

Railroad Commission of Texas
Water Well Complaint Investigation Report
Silverado on the Brazos Neighborhood
Parker County, Texas
May 23, 2014

Introduction

Between August 5, 2013 and September 6, 2013, the Railroad Commission of Texas (RRC) District 7B Office was contacted by seven property owners concerning the occurrence and apparent increase in methane in their water wells and an eighth property owner regarding the occurrence and apparent increase of chloride in two water wells. The District Office performed initial inspections in August and September 2013. Complaint status reports were issued January 24, 2014.

A ninth complaint was filed on January 28, 2014, due to the complainant's concern about methane in a water well based on proximity to other complaints. An initial inspection was performed February 4, 2014.

The properties and water wells are situated in or near an area that was investigated in late 2010 and early 2011 for possible oil and gas operational sources of natural gas that was occurring in water wells in the Silverado on the Brazos (Silverado) neighborhood, located in southern Parker County. Information gathered during that investigation identified occurrences of natural gas in area water wells unrelated to nearby Barnett shale production. The investigation also identified a shallow source of natural gas, the Strawn formation, which occurs beneath the neighborhood at depths as shallow as 200 feet below ground surface (bgs) based on information submitted to the RRC.

In order to further evaluate the source of gas in neighborhood water wells, RRC staff, utilizing services of an environmental engineering firm, Terracon, sampled four water wells in the neighborhood on September 26 and 27, 2013. Commission staff also gathered information from water well drillers logs on file at the Texas Department of Licensing and Regulation (TDLR) and provided by residents; published reports about the geology of the area; and reviewed technical information and expert testimony pertinent to the Commission-called hearing held January 19 and 20, 2011, on the subject of the former Range Resources Butler 1-H and Teal 1-H gas production wells.

Additionally, RRC staff reviewed analytical data collected by Range Resources on a quarterly basis between May 2012 and February 2013 from other water wells in the neighborhood in cooperation with the US EPA's Region 6 office.

In lieu of the complainants' names, the following discussion of analytical data and water well construction information refers to water well numbers used by Range Resources during the course of their earlier investigation. The complainants' water wells evaluated in this report include the following: Well No. 2, Well Nos. 8 and 8A, Well No. 9, Well No. 11, Well Nos. 13 and 18, Well No. 24, and Well No. 26.

Two of the nine complaints involve properties that were not previously investigated by Range Resources because they are located greater than 3,000 feet away from the Butler 1-H wellbore. As such sampling and analysis data are only available for seven of the nine complaints.

Groundwater Sampling and Analysis

On September 26 and 27, 2013, Terracon, on behalf of the RRC, collected groundwater samples from four water wells located on three of the complainants properties: Well No. 2 (Complaint No. 7B-10433), Well Nos. 8 and 8A (Complaint No. 7B-10444), and Well No. 26 (Complaint No. 7B-10441). Groundwater samples were analyzed for dissolved methane, ethane, propane, n-butane, and acetylene. Samples of water well head-space gas and dissolved gas were also analyzed for natural gas composition and carbon and hydrogen isotopes of methane, ethane and propane. Copies of the laboratory reports were submitted to the three property owners in complaint update letters dated January 24, 2014.

Range Resources collected groundwater samples from twenty-six water wells (including water wells associated with seven of the nine complaints) located in the Silverado neighborhood between December 27, 2010, and January 6, 2011, as part of their investigation presented at the January 19-21, 2011, RRC hearing. Water samples (dissolved gas) and water well head-space gas samples were tested for isotopic and compositional analysis. These samples also were analyzed for total metals, volatile organic compounds (VOCs), total petroleum hydrocarbons (TPH), general chemistry parameters, dissolved gases, and other tentatively identified compounds (TICs).

Range Resources collected samples from fourteen water wells (including water wells associated with four of the nine complaints) located in the Silverado neighborhood on a quarterly basis between May 2012 and February 2013, and on a less frequent basis from another six water wells (including a water well associated with one of the complaints) during the same time period. Groundwater samples from the water wells were tested for isotopic and compositional analysis of dissolved gases; and dissolved benzene, toluene, ethylbenzene, xylene (BTEX), methane, ethane, ethene, propane, and butane.

