contrary, the analysis shows that injection zone pressures will be significantly less than previously predicted because the EWS, both as currently configured and with respect to likely future optimization, will continue to reduce injection volumes and associated rates of reservoir pressure increase within the injection zone over time. Based on this new information, PEC re-evaluated each well within the AoR, including the Souza #2, Silver Creek #18, and England #1-31 wells, and determined that reduced injection volumes will add an even greater safety factor because mud weight alone will resist the upward movement of formation fluids in each well (i.e., mud gel strength resistance is not needed at any well, including Souza #2).

Finally, on December 14, 2020,[3] PEC submitted additional empirical analysis evaluating site specific mud column characteristics and conditions in the Cheney Ranch Field, which encompasses the AoR. This analysis, which is based on 80 years of empirical analysis,[4] shows that the Cheney Ranch wells do not constitute a possible conduit for movement of fluids into the USDW. Furthermore, the muds evaluated in the December 14 report are the same types of muds used in the plugged and abandoned wells within the AoR. The Cheney Field records confirm that all of the wells within the field (*i.e.*, within the AoR and in the larger field area) were drilled and plugged using clay-based muds and rotary-drilling methods. Therefore, these clay-based mud systems will act in a similar manner. In Attachment B, PEC provides additional analysis derived from empirical data for the three wells (Lockhart England #1-31, American Hunter Souza #1, and Bender Silver Creek #57X-18) document and detail that thick, heavy static mud conditions were encountered during well activities (drilling and/or plugging). These thick, heavy muds provide significant displacement resistance to inflow of formation fluids into the wellbores.

Improperly Plugged and Abandoned Wells

EPA regulations state that for any wells within the AoR that are "improperly sealed, completed, or abandoned, the applicant shall also submit a plan consisting of such steps or modifications as are necessary to prevent movement of fluid into underground sources of drinking water ("corrective action")."[5] The regulations also state that identifying such "improperly sealed, completed or abandoned" wells is a ***condition precedent*** to any required corrective action.[6] PEC is, in fact,

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[3] Mud Column Characteristics And Conditions In The Cheney Ranch Field, December 14, 2020.

[4] *Id*. at Appendix 4.

[5] 40 C.F.R. § 144.55(a).

[6] Environmental Appeals Board ("Board") decisions affirm this approach to evaluating wells within an AoR. For example, in the matter *In Re: Jordan Development Co., L.L.C.*, 2019 WL 3816212, at *25, the

monitoring pressures in the Injection Interval on an annual basis and these pressures are considered in its analysis of whether any wells in the AoR are "improperly sealed, completed, or abandoned."

By contrast, no EPA regulations require a cement plug to be present at the base of the USDW in every historic artificial penetration within an AoR; nor do EPA regulations require corrective action for every historic artificial penetration within an AoR that was not plugged with cement at the base of the USDW.

Rather, 40 C.F.R § 146.7 states that when "determining the adequacy of corrective action proposed by the applicant under 40 CFR 144.55 and in determining the additional steps needed to prevent fluid movement into underground sources of drinking water", EPA shall evaluate a range of the factors to determine if a well within the AoR may become a conduit for the movement of fluids from the injection zone and into the USDW. In particular, 40 C.F.R § 146.7 identifies the following relevant factors: the history of the injection well operations, completion and plugging records for artificial penetrations, and artificial penetration plugging and abandonment procedures in effect at the time the well was plugged and abandoned.

Here, PEC relied on existing well records, logs and schematics, which provide reported weight(s) of the drilling fluid left in the artificial penetrations and reported height(s) of the drilling fluid column remaining in each artificial penetration. PEC confirmed that all wells within the AoR filed plugging and abandonment records with CalGEM. These records show that each well within the AoR was plugged and abandoned as required by CalGEM, and concurrence letters were issued by CalGEM. Moreover, each of these wells currently meet plugging and abandonment requirements as specified in CalGEM 2020 regulations. Barring evidence that these CalGEM records are untrue, inaccurate or do not contain complete information, there is no basis to conclude that the wells evaluated in the AoR were improperly plugged and abandoned. Furthermore, EPA has not provided PEC any data or records to demonstrate that any of the wells within the AoR were improperly plugged and abandoned, and EPA's statements during our December 18th meeting of the "need for empirical data" does not justify including the monitoring well requirement in the Draft Permit.

Based on our discussion on December 18th, Region 9 appears to be defining any well that does not have a cement plug across the base of the USDW to be an "improperly sealed, completed or abandoned well". Region 9's approach means that any well without a cement plug across the base of the USDW, regardless of other factors, requires corrective action. This approach is not

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Board restated the regulation and clarified the condition precedent: "If any such existing well (whether producing, injecting, temporarily abandoned, or plugged and abandoned) could provide a conduit for fluid migration into USDWs because it is improperly constructed, sealed, or plugged, the applicant must develop a corrective action plan to address the deficiency. 40 C.F.R. §§ 144.55, 146.7."

in accordance with 40 C.F.R §§ 146.7 or 144.55 and renders all of the other factors listed to be evaluated superfluous.

