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TECHNICAL MEMORANDUM

TO: MARAGARET ASH AND PETER GINTAUTAS (COGCC)

FROM: NORWEST APPLIED HYDROLOGY

SUBJECT: RESPONSE TO TECHNICAL REVIEW OF NORWEST APPLIED HYDROLOGY REPORT ON MONITOR WELL POCI 55 (PETROGLYPH ENERGY, INC.)

DATE: JUNE 12, 2008

CC: PETROGLYPH ENERGY, INC.

This document was prepared in response to the technical memorandum from Susan Wyman of Whetstone Associates dated May 23, 2008 addressing concerns and comments on the report "Monitor Well POCI 55 Drilling, Logging, Completion, And Testing Summary Report" (Norwest, 2008). The intended purpose of the POCI 55 well was to identify the presence of gas within the Poison Canyon formation and to begin characterization of the area impacted by fugitive methane for mitigation. The POCI 55 well is the first of several wells that will be tested during this mitigation program and serves as a starting point for data collection. The overall intent of the well was achieved in that the primary zone of fugitive gas was identified and continuing monitoring is being carried out as the mitigation system is being developed and the injection and recovery wells are drilled and tested. To date all injection and recovery wells have been drilled and confirm the findings from the POCI 55 monitor well. The comments provided in the technical memorandum are repeated below and addressed following the comment or group of comments.

COMMENT
Overall Completeness

The report is substantially complete, and provides source data (drillers logs, geophysical logs, gas charts, and laboratory analytical data sheets) that were used in selecting well completion intervals and interpreting test results. However, some of the field data collected by Norwest is omitted. Field measurements during well development were not presented, and neither paper nor digital records of packer pumping test data were provided.

RESPONSE

The field measurements during well development are provided below in response to comments on **Section 4.3 Well Development**. The packer pumping test data will be provided to the COGCC in digital format along with this response.

COMMENT
Section 3.9 Geophysical Logs Evaluation

The report provides all logs and provides good justification for the selection of aquifer completion intervals, based on gamma ray (GR), deep induction resistivity (DIR), short normal (SN), neutron porosity (NPOR,) and density porosity (DPOR) logs.

Section 4.1 Casing Placement

The screen and blank casing were successfully placed at the target locations, identified based on geophysical logging.

The report does not discuss the number, size, and location of centralizers on the well casing, although the driller’s log (page 10) indicates that centralizers were used.

RESPONSE

The use of centralizers is important in order to assure spacing between the casing and the open borehole wall such that sand and grout can be placed properly. Centralizers were placed at the following depths:

Depth Below Surface (ft)
147
216
325
428
527
611
744
896
1074

COMMENT
Section 4.2 Annular Completion

A. Grout Level in Bottom Interval
The first batch of cement grout placed at the bottom of the hole did not account for slough in the hole. This error resulted in cementing up approximately 9 feet of well screen in the lower interval.

B. Bentonite Placement
Although the contractor used several good methods for placing annular materials (such as tremiing materials into the annular space and tagging materials with the tremie pipe), these practices were not always followed. The coated bentonite pellets used to form plugs between the sand and cement were poured from the surface rather than placed by tremie pipe, as stated by Norwest:

“When applying Bentonite between sand and grout approximately nine feet of bentonite was placed by pouring from ground surface down the annular space.” (Norwest, 2008, pg 4-3)

The driller’s log concurs; for example, the log indicates ‘Pour 7 ea 50# buckets 3/8 bentonite tablets down annulus’ (Layne, drilling log, page 11).

Bentonite plugs were intended to be placed from 981- 990 ft below ground surface (bgs), 871-880 ft bgs, and 411- 420 ft bgs. Pouring bentonite pellets down the annulus to a depth of 990 feet is poor practice and violates Colorado well construction rules. Rule 10.5.3.4 states that:

Bentonite grout may be used in required grout intervals only pursuant to a variance from the Board and if its use is consistent with the requirements of this Rule and Table 3. Bentonite shall not be used to seal the outermost casing of a well within 40 feet below ground surface. Bentonite shall not be poured from the surface, but shall be placed directly into the appropriate interval. (2 CCR 402-2, Section 10.5.3.4, emphasis added).

RESPONSE

Rule 10.5.3.4 applies to the isolation of separate aquifers to prevent co-mingling. However, in this case this concept does not apply as the isolation was of sands within the same aquifer system and specific separate aquifers within the Poison Canyon are not defined. The use of bentonite was to provide a seal and a transition between the sand and the grout. The bentonite was not placed using the tremie pipe due to the potential for the tremie pipe to become plugged with the bentonite as it swells. The bentonite and grout were placed such that a seal was created between upper and lower sands within the annular space coinciding with natural shale and or clay seals as identified in well logs within the Poison Canyon. The sands identified for isolation were within the same Poison Canyon aquifer and were chosen for closer observation and testing and not chosen on the basis of being separate aquifers.