Tables of cumulative analytical results for water wells pertinent to this investigation are attached. Table 1 presents dissolved gas concentration data for the complainants' water wells. Table 2 contains dissolved and head-space gas composition and isotope data for the complainants' water wells. Table 3 presents calculations of nitrogen content of water well head-space samples (corrected for atmospheric influence) from the four water wells sampled by the RRC in September 2013. Table 4 contains dissolved and head-space gas composition and isotope data for additional samples from the Silverado neighborhood and surrounding areas for comparison purposes.

For each complaint where groundwater sampling was performed, RRC staff compared the results of the most recent analyses with the results of earlier tests to determine if conditions have changed since the original sampling that occurred prior to the January 2011 hearing.

Findings are summarized by well number below.

Well No. 2

Well No. 2 was sampled by Range Resources on December 28, 2010, as part of their initial investigation, and then on a quarterly basis between May 2012 and February 2013, as part of Range Resources quarterly sampling program. This well was most recently sampled by the RRC on September 27, 2013.

The concentration of methane measured in the September 2013 dissolved gas sample (21.9 milligrams per liter, mg/L) is higher than the concentration measured in December 2010 (2.8 mg/L). Likewise, the methane composition measured in the September 2013 dissolved gas sample (83.44 mol. %) is higher than the methane composition measured in December 2010 (73.71 mol. %).

In general, cumulative data collected between December 2010 and September 2013 show that methane levels in both well head gas samples and dissolved gas samples have increased since the initial sampling event in December 2010.

Analysis of the carbon and hydrogen isotope data from the most recent sampling event indicates that the gas in Well No. 2 is mostly of thermogenic origin, consistent with past sample data. Based on the isotope values compared with the other gas samples, the methane carbon and hydrogen isotope values are more negative relative to other gas samples collected in the area, suggesting that the gas in Well No. 2 may be mixed with gas from a biogenic source.

The nitrogen content of headspace gas (corrected for atmospheric influence) was 0.95 mol. % in 2010 and 0 mol. % in 2013. Carbon dioxide content was 0.11 mol. % in December 2010 and 0.12 mol. % in September 2013.

Well Nos. 8 and 8A

Well No. 8 was sampled by the EPA on October 26, 2010, by Range Resources on January 6, 2011, and again by the EPA on July 6, 2011. This well was most recently sampled by the RRC on September 27, 2013. Well No. 8A was sampled by the EPA on July 6, 2011 and more recently sampled by the RRC on September 27, 2013.

The concentration of methane measured in Well No. 8 in the September 27, 2013, dissolved gas sample (8.6 mg/L) is higher than the concentration measured in January 2011 (2.3 mg/L). The methane composition measured in Well No. 8 in September 2013 dissolved gas sample (84.95 mol. %) is slightly higher than the methane composition measured in January 2011 (81.42 mol. %).

The methane composition measured in Well No. 8A in the September 2013 dissolved gas sample (35.16 mol. %) is less than the methane composition measured in January 2011 (61.87 mol. %).

Analysis of the carbon and hydrogen isotopes from the most recent sampling event indicates that the gas in both Well No. 8 and 8A is of thermogenic origin, consistent with past sampling events.

The nitrogen content of gas samples collected from the headspace of Well No. 8 (corrected for atmospheric influence) ranges from 1.04 to 1.55 mol. %. The nitrogen content of the headspace gas sample from Well No. 8A (corrected for atmospheric influence) is 4.53%. The carbon dioxide content measured in headspace samples from both wells ranges from 0.046 mol. % to 0.059 mol. %.

Well No. 9

Well No. 9 was sampled by Range Resources, on December 30, 2010, and again on May 11, 2012.

The concentration of dissolved methane measured in the May 2012 sample (2.44 mg/L) is higher than the concentration measured in January 2011 (0.67 mg/L). Likewise, the methane composition measured in the May 11, 2012, dissolved gas sample (63.0 mol. %) is higher than the concentration measured in January 4, 2011 (26.29 mol. %).