With this letter, in conjunction with our September 25, 2020 letter, PEC provides Region 9 an empirical and evidentiary basis --relying on state certified records-- that each well within the AoR was plugged consistent with procedures in effect at the time the well was abandoned; and that all wells within the AoR are protective of the USDW.

EPA's Proposed Corrective Action

EPA proposes that PEC accept the following corrective action: "Install a monitoring well as described in the draft permit, near Silver Creek 18, to the USDW and conduct associated testing as described."

Before PEC can respond to or consider accepting this proposed condition, PEC requests additional information to understand how the condition would be implemented. For instance, it is unclear from EPA's proposal what the performance standards the monitoring protocol would evaluate. In addition, it is unclear how EPA would determine if PEC's injection activity would be the cause of a failure to achieve such performance standards. Attachment C articulates the questions PEC has about EPA's proposed corrective action condition.

Conclusion

PEC acknowledges and appreciates that EPA has reduced the scope of its proposed corrective action; however, the proposed monitoring condition is not insignificant. Indeed, PEC estimates that the proposed monitoring well would cost in the range of **$2 Million to $2.5 Million**, including 10 years of operational/monitoring costs. As discussed above, PEC requests additional information from EPA to properly evaluate and respond to the proposed condition.

However, as outlined above, even with additional information concerning the proposed monitoring condition, PEC disagrees that any corrective action is warranted or necessary. PEC has provided an empirically and technically sound basis for EPA to conclude that the wells within the AoR were plugged consistent with the procedures in place at the time those wells were abandoned, and that there is no endangerment to the USDW. By contrast, there is not sufficient evidence to support EPA's current position that historic wells within the AoR were improperly plugged and abandoned, or sufficient evidence to support a conclusion that PEC's injection activity would result in endangerment to the USDW. As such, PEC would like to better understand EPA's empirical evidence regarding the need for corrective action before it can reach agreement on the terms and conditions of the Draft Permit.

In lieu of installing a monitoring well that has uncertain benefits at best, PEC would prefer to invest in the optimization of its wastewater system. Since the EWS was installed in 2016, injection volumes have been reduced by up to 80 percent. This has directly resulted in a reduction of formation pressures within the injection interval. PEC believes that continued optimization of this system will result in far more certain protection to the USDW than a monitoring well.

PEC remains optimistic that this letter and related information will provide additional details helpful in EPA's analysis; and PEC remains committed to engagement with you on the issues presented here. To that end, we are available to discuss the information presented here and in prior communications with EPA at your convenience.

Sincerely,

Ankur K. Tohan

CC:

Michele Dermer (EPA Region 9)
Desean Garnett (EPA Region 9)
Robin Shropshire (Panoche Energy Center)
Daniel Collins (Geostock Sandia, LLC)
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Robert Hines (Farella Braun + Martel)