COMMENT

C. Filter Pack Size and Settlement

The silica sand filter pack is a suitable inert material, and meets the standards for environmental monitoring well construction. However, no justification was provided for the selection of filter pack grain size. The Raton Formation is logged as a fine-grained to very fine-grained sandstone with calcareous cement, noted as friable in some intervals (Norwest, 2008, Appendix B). No discussion of formation grain size or cementation was provided in the text. The 6-9 sand may not be sized to formation, and could be too coarse.

Coarser filter pack materials tend to have more settlement than finer materials. In most intervals, the filter pack was extended 9 – 18 feet above the top of the screen. In the uppermost interval, the filter pack was extended approximately 110 feet above the top of the screen. Given the long intervals of filter pack sand (51 ft, 101 ft, 119 ft, and 208 ft, the settlement could be excessive, possibly lowering the sand below the top of the screen. To prevent excessive settlement from such long screened intervals, the filter pack for the lower intervals should have been surged during placement, or extended farther above the screen, or placed in shorter intervals.

D. Likely Cement Encroachment into Filter Pack

At 640 feet, cement was placed directly on 6-9 sand, with no bentonite seal or transition sand. (A transition sand is a fine-grained or very fine-grained sand that impedes the movement of grout into the underlying coarser filter pack sand.) Without these materials in place, the cement may migrate into the filter pack, clogging the filter pack and affecting the chemistry of the monitored groundwater. According to Nielsen (1991):

“Neat cement, because of it’s chemical nature…is a highly alkaline substance (pH from 10 to 12), and thus introduces the potential for altering the pH of water which it contacts. The alteration of pH, in turn, can affect other chemical constituents in the water. In addition, because the emplaced mixture is a slurry…it may tend to infiltrate into the coarse materials that comprise the primary filter pack around the monitoring well screen if it is placed directly on top of the primary filter pack.” (Nielsen, 1991, pg 319)

Although the cement was ordered at the correct mix ratio (6 gallons per sack) according to the drillers log, an undiluted cement could have still penetrated into the sand pack. Any dilution from water added before pumping the cement down the tremie pipe, or any fall through groundwater from the bottom of the tremie pipe to the placed location, could contribute to an even less viscous cement that could further penetrate a coarse (6-9) sand.

RESPONSE

As a note, the above comment "C. Filter Pack Size and Settlement" refers to the Raton Formation. All drilling associated with the POCI 55 monitor well was within the Poison Canyon Formation having a very different geologic setting than that of the Raton Formation.

The sand chosen for completion is suited to the well screen and the usage of the well as a monitoring point for water pressure and gas flows. This well was completed with much more rigorous methods than the majority of water wells in the area as indicated by SEO records where many of the water wells do not have any type of seal, filter pack, or surface grout.

The sand was tagged each time with tremie pipe after placement and allowing it to settle for approximately fifteen minutes. This provided some insight into the level to which the sand was placed before placing bentonite and grout.

COMMENT
Section 4.3 Well Development

The well was developed by airlifting (15 minutes on, 5 minutes off) for a total of 10 hours, with a reported flow rate of 35 – 40 gpm. At 40 gpm for 450 minutes out of 10 hours, a total of 18,000 gallons would have been removed. At the end of 7 hours of airlifting (approximately 12,600 gallons), the water remained "very murky" with high pH values (9.7 s.u.).

A. Limited Reporting
Norwest does not provide tables of field measurements or observations during development. Changes in electrical conductivity and pH during development could provide insight as to whether the well was cleaning up, whether breakthrough of a cement of bentonite plug occurred, or whether the observed turbidity was derived from the formation, bentonite, or cement grout. The color of the the "very murky" airlift discharge is not reported. Grain size or Imhoff cone sediment volumes are not provided.

B. Inadequate Development or Incorrect Completion Indicated by High Turbidity and pH
The high turbidity and pH could indicate that either (1) the well was inadequately developed, (2) the well was incorrectly sealed, or (3) the filter pack grain size was too coarse.

The duration of well development (10 hours, ¾ time, at 35 – 45 gpm) should have been adequate to remove drilling fluids from within the screened intervals. The annular volume of an 11-inch hole with 6-inch OD casing is 37.6 gallons per foot, or 9.4 gallons per foot assuming 25% porosity. Given the 479 linear feet of sand pack, airlifting 18,000 gallons removed approximately 43 times the filter pack purge volume of 415 gallons. Although the number of purge volumes required to adequately develop a well varies based on annular thickness, drilling fluid, casing slot size, and other factors, 6 to 20 volumes are typically adequate to properly develop a well. The excessive purge volumes required for POCI55 may indicated that the well was improperly completed and, if so, it is possible that the well may never be adequately developed.