Methane levels in the dissolved gas samples appear to have increased between January 2011 and May 2012.

Analysis of the carbon and hydrogen isotopes indicates that the gas in Well No. 9 is of thermogenic origin, consistent with findings from other water wells sampled in the Silverado neighborhood. However, the data also indicate that the May 2012 sample contained gas that is relatively fresher (i.e., less biodegraded) than the gas that was present in the 2010 sample.

Well No. 11

Well No. 11 was initially sampled by Range Resources on December 30, 2010, and then on a quarterly basis between May 2012 and February 2013, as part of Range Resources quarterly sampling program.

Staff compared the results of the five sampling events. Dissolved methane concentrations detected in samples ranged from 0.002 to 0.050 mg/L methane. Dissolved methane composition measured in samples ranged from 0.05 mol. % to 1.38 mol. %.

Methane levels in the dissolved gas samples do not appear to have increased appreciably between December 2010 and February 2013.

Analysis of the carbon and hydrogen isotopes indicate that the gas in Well No. 11 is of thermogenic origin, consistent with findings from other water wells sampled in the Silverado neighborhood. However, the gas appears to occur in relatively low concentrations and is relatively weathered (i.e. showing more biodegradation) compared with other water wells in the neighborhood.

Well Nos. 13 and 18

RRC Sampling Event

RRC staff sampled Well Nos. 13 and 18, during the initial complaint inspection on August 15, 2013. Water samples were tested for total petroleum hydrocarbons (TPH), benzene toluene, ethylbenzene, and xylenes (BTEX), and major anions and cations (including chloride). Laboratory results revealed no detections of TPH, or BTEX. Chlorides ranged from 221 mg/L at Well No. 18 to 411 mg/L at Well No. 13.

Range Resources Sampling Events

Well Nos. 13 and 18 were initially sampled by Range Resources on December 30, 2010, and then on a quarterly basis between May 2012 and February 2013, as part of Range Resources quarterly sampling program.

Staff compared the results of the five sampling events. The concentrations of dissolved methane measured in the February 2013 samples from Well No. 13 and Well No. 18, 5.43 mg/L and 1.03 mg/L, respectively, are higher than the concentrations measured in the wells in December 30, 2010, 1.0 mg/L and 0.96 mg/L, respectively. Likewise, the methane composition measured in the February 2013 dissolved gas sample at Well No. 13, 38.45 mol. % is higher than the concentration measured in December 30, 2010, sample, 35.44 mol. %.

Methane levels in the dissolved gas samples appear to have increased in Well No. 13 between December 2010 and February 2013.

Analysis of the carbon and hydrogen isotopes indicate that the gas in Well No. 13 is of thermogenic origin, consistent with findings from other water wells sampled in the Silverado neighborhood. The isotopes also reveal that the biodegradation state in gas samples from well No. 13 is relatively unchanged.

Chloride concentrations measured during RRC sampling event in August 2013 (411 mg/L at Well No. 13 and 221 mg/L at Well No. 18) are similar to concentrations detected by Range Resources in December 2010 (433 mg/L in Well No. 13 and 217 mg/L in Well No. 18).

Well No. 24

Well No. 24 was initially sampled by Range Resources on December 30, 2010, and then on a quarterly basis between May 2012 and February 2013, as part of Range Resources quarterly sampling program.

Staff compared the results of the five sampling events. Dissolved methane concentrations detected in samples ranged from 0.018 to 0.117 mg/L methane. Dissolved methane composition measured in samples ranged from 0.336 mol. % to 1.66 mol. %.

Methane levels in the dissolved gas samples do not appear to have increased appreciably between December 2010 and February 2013.

Analysis of the carbon and hydrogen isotopes indicate that the gas in Well No. 24 is of thermogenic origin, consistent with findings from other water wells sampled in the Silverado neighborhood. However, the gas appears to occur in relatively low concentrations and is relatively weathered compared with other water wells in the neighborhood.

Well No. 26

Well No. 26 was sampled by Range Resources on December 29, 2010, and most recently by the RRC on September 26, 2013.