Attachment A

ITEM #	Part	Sub-Part	Para.	Sub-Par.	Permit Condition	Comment	Follow Up Comment / Resolution
2	I				**Authorizes injection into 4 existing wells; new wells not mentioned.**	**PEC requests that the Permit retain all six wells originally permitted. PEC would like to retain the option to construct two additional wells if necessary.**	**PEC agrees to limit the max number of operational wells to 4 Wells. PEC would like to maintain the flexibility to drill new wells, but with the condition that only 4 wells would be operational at a single time,**
3		A	2	a	**Work Plans (with specific procedures) submitted to EPA 60 days before "field demonstrations" - such as MIT and FoT test**	**PEC would like to reduce the time requirements to 30 days, as in the original permit, to assist in operational planning.**	**PEC proposes to clarify this by adding procedures for acid cleaning that have been previously approved to allow for expediant turnaroun for issues need that need faster response. PEC suggest adding an Appendix to Attachment J of the application that would clarify this condition.**
4		B	3	a	Other injection wells shall be inactive during the FoT.	PEC would like to retain the ability to have other wells operational during FOT as authorized in the existing Permit, and calculate results mathematically as previously accepted by EPA and contemplated as an option by Region IX guidance. Otherwise, given the facility's reliance on the wells operation for wastewater discharge and plant operation, scheduling FOTs may become much more difficult.	
5		C			**Corrective action is required in one existing well in the AOR (Souza #2), which penetrates the injection zone.**	**Please see PEC discussion contained in accompanying documents.**	**It is PEC's understanding that during the December 18 meeting,it was discussed that EPA is removing this corrective action requirement.**
6			1	a-e (Correc-tive Action)	Submit a plan to EPA within 60 days to re-enter, plug (with cement), and abandon the Souza #2 well.	Please see PEC discussion contained in accompanying documents.	
7					Formation pressures shall be measured.	Please see PEC discussion contained in accompanying documents.	
8					Geophysical logs shall be run and formation fluid samples obtained from selected intervals for analysis of specific conductance and determination of the base of the USDW in the Souza #2 well.	Please see PEC discussion contained in accompanying documents.	
9					Collect data on the mud level and density with depth.	Please see PEC discussion contained in accompanying documents.	
10					If log analyses are inconclusive for the depth of the USDW and formation pressure, run a wireline tool for fluid sampling and pressure testing.	Please see PEC discussion contained in accompanying documents.	
11					Review and modify the plugging program if necessary based on the data collected above.	Please see PEC discussion contained in accompanying documents.	
12					Install 2 monitoring wells to perform chemical analysis and measure specific conductance and formation pressure near two abandoned wells.	Please see PEC discussion contained in accompanying documents.	
13					One well within 100 feet to the SSW of the Silver Creek 18 well	Please see PEC discussion contained in accompanying documents.	
14					One well within 100 feet to the S of the England 1-31 well	Please see PEC discussion contained in accompanying documents.	
15					Submit detailed construction plans and procedures for well installations, describing the following requirements:	Please see PEC discussion contained in accompanying documents.	
16					Field coordinates for the wells	Please see PEC discussion contained in accompanying documents.	
17					Drill the wellbore to the Panoche formation injection zone	Please see PEC discussion contained in accompanying documents.	
18					Record static pressure of Panoche formation, obtain a fluid sample from injection zone, analyze for: TDS, alkalinity, anions/cations, hardness, pH, specific conductance, specific gravity, total sulfide, oil/grease, and total metals.	Please see PEC discussion contained in accompanying documents.	
19					Plug the borehole to the base of the USDW (located a the contact between the Keyenhagen Shale and the sandy interval in the overlying Tumey Formation.	Please see PEC discussion contained in accompanying documents.	
20					Equip the well with transducers (pressure and specific conductance) in the USDW, and with monitoring equipment to allow for sampling of the USDW.	Please see PEC discussion contained in accompanying documents.	
21					Performa a baseline chemical analysis of the USDW, for the same analytes shown above.	Please see PEC discussion contained in accompanying documents.	
22					Submit a well construction report to EPA within 60 days of well completion that includes logging and other results, a schematic diagram, and detailed description of construction. Include geophysical logs, drillers log, materials used, and volumes of cement and other materials.	Please see PEC discussion contained in accompanying documents.	
23					Submit a notice of completion of construction to EPA using the form in Appendix C within 60 days after well completion.	Please see PEC discussion contained in accompanying documents.	
24		D	1	a	**Perform an MIT on each well to demonstrate mechanical integrity within 90 days of permit date. References CFR 146.8 for mechanical integrity**	**PEC requests that this requirement be deleted as these are existing wells on an already established MIT schedule.**	**EPA agreed that if testing occurred prior to reissuance that those tests will be valid until the next testing cycle requires the testing to occur. Additional repeat testing immediately after new permit issuance would not be required.**
25					**Demonstrate that there are no significant leaks in the casing and tubing nor fluid movement into or between USDW through the annulus.**	**PEC requests that this requirement be deleted as these are existing wells on an already established MIT schedule.**	**PEC is already doing this with existing MIT testing schedule. Don't recall if this was discussed on the call.**
26				b	**Certify that the existing hazardous waste determination for each waste stream is unchanged within 60 days of the permit date. References 40 CFR 262.11**	**PEC requests that this provision be deleted as this is a renewal permit and PEC has already certified such waste streams.**	**For Clarification, if PEC introduces new waste streams, they will be characterized in advance of injection to demonstrate non hazaardous.**
27			2	a	**Submit an MIT Report to EPA within 60 days of test completion.**	**~~PEC requests that this timing requirement revert back to the requirement in the existing Permit, which allows the Report to be submitted with the next quarterly report.~~**	**PEC agrees to this condition**