Improper completion could be attributed to either cement grout penetrating the filter pack or an excessively long filter pack that is not in contact with the well screen. It can be very difficult to develop “dead” filter pack that is tens or hundreds of feet from the screen and filled with drilling mud. Inadequate information is provided in the report to determine whether the turbidity and high pH result from cement (pH 10 -12) or drilling mud (typically pH 8.5 – 9.5).

RESPONSE

The parameters collected during development are provided in a table below. Only two data points were collected. Visual inspection showed continued grey and turbid water. The equipment provided by Layne Christensen was inadequate for proper measurement of flow rates during the development. Water was discharged to a pit using a diverter pipe where a 5 gallon bucket and a timer were used to estimate flow rates. The flow rates measured were on the order of 35 gallons per minute. The actual flow rate is estimated at approximately 10 gallons per minute higher (45gpm) due to losses around the wellhead. The wellhead leaked and a portion of the water flowing from the well was captured around the wellhead and diverted to the pit in a small trench. The pH did drop from the initial value of 12.4 to 9.8 and specific conductivity dropped. However, turbidity was out of range during the higher flow rates of development.

Date	Time	Air Lift	Flow Rate (gpm)*	Total Flow (gal)*	Temp (°C)	Turbidity (NTU)	pH	SpC (mS/cm)	Comments
2/14/08	16:57	on	4						pipe at 1,030' bgs. brown with sediment.
2/14/08	17:00	off		12					
2/14/08	17:07	on	8						brown with sediment. clearing up some.
2/14/08	17:15	on			17.6	65.5	12.4	6.53	collect WQ parameters
2/14/08	17:20	off		116					lower pipe 90'
2/14/08	17:30	on	10						water clearing up some
2/14/08	17:35	off		166					
2/14/08	17:40	on	10						
2/14/08	18:00	off		366					raise pipe to 810' bgs
2/14/08	19:15	on	20						
2/14/08	19:25	off		566					raise pipe to 630' bgs
2/14/08	20:00	on	5						4.5" drill pipe too large diameter for 5.5" casing.
2/14/08	20:05	off		591					
2/15/08	2:00	on	35						switch to 2.875" tremie pipe for air lift at 1,030' bgs.
2/15/08	2:05	off		766					murky water.
2/15/08	2:10	on	35						
2/15/08	2:28	off		1,396					
2/15/08	2:40	on	35						grey and very trubid water.
2/15/08	2:55	off		1,921					grey and very trubid water.
2/15/08	3:10	on	35						grey and very trubid water.
2/15/08	3:30	off		2,621					
2/15/08	4:00								have rig crew continue surging for 15 minutes on and 5 minutes off.
2/15/08	7:00			7,346					
2/15/08	7:30	on	35		17.2	Out of range	9.8	0.868	collect WQ parameters after 15 minutes of flow.
2/15/08	7:30	off		7,871					have rig crew continue surging for 15 minutes on and 5 minutes off.
2/15/08	9:00			9,446					leave site with Petroglyph and have crew continue air lifting
2/15/08	12:00			14,171					stopped developing well according to the driller's records

* Flow rates were measured using a 5 gallon bucket and timer. Measured flow was less than true flow due to improper equipment and loss of water at wellhead Total flows are estimates.

COMMENT
Section 4.4 Total Depth Drill Out

The lower 37 feet of the well (including approximately 9 feet of screen) was mistakenly cemented. The text in section 4.4 states that the cement plug started at 1,035 feet, while Table 4.2.1 indicates that the cement in the annulus starts at 1041 feet. There is a 6-foot discrepancy between these two values.

The cement plug inside the casing was drilled out after 7 hours of well development. However, drilling the plug did not remove cement from the filter pack. Since the filter pack is likely plugged with cement, hydraulic calculations should not include the length of the drilled out section of screen.

RESPONSE

Type G cement was purposefully placed to seal the bottom below the bottom of the sands identified at 1,044 bgs. Thus, 37 feet was not mistakenly grouted. Rather the placement of grout was over shot by 10 feet that ended up within the slotted interval due to slough within the borehole. The discrepancy in the annular grout level and the level of grout within the well can be explained by the grout moving into the formation lowering its height within the annular space while the grout within the casing did not have anywhere to go and remained at a higher level.

The drill out was performed to provide a "rat's nest" or room for the pump and packer assembly and not to unplug the filter pack.

Any hydraulic calculations will take into account the filter pack plugged with grout.