The concentration of methane measured in the September 2013 dissolved gas sample (8.08 mg/L) is higher than the concentration measured in December 2010 (0.28 mg/L). Likewise, the methane composition measured in the September 2013 dissolved gas sample (60.69 mol. %) is higher than the concentration measured in December 2010 (5.38 mol. %).

Methane levels in both head-space gas samples and dissolved gas samples appear to have increased since the initial sampling event in December 2010.

Analysis of the carbon and hydrogen isotope data from the most recent sampling event indicates that the gas in Well No. 26 is of thermogenic origin, consistent with the earlier sampling event. However, the data also indicate that the September 2013 samples contain gas that is less biodegraded than the gas that was present in the 2010 samples.

The nitrogen content of head-space gas (corrected for atmospheric influence) was 0.68 mol. % in 2010 and 3.8 mol. % in 2013. The carbon dioxide content was 0.22 mol. % in December 2010 and 0.091 mol. % in September 2013.

Summary of Analytical Findings

The analytical data show that concentrations of natural gas constituents in certain wells (Well Nos. 2, 8, 9, 13, and 26) have increased since the initial sampling event performed by Range Resources. The most recent gas sample in Well No. 26 appears to be less biodegraded than the earlier sample based on carbon isotopes of methane and ethane. Likewise, the most recent sample from Well No. 9 appears to be less biodegraded, but to a lesser degree, than the earlier sample based on the carbon isotope of ethane.

Data from Well No. 8A suggest that the concentration of methane in groundwater decreased between July 2011 and September 2013, based on methane composition of dissolved gas.

Data from Well Nos. 11 and 24 reveal only low levels of relatively weathered dissolved methane present in groundwater with little, if any, indication of increasing concentrations since December 2010.

Nitrogen content of head-space gas was measured in samples collected by the RRC from Well Nos. 2, 8, 8A and 26 in September 2013. The data, corrected for atmospheric influence, are summarized in Table 3. When compared with past data, the nitrogen content of head-space gas is higher in Well No. 26, similar in Well No. 8, and lower in Well No. 2. The nitrogen content of the September 2013 head-space gas sample from Well No. 8A is relatively high compared with the other September 2013 samples.

Staff compared methane carbon and hydrogen isotope data from the complainants' water wells with data from other occurrences of gas, including gas produced from three different Barnett shale production wells and water wells containing gas that are located outside of the Silverado neighborhood, and data from other water wells within the Silverado neighborhood (Table 4). These include:

- Samples collected from Well No. 1, within the Silverado neighborhood, reveal moderate levels of methane. The carbon isotopes of ethane indicate that gas in Well No. 1 is relatively weathered compared with samples from the complainants' water wells.
- Sample PWS was collected by the EPA in July 2011 from a public water supply well associated with the Lake Country Estates, located approximately one mile east of the Silverado neighborhood, where the occurrence of natural gas has been attributed to the underlying Strawn Formation.

- Samples WW03 and WW05 were collected by Carrizo Oil & Gas Corp. in August 2011 from water wells near the Mund-Lipscomb Unit 1-H well, located about one-half mile west of the Brazos River, across from the Silverado neighborhood.
- Production gas samples from the Carrizo Oil & Gas Corp. Mund-Lipscomb Unit 1-H well production tubing and casing.
- Production and injection gas samples from the former Range Resources Teal Unit 1-H and Butler Unit 1-H gas wells.
- Brandenhead gas samples from the former Range Resources Teal Unit 1-H and Butler Unit 1-H gas wells.

Collectively, the data identify variability both between water well locations and within individual water wells that could be explained by the migration of gas from different thermogenic sources (e.g., the Strawn Formation or the Barnett Shale), or mixing of gases, or the influence of bacterial oxidation. The processes of mixing, migration, and bacterial oxidation all have the potential to impede a clear diagnosis of methane contamination (*The Role of Isotopes in Monitoring Water Quality, Water Resources Institute, Cornell University, February 17, 2011*).