28				b	**At least once every 5 years, a casing evaluation log shall be conducted in each well (copy provided to EPA within 60 days).**	**Depending on the methodology used, PEC is concerned that this test may require removal of the injection tubing and a casing scraper be run to achieve accurate results. PEC is unaware that this test has been required in any cases other than new construction or a workover. PEC believes that an APT (along with continuous pressure monitoring of the tubing and annulus during normal well operations) is the standard and best way to prove internal well integrity.**	**It is PEC's understanding that during the December 18 meeting it was discussed that EPA agreed to remove this condition. Consistant with 40 CR 146.68(d)(4), PEC will run casing inspection logs whenever a workover in which the injection string is pulled, unless the Director waives this requirement.**
29	II		5	a	Authorizes cooling tower blowdown water, reverse osmosis system reject water, evaporative cooler blowdown water, combustion turbine intercooler condensate, and oil/water separator discharge water.	~~PEC requests that EWS water be included in the approved list of injectate.~~	**For Clarification the EWS is not a new waste stream. EWS does not need to be added to the permit.**
30		E	1	a	**Anions by USEPA 300.0**	**Currently, most anions analyzed by 300.0 but Fluoride analyzed by SM 4500-F. Current permit specifies "appropriate USEPA methods for major anions and cations). PEC requests that language revert to existing permit or state: use methods in 40 CFR Part 136 or SW-186**	**It is PEC's understanding that during the December 18 meeting that it was discussed that EPA agreed to clarify this condition**
31					**Cations by USEPA 200.8**	**Currently, cations are analyzed by 200.8 (ICP-MS) or 200.7 (ICP-AES). PEC requests that language revert to existing Permit or state: use methods in 40 CFR Part 136 or SW-846, which is consistent with guidance.**	**It is PEC's understanding that during the December 18 meeting that it was discussed that EPA agreed to clarify this condition**
32					**Trace metals by USEPA 200.8**	**Currently, metals analyzed by 200.8 (ICP-MS) or 200.7 (ICP-AES) which is consistent with new permit requirement to use methods in 40 CFR Part 136 or SW-846. PEC requests that language revert to existing Permit or state: use methods in 40 CFR Part 136 or SW-846, which is consistent with guidance.**	**It is PEC's understanding that during the December 18 meeting that it was discussed that EPA agreed to clarify this condition**
33					**Temperature**	**PEC delivers samples to a certified laboratory an hour away. Temperature readings at that point are likely not representative of conditions in the formation. In addition, temperature is already continuously measured on site. PEC requests that the requirement to measure temperature of samples, which was not in the existing Permit, be deleted.**	**It is PEC's understanding that during the December 18 meeting that it was discussed that EPA agreed to clarify this condition**
34			**2**	**a-c**	**Conduct the following monitoring for the 2 monitoring wells installed in the lowest USDW:** **- Record pressure and specific conductance with transducers daily.** **- Collect samples from the wells and analyze for TDS, alkalinity, anions/cations, hardness, pH, specific gravity, total sulfide, oil and grease, and total metals.** **- Collect and analyze samples monthly for the first year, then quarterly thereafter.** **- Report the results to EPA monthly (by the 15th) for one year, then quarterly (with the standard quarterly report) thereafter. Details of the report are in II.E.6.**	**Please see PEC discussion contained in accompanying documents.**	**It is PEC's understanding that during the December 18 meeting that it was discussed that EPA is removing one of the monitoring well requirements. Please see the attached letter that discuses that PEC would propose that in lieu of drilling a monitoring well that PEC would work with EPA to continue to enhance wastewater efficiences with the onsite EWS.**
35			5	a	**Results of logging and chemical analysis of the injection zone and USDW performed in the Souza #2 well and the two new monitoring wells to be retained and be made available at the facility at all times for inspection.**	**Please see PEC discussion contained in accompanying documents.**	**It is PEC's understanding that during the December 18 meeting that it was discussed that EPA agreed to remove this condition.**
36			6	a-e	Conditions regarding the monitoring requirements to EPA: - Pressure and specific conductance monitoring results, and laboratory analytical results, for the 2 monitoring wells to be included in quarterly reports. - Results of formation pressure and specific conductance and the chemical analysis of the monitoring wells, means and standard deviations of the values in tabular form, and graphical representations of the data. Submitted monthly (by the 15th) for the first year, and quarterly (with the regular reports) thereafter. - At the end of each year, submit a report summarizing the pressure, specific conductance, and water quality data that includes: cumulative tabulation of measurements and analytical results since the start of monitoring, description of trends in measurement over time, and interpretation of data to demonstrate that there is no hydraulic communication between the injection zone and the USDW via abandoned wells in the AOR and that the USDWs are not endangered.	Please see PEC discussion contained in accompanying documents.	
37		G	1	a	This simply states the previously-approved financial assurances for the four existing wells. However, it appears to require financial assurances to be develop for the two new monitoring wells.	With respect to the two requested monitoring wells, please see PEC's comments in the accompanying documents.	
38				b	For each authorized well, review and update (if needed) the financial assurances mechanism annually. A description of the review to be included in the Q4 report due in January of each year. Changes to an alternate method of financial assurance can be made in writing to EPA for their review/approval.	With respect to the two requested monitoring wells, please see PEC's comments in the accompanying documents.	
39	III	E	14		All reports prepared under this permit shall be available for public inspection at appropriate offices of the EPA. Permit applications, permits, and well operational data shall not be considered confidential.	PEC requests that this requirement be modified to state, except as otherwise provided by law. For example, Permit Section III.D recognizes that some submittals may be confidential.	