COMMENT
Section 5 Cased Hole Geophysical Logging

After well completion, a cement bond log, collar locater log, gamma log, and neutron log were run in the cased hole. The cement bond log was unable to indicate whether or not cement had penetrated the filter pack.

RESPONSE
No response necessary.

COMMENT
Section 6 Aquifer Packer Testing

Aquifer pumping tests were conducted in four screened intervals (1,010–1,049 ft, 896–976 ft, 687–788 ft, and 527–542 ft) by isolating the screens using inflatable packers. The report interprets the results qualitatively. No quantitative analyses are presented for pumping test drawdown and recovery tests.

The text refers to Figure 6-1 as a diagram showing the packer and transducer assembly. However, Figure 6-1 shows the transducer pressure response while testing the first interval. The equipment configuration is provided in an un-numbered figure at the end of Section 6.

Although lengthy written descriptions of testing are provided for each interval, no summary sections or summary tables of tested intervals, pumping rates, or aquifer hydraulic conductivities are provided.

Section 6.1 Aquifer Test Interval 1

It is confusing to refer to the flow rate adjustments during the initial pumping tests as "step tests" because the tests were not conducted like a typical step test. In a formal step test, the pump is not shut off between steps. Typically, step-drawdown tests involve pumping the well at a fixed flow rate until water levels stabilize (typically 20 – 60 minutes) at a given drawdown (Step #1), then increasing the flow rate to a new fixed flow and drawdown (Step #2), and repeating at a new, higher flow rate (Step #3). These test results are often analyzed to determine the non-linear well loss coefficient and aquifer loss term. Since the initial tests in POCI 55 were not conducted using this method, the term "step tests" is probably not applicable.

The report also incorrectly states that "after the rate test the formation was allowed to recover to its approximate original starting pressure." Figure 6-1 shows that, at the end of the second step test, the pressure was about 26 psi (60.7 feet) below the original starting pressure. It would be more accurate to say that the aquifer was allowed to recover for X minutes, or X%. Failing to allow the aquifer to recover before starting the longer duration constant-discharge test can make test analysis difficult, because it violates the mathematical assumptions underlying most solution methods. However, since the test results were not analyzed quantitatively (or at least a quantitative analysis was not presented), the dynamic pre-test conditions are less problematic.

The gas measurements collected from the isolated (packed off) zone and from the upper zone above the packer provide very useful information for identifying the source of gas entering the well. The report text and chart recorder in Appendix E clearly indicate that the lower screened zone did not produce measurable quantities of gas during the pumping test, while methane was produced from the zone above the packed interval.

Section 6.2 Aquifer Test Interval 2

The discussion of transducer pressure readings in the second paragraph on page 6-6 is incorrect. Although the three transducers were attached at the same location on the pipe string (ie, on the first joint above the packer assembly) the middle and lower transducers were equipped with ¼-inch nylon drop tubes such that their measuring points were not the same as their location. Since the three transducers are measuring pressure at different points, they would not be expected to read the same pressure. Rather than question why the three pressure readings were not identical, the author should question why the readings were not farther apart, given the vertical separation between the measuring points. If the middle transducer drop tube extended to the center of the packed interval, the difference in measuring point elevation would have been 75 feet and the transducer should have recorded a 32.5 psi difference. Similarly, if the vertical separation on the lower transducer was 150 feet, the transducer should have recorded a 65 psi difference. If properly connected, the nylon drop tube has no effect on the transducer readings other than to change the measuring point.

The static water level prior to the test (provided on page 6-6) was 482 ft bgs, which is 15 feet lower than the pre-test static water level measured for aquifer test Interval 1. This is inconsistent with observations from the first packer pumping test, which indicated downward flow and downward vertical gradients. If the first observations were correct, the water level should have been higher at isolated intervals higher in the hole.

As the report states, the lower packer was not seated during the aquifer test on this interval. The packer may have leaked, but no mention is made of pressures at the surface tank to confirm the leakage. Since nitrogen gas is typically used for inflating packers, if the gas flow to the lower packer was not turned off during the test, the escaping nitrogen could have influenced water chemistry. (The laboratory data sheets do not provide nitrate or nitrite results for the sample collected from aquifer test Interval 2, although they are provided for Interval 1.)

The term "significant well bore damage" (in the first paragraph at the top of page 6-7) is unclear.

Two longer duration pumping tests were conducted, with stable pre-test water levels and constant pumping rates. The measurements collected should provide good information for quantitative analysis of aquifer hydraulic conductivity. This analysis was not provided.