As such, while the analytical data show that methane levels and isotopic signature changed in certain water wells in the Silverado neighborhood, the isotope data alone do not appear to be diagnostic of a specific source of gas.

In order to further evaluate possible sources and pathways for gas migration, RRC staff has evaluated information about the subsurface geology in the vicinity of the neighborhood, well construction records for the complainants' water wells, and well construction information about nearby Barnett shale production wells.

Geological Setting

Based on information submitted to the RRC in December 2010 and January 2011, the Cretaceous Twin Mountains Aquifer rests on top of the Pennsylvanian Strawn Formation which represents the upper section of the Ft. Worth Basin. The Twin Mountains Aquifer and underlying Strawn Formation are separated by an erosional unconformity that constitutes a transitional contact between the interbedded sandstones, shales and limestones of the Strawn Formation and the overlying Twin Mountains sandstone aquifer. The Strawn Formation is known to have produced natural gas from shallow depths, ranging from 358 feet to 426 feet below ground surface (bgs) in the Center Mill (Strawn) field, located less than a mile southeast from the neighborhood. Natural gas has occurred in water wells in the area prior to recent production from the Teal 1-H and Butler 1-H gas wells that produce from the Barnett Shale. These include water wells associated with a public water supply system (Lake Country Acres) located approximately one mile east of the neighborhood, the Hurst water well which flowed natural gas for a period of time after it was installed in 2005 within the Silverado neighborhood, the Oujesky water well which flowed natural gas for a period of time after it was installed in 2007 in the neighborhood, and water wells associated with past complaints of natural gas in groundwater at locations approximately one-half mile west of the Brazos River across from the Silverado neighborhood.

The Barnett Shale occurs at a depth of approximately 5,700 feet bgs beneath the neighborhood. The Cretaceous Twin Mountain Aquifer and Barnett Shale are separated by approximately 5,300 feet of Pennsylvanian-aged strata (Marble Falls Formation, Bend Group, and Strawn Group).

Seismic lines constructed from three-dimensional seismic reflection data collected in the vicinity of the neighborhood were submitted by Range Resources to RRC staff for review. The seismic data not reveal any discernible faults present above the Barnett Shale beneath the neighborhood. Published reports reviewed by RRC staff regarding the geology of Parker County show that faults have been identified in southwestern and northern Parker County, but the reports do not show faults in proximity to the Silverado neighborhood in south central Parker County.

Water Well Information

Water well construction information is provided in Table 5.

RRC staff reviewed driller's logs for water wells in the surrounding area, and constructed geological cross sections based on those logs. Based on this information, RRC staff has identified the base of Cretaceous, as identified by "red beds" described on driller's logs, beneath the neighborhood. The occurrence of the red bed marker in each well bore log is identified in the table. The red beds occur at depths ranging from 180 to 255 feet bgs.

Based on this information, it appears that the complainants' water wells either penetrate into or beneath the transitional zone that separates the Cretaceous Twin Mountains Aquifer and the underlying Pennsylvanian Strawn formation, with the exception of Well No. 8A which was set at total depth of 120 feet and Well No. 11 for which water well construction information was not available.

Well Completion Information – Butler Unit 1-H, Teal Unit 1-H, and Mund-Lipscomb Unit 1-H Gas Production Wells

Staff reviewed well completion data for the Teal Unit 1-H and Butler Unit 1-H gas wells formerly operated by Range Resources and the Mund-Lipscomb Unit 1-H gas well formerly operated and plugged by Carrizo Oil & Gas Inc.

Butler Unit 1-H

The Butler Unit 1-H well surface location is situated less than one half mile south from the Silverado neighborhood. The horizontal portion of the well bore extends to the northwest beneath the neighborhood at a depth of approximately one mile below ground surface.

The Butler 1-H surface casing was set at a depth of 394 feet bgs and cemented with 234 sacks of cement circulated to ground surface with six centralizers and pipe reciprocation. The base of usable quality water was determined to occur at the base of the Cretaceous-age beds estimated at a depth of approximately 175 feet bgs. Range Resources independently determined the base of Cretaceous to occur at a depth of approximately 279 feet bgs at the Butler 1-H location. As such, the surface casing of the Butler 1-H is sufficiently deep to isolate useable quality groundwater.