ATTACHMENT B

EMPIRICAL MUD CHARACTERISTICS IN THE CHENEY RANCH FIELD

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1.0 EMPIRICAL MUD CHARACTERISTICS IN CHENEY RANCH FIELD

1.1 SUMMARY

Empirical evidence for the static condition of clay-based mud systems for wells (artificial penetrations) in the vicinity of the Panoche Energy Center (PEC) are contained within the California Geologic Energy Management Division (CalGEM) records. First, these records confirm that all of the wells in field were drilled and plugged using clay-based muds and rotary-drilling methods. Therefore, mud properties found in all of the field wells are expected to be very similar in nature as the wells only used variations of a clay-based (bentonite) mud system. No oil-based or emulsion muds that would potentially have properties fundamentally different from common clay-based mud systems have been used in the field. Second, three of the CalGEM well summaries (Lockhart England 1-31, American Hunter Souza 1, and Bender Silver Creek 57X-18) document and detail static mud conditions encountered during well activities (drilling and/or plugging). In each case, the static mud column in the wellbore was found to have set quickly (formation of gel), providing a significant displacement resistance to flow of fluids and were described as “heavy”, indicating that they maintained their drilling weight.

Encountered mud conditions in Cheney Ranch Field include:

- “stuck” a bailer in heavy mud, with the bailer having to be worked free (Lockhart England 1-31);
- drilling mud had to be reversed out with fresh water every 1,000 feet below a depth of 8,400 feet and every 6 joints below a depth of 9,000 feet with "thick drilling mud" being circulated from the well (American Hunter Souza 1); and
- the rig ran a work string in the well to 3,700 feet (the day after setting a cement kick-off plug) but could not break circulation in the mud at that depth (Bender Silver Creek 57X-18).

Each of these statements indicate the presence of thick, gelled clay-based drilling mud in the wellbore at the time of the documented activity. These field mud characteristics match anticipated behaviors for clay-based mud systems as contained in the drilling literature. These characteristics of static clay-based mud systems are also substantiated from data collected during other well re-entries, which have been documented in the literature.

Collectively, these empirical findings validate the PEC screening methodology preformed for wells in the Area of Review. That the recovered muds in the Cheney Ranch Field have demonstrated both weight (density) and gel characteristics, the screening calculations employed by PEC for displacement pressures within wells in the Area of Review, which considers both of these components, are correct. As PEC has applied conservative assumptions in these screening calculations, they represent minimum thresholds below which fluid movement within a wellbore cannot occur. Actual pressures required prior to displacement of these muds is substantially higher, providing a margin of safety in the evaluations. Therefore, all wells are safe as currently abandoned and no corrective action is warranted.

1.2 INTRODUCTION

Common drilling mud is largely composed of clays and water, forming a colloidal base. These muds are known colloquially as “clay-based” mud systems. The clay is used to obtain and increase viscosity in the slurry and also to promote the formation of wall cake (the low-permeability layer of clay lining the borehole wall between the mud column and the formation). Typically, a clay based mud system is composed of bentonite (sodium montmorillonite). Bentonite is hydrophilic (readily absorbs water), and its flat, platy shape is the primary reason it is desired for use in clay-based drilling fluids. The platy nature of the bentonite particles results in the development of gel strength in a static, quiescent mud column due to the tendency of the individual clay platelets to align in a configuration where positively charged edges are located adjacent to negatively charged surfaces. This process results in a medium with thixotropic properties. Thixotropy is the characteristic whereby certain gels evolve in liquids to a semi-solid state when allowed to stand undisturbed but liquefy upon shock disturbance. The gel phase is desirable in drilling muds because it assists in suspending cuttings released by the drilling procedure, producing the required viscosity and mud cake properties in the circulating mud system.

The physical characteristics that make clay-based drilling mud useful during active drilling operations also make it an effective barrier to vertical fluid movement within abandoned boreholes. In thixotropic behavior, under static conditions the clay platelets aggregate (flocculate) in three ways: 1) face-to-face, 2) edge-to-edge, or 3) edge-to-face, because the platelets are electrically charged. This thixotropic or gelling property of a clay-based bentonite slurry is what gives drilling mud its gel strength. In clay-based mud systems, gel structures build with time (progressive gel) as the positive edge of one particle or plate moves toward the negative surface of another; that is, when the platelets are layered (Gray et al., 1980). Therefore, the development of gel strength in clay, water-based drilling fluids is a natural phenomenon that can be explained using the basic chemical and physical laws of nature. Laboratory studies have shown that although the exact relationship between gel strength and time varies, depending on specific mud composition and additives, the gel strength always increases with time (Garrison, 1939; Srini-Vasan, 1957; Davis and Pearce, 1989). Additionally, this orientation of the clay plates reduces the vertical permeability of the mud column significantly because tortuosity through the mud is increased. Hydrated pellets of bentonite have been advocated for sound, secure plugging of

underground injection wells that will not allow for interformational fluid flow.[1] Static columns of clay-based drilling mud are essentially hydrated bentonite fluids.