Gas measurements indicated 2-3 mcf/day for the first 15 – 20 minutes of the Interval 2 aquifer test. While the report appears to thoroughly and accurately document the measured gas flow rate and composition, it also editorializes the quantities of flow as "insignificant when compared to … that found venting from domestic wells in the near vicinity". While it is correct that the chemical signature is different from the signature in some local domestic wells (i.e., no hydrogen sulfide in POCI 55), and the quantities of gas are significantly lower than in the upper interval, the report should not trivialize a gas flow rate of 2-3 mcf/day. The effect of 2-3 mcf/day on a domestic well can be significant. The conclusion, however, that "this aquifer zone is not capable of sustaining a significant volume of gas and is not expected to be included in the mitigation efforts" may be valid at this location. More data or analysis may be required to extrapolate this conclusion over a broader area.

Section 6.3 Aquifer Test Interval 3

The leaking lower packer was evident again in test Interval 3. (No attempt was made to pull the packer string, identify to source of the leak, check fittings, or replace the lower packer.) The statement that "The inflation of the packers did not influence the pressure monitored in the lower zone" should be followed with "because the lower packer was not fully seated".

The report refers to transducers pressures indicating a separation of aquifers, but does not provide head in feet or pressure in psi at the measuring points for the upper and middle transducers. A complete table or figure showing head or pressure measurements and the intervals represented may be useful for understanding the hydrogeologic system and for further decision making.

While the pumping rate (17 gpm) provides some useful information, it does not necessarily indicate that this aquifer zone is more productive than test Interval 2, which yield 14 gpm. The pumping rate is a function of the pump curve (which would allow higher yields from isolated intervals higher in the well, due to the downward vertical gradients), the hydraulic conductivity, and the length of the producing interval. Because the lower packer was not seated correctly, the length of the test interval is greater for aquifer test Interval 3 than for Interval 2. If the test results were analyzed, they might indicate a lower hydraulic conductivity in Interval 3 although the pumping rate was higher than in Interval 2.

The text states that "this amount of gas is insignificant" but does not report the flow rates in the text or in Table 6.3.2. The chart recorder (Appendix E) indicates higher and more consistent flows than in the previous test interval. The rates should be reported in the text.

Section 6.4 Aquifer Test Interval 4

Problems with the pump and with gas production in this interval made it impossible to pack off Interval 4 and conduct a pumping test.

As previously noted, the statement that "the lower transducer is reading a pressure significantly higher than the middle and upper transducer indicating an inaccurate but precise value due to the use of the ¼-inch nylon tubing" is false. If properly installed, the drop tubing does not affect the transducer reading. The lower transducer should measure a higher pressure because the measuring point is lower in the hole and submerged under a greater water column. The fact that the middle and upper transducers produced the same pressure reading should be a cause for concern, unless they are located close together on the pipe string.

The depth to water of 493 feet bgs measured by the upper transducer indicates upward vertical gradients in the well, compared to water levels calculated from transducer data for the previous test intervals. However, this water level is higher than the water level physically measured in the open hole (530 ft) which would indicate downward vertical gradients. Complications due to gas production from this zone could have made the transducer readings inaccurate.

The build up of gas pressure in Interval 4 was significant when both packers were inflated. The gas flow rate was measured at 30 to 50 mcf/day and was composed of 100% combustible gas v/v measured using a hand-held RKI 4-gas meter. The report did not analyze the shut-in test data quantitatively, and no water quality samples were collected from this zone.

RESPONSE

The drilling and aquifer testing of POCI 55 was used as an initial investigation into the occurrence and connectivity of fugitive gas within the Poison Canyon Formation and to describe the geologic setting because of a lack in currently available data for this formation. This well served as a starting point for a much larger plan including twelve more wells with additional logs and testing. The report was provided as an update to the long term project. Future testing of injection and recovery wells will be used in conjunction with continued monitoring of POCI 55. Data collected from the mitigation system wells and POCI 55 in future testing will be reviewed and analyzed more quantitatively after the data is collected.

Figure 6-1 was referenced incorrectly and the testing configuration was mislabeled. This was an oversight.

While it is difficult to see in the plots provided, step tests were attempted. The idea is well understood and can be visualized within the original test files supplied with this document for other tests. While a step test was attempted it was not successful as hoped during the first test due to the significant drawdown at a very low pumping rate. The on and off responses observed were not what were referred to as the step test.

It is noted that the starting point of the actual first interval test should be replaced with 90% recovery and not referred to as approximately recovered.