Production casing was set at 9,073 feet measured depth (MD) and cemented with 409 sacks of cement. A cement bond log (CBL) was run from 5,650 ft to 4,330 ft. The estimated top of cement occurs at 4,580 feet. The CBL indicates excellent cement bond across the cemented interval, based on expert testimony provided in the January 19-20, 2011, hearing

During a RRC inspection on August 10, 2010, it was determined that the Butler 1-H well had a pressure of 30 pounds per square inch (psi) on its bradenhead. A Mechanical Integrity Test (MIT) was performed on the Butler 1-H production casing on October 14, 2010. The MIT revealed no leaks in the production casing. The presence of gas in the bradenhead is most likely due to seepage of gas from the shallow Strawn formation into the wellbore above the production string cement as evidenced by geochemical analysis of the bradenhead gas and the results of the MIT as presented at the January 19-20, 2011, hearing.

Using the RRC's Bradenhead Pressure Management Guidance procedure, staff determined an Annular Pressure Threshold (APT) of 197 psi for the Butler 1-H surface casing (Table 6). The APT is the theoretical pressure above which bradenhead gas pressure may present a risk to the surface casing integrity. The maximum bradenhead pressure observed after three separate RRC inspections of the Butler 1-H well was 30 psi. As such, the bradenhead pressures observed in the Butler 1-H are below the APT and thus are not considered a threat to the integrity of the surface casing.

Hydraulic fracturing within the Butler 1-H well bore was performed Aug 10, 11, and 12, 2009. Range Resources submitted well stimulation reports and provided expert testimony in the January 19-20, 2011, hearing that hydraulic fracturing can be ruled out as a potential source of natural gas in water wells in the Silverado neighborhood.

Teal Unit 1-H

The Teal Unit 1-H well surface location is situated less than one half mile south from the Silverado neighborhood. The horizontal portion of the well bore extends to the northwest beneath the neighborhood at a depth of approximately one mile below ground surface.

The Teal 1-H surface casing was set at a depth of 409 feet bgs and cemented with 234 sacks of cement circulated to ground surface with five centralizers and pipe reciprocation. The base of usable quality water was determined to occur at the base of the Cretaceous-age beds estimated to occur at a depth of approximately 175 feet bgs. Range Resources independently determined the base of Cretaceous to occur at a depth of approximately 282 feet bgs at the Teal 1-H location. As such, surface casing of the Teal 1-H well is sufficiently deep to isolate usable quality groundwater.

Production casing was set at 8,648 feet MD and cemented with 364 sacks of cement. A CBL was run from 5,808 ft to 4,600 ft. The estimated top of cement occurs at 4,810 ft. The CBL indicates excellent cement bond across most of the cemented interval, which is designed to prevent migration of gas to surface casing.

A Mechanical Integrity Test (MIT) was performed on the Teal 1-H production casing on December 27, 2010. The MIT revealed no leaks in the production casing. A segmented radial cement bond log was run from 5,348 ft to 4,600 ft on December 30, 2010. The bond log revealed 100% bond with no microannulus or channels in the cement from 5,428 ft to 4,830 ft.

Bradenhead pressure was not observed in the Teal 1-H well during the RRC's August 2010 inspection. However, pressures of 14 psi and 12 psi were observed by RRC inspection in May 2013 and January 2014 respectively. RRC staff determined an APT of 204 psi for the Teal 1-H surface casing (Table 6). The maximum bradenhead pressure observed after three separate RRC inspections of the Teal 1-H well was 14 psi. As such, the bradenhead pressures observed in the Teal 1-H are below the APT and thus are not considered a threat to the integrity of surface casing.

Hydraulic fracturing within the Teal 1-H well bore was performed April 20 – 23, 2009. Range Resources submitted well stimulation reports and provided expert testimony in the January 19-20, 2011, hearing that hydraulic fracturing can be ruled out as a potential source of natural gas in water wells in the Silverado neighborhood.