[1] Notes from the Underground, Fall 2002, EPA 909-N-02-003, U.S. Environmental Protection Agency (EPA) Pacific Southwest/Region 9.

1.3 CLAY-BASED MUD CHARACTERISTICS – EMPIRICAL DATA

1.3.1 Encountered Drilling Mud Characteristics – Cheney Ranch Field

Well records on file at the California Geologic Energy Management Division's (CalGEM) online mapping application (https://maps.conservation.ca.gov/doggr/wellfinder/#openModal) were obtained for all wells located within the Cheney Ranch Field. Well-specific chronologies in the records were reviewed for documentation of encountered mud conditions, either during well construction or plugging activities within the field. Documentation of mud conditions for three wells were identified during records review. The following information was found for these three installed and abandoned wells:

- **Lockhart England 1-31** – This well was spudded in December 1950 and drilled to a total depth of 10,357 feet in March 1951, with oil and gas shows observed below a depth of 10,000 feet. A production casing string (5-1/2 inch) was set to 10,038 feet and cemented with 300 sacks of cement. The oil and gas show interval from 10,038 feet and 10,169 feet (plugged back total well depth) were tested by displacing the drilling mud with fresh water and then swabbing the well. Results were inconclusive and operations on the well were suspended by setting a cement plug in the 5-1/2 inch protection casing from 9,880 to 10,169 feet and filling the wellbore with “heavy drilling mud”. The top of the 5-1/2-inch production casing was also plugged with 10 feet of cement and was capped with a welded steel plate. The details are documented as reported on Notice of Intention to Abandon Well - Form 108 (dated August 9, 1952). The abandonment was approved by the Division of Oil and Gas on October 27, 1952.

  A Supplementary Notice – Form 123 was filed on August 28, 1964, with the intent of salvaging as much of the 5-1/2-inch production casing as possible from the well. The Division of Oil and Gas approved the plan on the Report of Proposed Operations – Form 111, also dated August 28, 1964. A hand-written note dated 9/21/64 on this Report of Proposed Operations, indicates that very heavy mud was encountered during a bailer run at a depth of 1,045 feet, with the bailer becoming “stuck” in the heavy mud. The bailer was worked free and recovery of casing and final well plugging operations were subsequently conducted. The Special Report on Operations Witnessed – Form 109-D (prepared by Division of Oil and Gas Inspector F. L. Hill and dated September 25, 1964) indicates that the well was cleaned out to a depth of 1,045 feet where very heavy mud was encountered. Six sacks of cement were dumped at that point and additional plugs were placed at 987 to 1,045 feet (6 sacks), 744 to 794 feet (26 sacks), 552 to 629 feet (33

sacks), and 5 to 15 feet (14 sacks), with 5-1/2-inch production casing recovered from a depth of 792 feet in the well.

Work on the well had originally been suspended on March 19, 1952, so the encountered mud during final abandonment had been in place for approximately 12 years. The gel strength of this 12-year-old column of mud was such that a bailer on wireline could not be advanced deeper that a depth of 1,045 feet, let alone to the shallowest cement plug depth of 9,880 feet in the casing string.

- **American Hunter Souza 1**– The well was drilled to a total depth of 7,332 feet in November/ December 1983, using Benex mud (BENEX is an organic polymer designed for use as a bentonite extender and selective flocculant in clay-based freshwater drilling muds) with a final density of 11.2 pounds/gallon and a funnel viscosity of 37 seconds. Production casing (5-1/2 inch) was run to a depth of 10,213 feet and cemented with 2,287 cubic feet of cement. The drilling rig was released in mid-December 1983.

  A completion rig was set up at the end of March 1984, three and one-half months following completion of drilling activity. The well history attached to the Well Summary Report notes that the drilling mud had to be reversed out w/fresh water every 1,000 feet below a depth of 8,400 feet and then every 6 joints below a depth of 9,000 feet with "thick drilling mud" being circulated from the well.