The use of nylon tubing to measure pressure did result in some discrepancies. All transducers with the point of actual measurement, the pressure diaphragm on the transducer not the opening of the tubing, were strapped to the testing string at the same location within a couple of inches of one another. In an open borehole the pressure measured on all three transducers should be equal because the pressure is transmitted through the tubing to the actual pressure diaphragm on the pressure transducer in response to the head above the measuring point, the diaphragm. Thus, if the water level were to fall below the pressure transducer the pressure in a psig unit would be zero because the water is below the measuring point, the diaphragm, even though the tubing could have an outlet 150 feet into water. Thus, the differences observed were due to differences in the equipment or due to the tubing itself and potentially the meniscus formed in the tubing. Once the packers are inflated the transducers will reflect the pressure in that isolated zone and if the potentiometric surface drops below the transducer the transducer will read zero and not some value where the tubing opening is at. So the pressure is relative to the actual placement of the transducer and not the tubing opening such that the pressure measured is not a true pressure at the tubing opening and the importance of knowing the relative change is important with respect to the initial water level.

The vertical gradients are potentially upward from one to another and downward between others thus there appears to not be a single upward or downward gradient. Rather there are slightly different heads within each of the isolated sands that could result in different directional flow depending on what other sand is observed. The difference in static water level between the first test and the second test is potentially due to the dynamics of the system with significant gas flow and the perturbation of the system due to pumping. As noted previously the pressure in the lower zone did not recover quickly or to the previous initial pressure. The difference in static water level could be a reflection of the affects due to pumping. Thus, the second measurement may not be a true "static water level" and could be transient due to recovery of the bottom zone.

The table provided in Appendix D shows the packer pressures during testing. The packer pressures were pressures obtained from inflating the packers, turning off the nitrogen feed, and disconnecting the inflation line from the nitrogen tank. Thus, there were no leaks in terms of inflation gas. The packer may have been and is hypothesized as seating correctly. The "leak" referred to is assumed to be a leak in the fixtures or assembly of the pass through assembly used to allow the lower transducer line to reach below the lower packer. The fittings are assumed to not have formed a proper seal. No attempt was made to fix the "leak" because as noted in the text the upper and lower transducers were not direct read and the problem was not identified until the end of testing when the upper and lower transducer data was collected. Problems were also not detected prior to downloading the data from the upper and lower transducers because the middle transducer, with a direct read cable, did show divergence during packer inflations and the connectedness of the system could have been strong because the zones reside within the same aquifer system.

The amount of well bore damage was not quantitatively calculated. The data was reviewed qualitatively and the bumps and difference in drawdown from the duplicate tests run for the second test interval indicate well bore damage. The degree is not known and the word significant is retracted.

The statement "(i.e., no hydrogen sulfide in POCI 55)" is incorrect and not made in the document. Hydrogen sulfide is found in the deeper zone as shown in Table 6.2.2. The amount of gas was not meant to be trivialized and in terms of gas flow to a domestic well 2-3 mcf/day is important. However, the purpose of POCI 55 testing was to identify the main source of methane gas within the Poison Canyon Formation and the rates of gas emanating from the nearby domestic water wells was significantly higher (>10 mcf/day) and sustainable. The short lived non-continuous flow of 2-3 mcf/day for fifteen minutes is not considered the primary source of the gas venting to nearby water wells and is an order of magnitude lower than that emanating from the upper zone found during the testing. The vertical location of this gas was checked during subsequent drilling of the injection and recovery wells by drilling to greater depths below the upper sands found to have the highest gas production during testing of well POCI 55.

The separation of individual heads within the sands was observed during packer inflation. However, individual heads for each zone were not calculated because the values could be misleading due to the "leak" in the lower packer system and the influence of the lower zone(s) on the middle transducer readings. Thus, to prevent misinterpretation of the data this was left out. It can be included but must be taken in light of the malfunctioning lower packer.

During testing of aquifer test interval 3 the gas flow rate was not provided in text or Table 6.3.2 because as stated in the document, "During the testing of this interval only trace amounts of gas were identified and monitored using the RKI handheld gas meter. The amount of gas produced was below what could be recorded on the Barton chart recorder.", the flow rate was below what could be measured. The statement "The chart recorder (Appendix E) indicates higher and more consistent flows than in the previous test interval.", is incorrect. The chart in Appendix E shows a lot of noise and no actual flow. That day was extremely windy with significant gusts up to 30 or 40 mph that affected the chart recording. Test interval 3 had no measureable gas in terms of flow rate but gas was identified with the RKI handheld meter as stated in the text.

COMMENT
Section 6.5 Aquifer Water Quality Testing

The report correctly states that the water quality results are not considered representative of background water quality due to high pH values indicating the presence of mud or grout. It should be noted that the pH values up to 11.2 are clearly indicative of cement grout (pH 10-12) rather than drilling mud (typically pH 8.5 – 9.5). It is also noteworthy that the pH was highest in test Interval 3, which produced the most water and may have pulled in the most cement. The high pH values could affect the concentrations of metals, TDS, and other constituents in the water samples, a point that is not made clear in the text. The effects of pH on organic chemistry are not discussed.