Mund-Lipscomb Unit 1-H

The Mund-Lipscomb Unit 1-H well is a plugged gas production well that was operated by Carrizo Oil & Gas Inc. between March 2007 and December 2008. The surface location of this well is situated approximately one-half mile west of the Brazos River across from the Silverado neighborhood. The horizontal portion of this well extends to the north-northwest at a depth of approximately one mile below ground surface.

The Mund-Lipscomb 1-H surface casing was set at a depth of 647 feet MD with centralizers and cemented with 275 sacks of cement circulated to ground surface. The base of usable quality water was determined to occur at the base of the Cretaceous-age beds estimated to occur at a depth of approximately 300 feet bgs. As such, the surface casing of the Mund-Lipscomb well is sufficiently deep to isolate usable quality groundwater.

Production casing was set at 9,002 feet MD and cemented with 1,162 sacks of cement. The top of cement was set at 4,812 ft.

Hydraulic fracturing occurred in September 2006. The shallowest perforation was at 5,946 ft. Carrizo submitted well stimulation reports that revealed variability in measured treatment pressure during the first stage of hydraulic fracturing. Carrizo attributed the variability to changes in perforation efficiency. Carrizo further evaluated the stimulation data utilizing computer simulation of the hydraulic fracturing process performed at the Mund-Lipscomb well. The simulation results showed an average theoretical upward vertical fracture growth of 289 feet. However, since the model assumed ideal conditions, the results are not expected to reflect actual fracture geometry.

The well was operated from March 2007 until December 2008 when the well was shut in. Bradenhead pressure was not observed on the Mund-Lipscomb surface casing during RRC inspections in April and June 2011. The well was plugged July 2011.

Cement plugs were set at depths of 5,715 to 5,695 ft using 3 sacks of cement and 5,700 to 5,500 ft with 30 sacks of cement. The casing was cut at 3,484 ft. Additional plugs were set from 1,000 feet to 910 feet with 45 sacks of cement; 910 to 434 ft with 260 sacks of cement; 350 to 250 ft using 50 sacks of cement; and 15 to 3 ft using 5 sacks of cement.

Conclusions

Based on the information described above, Commission staff has determined that the evidence is insufficient to conclude that Barnett Shale production activities have caused or contributed to methane contamination in the aquifer beneath the neighborhood.

Analytical data collected by the RRC and by Range Resources in separate sampling events show that concentrations of methane have increased in some water wells since the initial investigation performed by Range Resources prior to the January 2011 RRC hearing. The isotope data also show that the gas more recently detected in some water wells appears to be less weathered than the gas detected previously. However, the isotope data are inconclusive as to a specific source of gas.

The occurrence of natural gas in the complainants' water wells may be attributed to processes unrelated to recent Barnett Shale gas production. Specifically, from natural migration of gas from the shallow Strawn Formation, exacerbated by water well construction practices whereby some water wells have penetrated "red beds" in the transition interval between the aquifer and the Strawn Formation.

Contribution of natural gas to the aquifer by nearby Barnett Shale gas production wells is not indicated by the physical evidence due to the following:

- Surface casings of nearby Barnett Shale wells are sufficiently deep to isolate useable quality groundwater. Records show that surface casing cement was circulated to ground surface at each well.
- Bradenhead pressures were either absent or sufficiently low when monitored so as not to be considered a threat to surface casing integrity based on the RRC's Bradenhead Pressure Management Guidance procedure.
- Records submitted to the RRC, including cement bond logs, show that tops of production casing cement occur in excess of 600 feet above the productive zones in each well.
- Mechanical Integrity Tests (MITs) performed by Range Resources on the Teal 1-H and Butler 1-H wells revealed no leaks in the production casing of each well, according to expert testimony provided at the January 19-20, 2011, hearing.
- Plugging records for the Carrizo Mund-Lipscomb 1-H well show that cement plugs were placed across the fresh water interval.
- Hydraulic fracturing was performed in the Barnett shale which occurs at approximately 5,700 feet below ground surface.