- **Bender Silver Creek 57X-18** – The well was initially drilled to a total depth of 7,500 feet in May 2, 1973, using Lignosulfonate clay-based mud with a weight of 74 pounds per cubic foot and a funnel viscosity 51 seconds. Following evaluation of the original borehole, the operator made a request on May 3, 1973, to sidetrack the well from a depth of 4,100 feet and redrill the open hole to approximately 7,300 feet. This request was approved by the by Division of Oil and Gas on May 4, 1973 (Report on Proposed Operations (Form 111)).

  The well was sidetracked with a kickoff plug set at 4,300 feet with 100 sacks of cement. After setting the cement kickoff plug, the rig ran in the well to 3,700 feet but could not break circulation of the static mud column at that depth (History of Oil or Gas Well – Form 103, Page 2) due to the combination of the weight of the mud and the additive pressure due to the gel strength of the mud (*i.e.*, unable to displace the mud from that depth with the rig pumps). This demonstrates that the mud “set” quickly as the kickoff plug had only been set the previous day. The drill pipe was moved up to the shallower depth of 3,560 feet, where pump pressures were sufficient to break the mud column and establish

circulation. The drill string was then staged in hole to the top of the kickoff plug while conditioning and increasing the mud to a higher weight.

These area-specific well records of encountered mud conditions confirm the longevity and efficacy of static mud columns within wells in and near the Area of Review for PEC. The CalGEM records document that encountered static mud columns are stiff and thick, having set up such that they are difficult to circulate and handle. These static clay-based muds provide significant resistance to inter-formational fluid flow through an abandoned well.

1.3.2 Experimental Laboratory Data

The relationship between gel strength and time varies with the mud type, depending on such variables as composition, additives, pH, temperature, pressure, solids, and degree of flocculation. Results of laboratory testing of the properties and characteristics of clay-based muds is documented in the literature. These sources, collectively, provide empirical laboratory results of mud properties with time. Davis (1986) and Pearce (1989) provide expanded discussion of these laboratory evaluations.

Garrison (1939) showed that the gel strength of a bentonite (montmorillonite) clay-water system is empirically correlated with time. In each case, the gel strength was found to increase over the laboratory test period. Weintritt and Hughes (1965) measured the gel strength of three field muds as a function of time. Their data was found to only follow Garrison's model at early times, finding that at longer times the gel strength continued to increase at a rate in excess of what Garrison's original model would have predicted. The Weintritt and Hughes (1965) data more closely follow a linear relationship with time after the first two hours. Srini-Vasan (1957) investigated the affect of temperature (up to 220 ^{o}F) on water-based muds with drilling weights like those used in the wells in Cheney Ranch Field. More recently, Annis (1967) showed that the gelling process depends on both time and temperature, with 18 parts per billion (ppb) bentonite solution at any temperature having a gel strength six times that of the initial gel strength of the mud. Vryzas et al. (2016) found that the gel-like structure of water/bentonite suspensions proved to be rheologically stable after an aging period of 30 and 60 days.

As shown in Davis and Pearce (1989), Chevron conducted laboratory experiments to determine the expected condition of mud left in wellbores after plugging. Chevron formulated muds like those used in its Mississippi operations and “aged” the mud samples at temperature and pressure for a two-week period. The testing showed that the muds developed significant compressive

strength and was described as a “plug”, with a gel strength too high to measure with standard laboratory equipment (Davis and Pearce, 1989).

The experimental data all support the formation of gel in clay-based mud systems and the progressive increase in the strength of the gel with time. The importance of these experimental data is not necessarily the exact values of the gel strength of the muds, but that in all cases the gel strength increased with time. Gel strength naturally increases with time, far exceeds the gel strength required to maintain the original fluid density, and will reach an ultimate strength approaching or in excess of 100 pounds/100 square feet (lbs./100 sq.-ft) in a matter of days. Therefore, inclusion of the gel strength component in PEC’s screening calculation is appropriate and use of a lower range gel strength of 20 lbs./100 sq.-ft will underestimate true threshold values.

1.3.3 Data from Other Re-entered Wells

Direct properties and characteristics of the longevity of clay-based mud as a plugging material was demonstrated during a well reentry of the Nora Schulze No. 2, located in Nueces County, Texas (late 1980’s). The well had been originally drilled with 10.6 to 11.0 lb./gal mud when abandoned in 1959 (Pearce, 1989). Mud samples were taken upon reentry to a depth of approximately 754 feet using tubing pushed into the mud column from a depth of 120 feet (base of top cement plug). Below a depth of 754 feet, the mud could only be displaced from the well by breaking circulation, so sampling was discontinued at that point (Pearce, 1989). The average mud weight of the recovered samples was 11.1 lb./gal, showing that the mud density did not appreciably change over the intervening 29 years following abandonment of the well. The gel strengths of the mud samples ranged between 217 lb./100 sq.-ft to greater than 320 lb./100 sq.-ft. These values are over an order of magnitude greater than the 20 lb./100 sq.-ft value required in California plugging rules and exceed the values used in the screening calculations by PEC. In addition, shear strengths of the mud samples ranged from 170 lb./100 sq.-ft to 7,000 lb./100 sq.-ft, increasing with depth (Pearce, 1989).