Similarly, Table 6.5.1 shows the lowest water temperature measured in water from the deepest perforated interval (Aquifer Test Interval 1), with higher temperatures in overlying Interval 2 and Interval 3. The temperature pattern of the coldest water coming from the deepest interval may be anomalous, and may be the result of the exothermic reaction of curing cement in the upper zones. If the higher temperatures measured in the discharge water from Interval 2 and 3 are the result of heat generated by exothermic reactions that take place when cement cures, then the results may indicate that testing and sampling of the well occurred prematurely, before the cement had fully cured.

No summary table of water quality results is provided. The reader is left to search through the laboratory data sheets in Appendix F. The data sheets appear to be complete, although nitrate and nitrate analyses for Interval 2 and Interval 3 are not presented. Similarly, water quality results for Interval 4, which produced the most gas, are not provided because a sample was not collected.

The presence of carbon dioxide (CO2) and other gasses should not be interpreted as evidence that "biogenic processes [are] involved in the oxidation of methane" when (a) the affects of cement and high pH on the carbonate geochemistry in the system are not explained and (b) the affects of sample preservation are not considered. The CO2 was most likely an artifact of sample collection and preservation, rather than a result of subsurface biological processes. The CO2 was reported as a Tentatively Identified Compound (TIC) in a sample submitted for volatile organic compound (VOC) analysis. Standard environmental protocols require that VOC samples be preserved to pH 2 or less. Because the carbonate alkalinity of the submitted samples ranged from 72 – 180 mg/l as CaCO3 and the bicarbonate alkalinity ranged from 8.25 to 129 mg/l as CaCO3, acidification of the samples to pH=2 would have converted the dissolved inorganic carbon to H2CO3(s) or CO2(g). The gaseous CO2 is likely the result of sample acidification, rather than biological processes.

RESPONSE

The data was not summarized for the reason that they were **not** considered representative as agreed to by the technical reviewer. The fact that these data may be misrepresentative indicates that they should not be emphasized to avoid misinterpretations being made about the background water quality of the Poison Canyon Formation. The impacts of the high pH and existence of either grout or drilling mud was not made clear because it was assumed intuitively obvious and the water quality is assumed not representative. The temperatures reported for the different test intervals are not reflective of true formation or borehole temperatures. The temperatures reflect the value after filling a beaker and placing the probe in the beaker and allowing it to stabilize. The time of day and ambient air temperature significantly affects this value and should be considered non-representative of the formation and or borehole. The pressure transducers also recorded temperature and provide values above 17 degrees Celsius for the lower zones indicating that the 13 and 14 degrees Celsius recorded are impacted by ambient air.

While the following statement suggests a potential for biogenic processes it does not emphatically state that it is occurring. Rather it is a suggested process that could result in the observed data.

"These are indicators of biogenic processes that may be involved in the oxidation of methane. These gas results support the observations of gas detected with the handheld RKI gas meter at the water gas separator vent from the same zones where combustible gases were detected in combination with carbon monoxide and hydrogen sulfide. Thus, there may be bioremediation of the dissolved gas in the deeper zones that will result in the removal of the methane over time." (Norwest, 2008).

While biogenic processes were mentioned as a possibility, the supplied quote "biogenic processes [are] involved in the oxidation of methane" from the technical memorandum author was not a quote at all and just a misrepresentation of the statement made in section 6.5 as provided above. And while the CO2 found as a tentatively identified compound in the water quality analysis might be a result of sampling, the presence of hydrogen sulfide and carbon monoxide as continuously measured in venting gas from the deeper zones using the RKI handheld unit supports potential microbial activity.

COMMENT
Section 6.6 Aquifer Testing Summary

The report identifies that a significant flow of combustible gas occurred from the upper zone (sand packed from 420 to 628 ft and screened from 526.6 to 541.6 ft) and lower quantities of gas were derived from the lower zones.

Too much emphasis is placed on the detection of sulfide and CO2 as being indicative of biological oxidation and removal of methane gas. Sample preservation may have generated gaseous CO2 in the sample (see comments above) and it may not be possible to determine the oxidative state of groundwater given the high pH (9.7 to 11.2) that resulted from improper well completion. Because the water quality data are suspect, the generalizations about biological oxidation and removal of methane gas may not be warranted. At least, further consideration of the geochemistry may be necessary.

The phrase "the aquifer testing showed a potential connection between aquifer zones as indicated by the lower pressure transducer' could be misinterpreted to imply that the aquifers were interconnected. Clearly, the differences in pressure head measured during the various tests indicate that the aquifers are not distinctly connected, and that the clay units provide vertical separation between aquifers. A more correct phrasing is that "during testing, the lower packer allowed connection between the test intervals." The connection between the test interval and the underlying well casing was not "potential", it was actual and was repeatedly measured by the lower transducer.

The statement that "significant amounts of water are available in the lower zones" is not consistent with a pumping rate of 5 gpm with a drawdown of 218 psi (504 ft) in test Interval 1 (the lowest test interval).

The statement that there is limited water available in the upper sands is not justified. A pumping test was not conducted because the pump was inoperable, so yield could not be tested. The low pressure measured by the upper transducer may simply indicate that the transducer was set near the top of the aquifer, not that the aquifer permeability (or yield) was low.

RESPONSE

There is no emphasis placed on biological oxidation of methane gas "There are trace amounts of gas in the deeper zones that **could potentially** be removed through biological oxidation of methane.". This is offered as a potential explanation that warrants more investigation. However, the presence of hydrogen sulfide gas does indicate the reduction of sulfate that is a microbially mediated process and whether or not it is related to methane oxidation requires more data. Additionally, the oxidative state of the groundwater can be anoxic where sulfate is used as the terminal electron acceptor in the oxidation of methane resulting in the observed hydrogen sulfide. This process is termed anaerobic oxidation of methane and can is shown by the general equation:

$CH_4 + SO_4^{2-} \rightarrow HCO_3^- + HS^- + H_2O$

Again this is a hypothesis to the observed data and is only offered as a potential process requiring additional data.

It is agreed that the connection between zones was artificially induced by equipment malfunction and the wording could be misleading. It was written in terms of someone seeing this data and interpreting it for themselves that that was the reason for the drawdown observed in the lower transducer. It was provided as a possible alternate interpretation.

The reference to significant amounts of water and limited water was to the actual potentiometric heads and not the yield. The amount of head available for drawdown in the upper most unit was extremely low in comparison to that in the deeper zones and this should be worded differently.

COMMENT
Section 7 Cased Video Logging

The video was not provided for review. However, from the text it is apparent that cement grout was visible in several screened sections. The statement that "grout is not thought to be the plugging agent because during completion sand was placed approximately 10 feet or higher above the slots with nine feet of bentonite above the sand prior to placing the grout" is incorrect, for reasons noted previously: (1) the bentonite was poured from ground surface, and may not have reached the target interval, (2) in some cases, cement grout was placed directly on top of very coarse (6-9) sand without any bentonite or transition sand, and (3) more than 10 feet of settlement of the transition sand is easily conceivable given the coarseness of the sand (which typically settles more than fine sand) and the very long length of sand pack (up to 208 ft).

It is not clear whether the statement that the water column starts at 526.5 feet was derived from the video or from the open hole measurement. In either case, an explanation as to why the water level mentioned in this section differs from the water level calculated from pressure transducer measurements is needed.

RESPONSE

The presence of grout within the casing slots is possible. However, if significant volumes of grout had entered through the slots the bottom of the well would be filled with grout.

The water column starting at 526.5 feet was derived from the video log as this section discusses those values obtained from the video log and why the water level measured with a sounding tape may be inaccurate.

COMMENT
Section 8 Conclusions and Recommendations

The conclusions summarize that the upper zone produces the most gas, and that gas is trapped in the upper Poison Canyon Formation. This conclusion is supported by the information and test results provided. However, the statement that "gas migration is not wide spread and is linked with the upper zone possibly by man-made conduit" does not result from the monitoring well data presented in this report. The data presented in this report does not provide a basis for this statement.

The recommendation that subsequent mitigation and monitoring wells should be drilled in the upper zone is probably valid. However, due to problems with well completion and the inherent variability in the subsurface (both stratigraphic variability and fracture variability), it may be premature to completely ignore the lower zones.

The recommendations in the third paragraph for packing off gas and monitoring water level (pressure) changes are excellent.

The fourth paragraph is correct that more representative water quality samples should be collected from other wells that are properly completed.

RESPONSE

The presence of high volume gas only within the upper zone supports that the gas is not within the deeper zones and if the process were due to a natural dike cutting up through the formation from the Vermejo Formation then the gas would potentially be trapped deeper within the Poison Canyon under the different shale sequences.

The suggestion of completing the mitigation wells in the upper zone was made in terms of the actual effectiveness of the system given that the primary gas source was found in the upper zone during the testing of well POCI 55. However, the drilling of the mitigation wells was extended to depths much greater than the upper sands identified in POCI 55 as the source to assure that there was no gas deeper within the Poison Canyon away from the POCI 55 location.

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