Additional information on mud characteristics from well reentries are:

- Subsurface, Inc. (1976) reentered and replugged the Brewster Bartle Drilling Company (British American Oil Production Company), University of Texas No. 1B well located in Galveston County, Texas, during 1976, at the request of Amoco and Monsanto. Cement plugs were placed from 11,000 to 11,200 feet, and from 130 to 180 feet, and near the surface (top cement plug) with mud-laden fluid filling the remainder of the wellbore (conforming to Texas Railroad Commission plugging and abandonment requirements of

1961). During the re-entry operation, drilling mud was found immediately below the surface cement plug with its properties relatively intact. The mud had to be circulated out using 12-lb/gal mud.

- AIC (1988), in a study of well reentries originally plugged 20 to 30 years prior, found that in the Texas Gulf Coast, most operators reported that the mud was generally “hard”, with the following comments reflecting the condition of the drilling mud and/or borehole fluids encountered in the Gulf Coast:

    - mud set up like cement;
    - mud set up firm after about five years; and
    - mud encountered is hard and firm

1.4 EFFECT OF PEC'S ENHANCED WASTEWATER SYSTEM ("EWS") ON PRESSURES IN THE PANOCHE FORMATION

Whenever wastewater is injected into a subsurface geologic formation, the pressure within the reservoir increases. This pressure increase is highest at the wells (point of injection) and decreases with lateral distance away from the wells as a logarithmic function. Since commissioning and start-up of the Enhanced Wastewater System ("EWS") in 2016, injection volumes have dropped by up to 80 percent over previously injected volumes. When the injection volume decreases, the pressure in the formation will also diminish and will approach a new, lower level. Based on PEC's September 2020 Analysis, injection formation pressures will be significantly less than previously observed in 2016 and as predicted in PEC's year-end 2018 model (January 2020 Analysis). Because the EWS will continue to reduce injection volumes and associated reservoir pressure within the injection zone over time, overall pressure increases due to injection will be lower than previously modeled. Based on this new information, PEC re-evaluated each well within the previously defined 2.6-mile Area of Review and determined that reduced injection volumes will add an even greater safety factor. In fact, mud weight alone will resist the upward movement of formation fluids in each well. The overall impact of EWS-reduced injection volumes and rates on the Area of Review shows that further reductions in reservoir pressure increases are expected to result in a significant, inward contraction of the Area of Review with time (see September 2020 Analyses).

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ATTACHMENT C

EPA PROPOSED CORRECTIVE ACTION MONITORING CONDITIONS

1.1 INTRODUCTION

The proposed draft permit corrective action requires the installation of a deep monitoring well within 100 feet of the Silver Creek 18 Well to perform chemical analysis and measure specific conductance and formation pressure in order to identify potential changes in the USDW. Monitoring includes equipping the well with transducers to monitor pressure and specific conductance within the USDW on a minimum daily basis. Water quality monitoring equipment to allow sampling of the USDW must also be installed in the well. Baseline chemical analysis of the USDW fluids consists of TDS, alkalinity, anions and cations, hardness, pH, specific gravity, total sulfide, oil and grease, and total metals using the analytical methods outlined in Section E.1. of the draft permit. These chemical analyses must be performed monthly for the first year of monitoring, and quarterly thereafter.

PEC's wastewater does not contain unique indicator parameters. Modeling included in the renewal application shows that the injected plumes will be contained within close proximity to the PEC injection wells and will be no closer to the monitoring location than a mile or more. Additionally, there are other changes that are currently occurring, such as the withdrawal of groundwater, that will be perturbing the aquifer system. For these reasons PEC has several questions concerning this proposed corrective action.

1.2 CLARIFICATIONS/QUESTIONS ON DRAFT MONITORING PROGRAM

PEC is requesting clarifications on several of the monitoring requirements, if imposed by the final well permit(s).

- How will the pressure monitoring data and the constituent monitoring data from the monitor well be used to identify an issue from PEC injection?

- How will EPA identify and account for possible contamination from other sources not associated with PEC's injection activity?

- How will the pressure dissipation due to reduced injection volumes from the PEC Injection

Zone affect pressure monitoring and constituent monitoring results from the monitor well?

- How will EPA account for impacts of area water wells/irrigation wells on monitoring well results?

    - Example: State Well Number 15S13E06J001M is an irrigation well located within 0.25 mile of the PEC facility wells.

    - How will large-volume withdrawals of groundwater in the Fresno Irrigation District affect pressure monitoring and constituent monitoring?