- The base of the aquifer and the Barnett shale are separated by approximately 5,300 feet of geological strata. Seismic reflection data submitted by Range Resources to the RRC do not show the presence of faults above the Barnett Shale beneath the neighborhood.

Further investigation by Commission staff is not planned at this time. However, Commission staff is aware of other ongoing studies of the occurrence of natural gas in groundwater in the Silverado neighborhood and welcomes the opportunity to review additional information that may become available in the future.

Based on the evidence of increasing methane concentrations in some water wells in the Silverado neighborhood, RRC staff recommends that neighborhood residents properly ventilate and aerate their water systems.

Peter G. Pope, P.G.

May 23, 2014

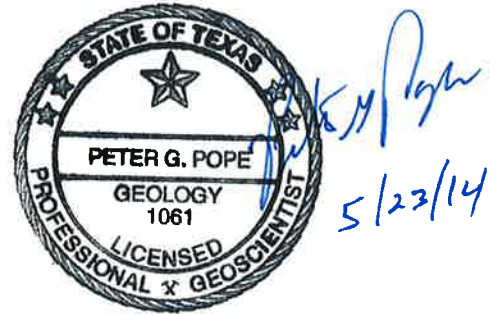


Table 1
Summary of Dissolved Gas Data
Complainants' Water Wells
Silverado on the Brazos Neighborhood
Parker County, Texas

Sample	Date	Butane mg/L	Ethane mg/L	Ethene mg/L	Methane mg/L	Propane mg/L
Well No. 2	12/28/2010	0.0025	0.36	ND	2.8	0.0041
Well No. 2	5/11/2012	ND	ND	ND	1.41	0.0027
Well No. 2	8/17/2012	0.0032	ND	ND	4.24	0.0213
Well No. 2	11/13/2012	0.0130	3.50	ND	20.1	0.0668
Well No. 2	2/18/2013	0.0031	1.74	ND	8.80	0.0242
Well No. 2	9/27/2013	0.0144	3.04	<0.005	21.9	0.145
Well No. 8	1/6/2011	0.027	0.6	ND	2.3	0.15
Well No. 8	9/27/2013	0.138	1.85	<0.005	8.6	1.28
Well No. 8A	9/27/2013	<0.005	0.449	<0.005	2.98	0.0912
Well No. 9	12/30/2010	ND	0.075	ND	0.67	0.016
Well No. 9	5/11/2012	0.0387	0.463	ND	2.44	0.186
Well No. 11	12/30/2010	ND	ND	ND	ND	ND
Well No. 11	5/11/2012	ND	ND	ND	0.00189	ND
Well No. 11	8/17/2012	ND	0.0022	ND	0.0504	ND
Well No. 11	12/1/2012	ND	ND	ND	0.0109	ND
Well No. 11	2/16/2013	ND	ND	ND	0.00572	ND
Well No. 13	12/30/2010	ND	0.13	ND	1	ND
Well No. 13	5/12/2012	ND	0.419	ND	2.65	ND
Well No. 13	8/18/2012	ND	0.334	ND	3.48	ND
Well No. 13	12/2/2012	ND	0.779	ND	5.64	ND
Well No. 13	2/17/2013	ND	0.442	ND	5.43	ND
Well No. 18	12/30/2010	ND	0.037	ND	0.96	ND
Well No. 18	5/12/2012	ND	0.0268	ND	0.586	ND
Well No. 18	8/18/2012	ND	0.0512	ND	0.944	ND
Well No. 18	12/2/2012	ND	0.0921	ND	1.26	ND
Well No. 18	2/17/2013	ND	0.0738	ND	1.03	ND
Well No. 24	12/30/2010	ND	ND	ND	ND	ND
Well No. 24	5/14/2012	ND	0.00581	ND	0.0184	ND
Well No. 24	8/17/2012	ND	0.00461	ND	0.0567	ND
Well No. 24	11/30/2012	ND	0.0136	ND	0.117	ND
Well No. 24	2/15/2013	ND	0.00318	ND	0.0434	ND
Well No. 26	12/29/2010	ND	0.015	ND	0.28	ND
Well No. 26	9/26/2013	0.048	1.45	<0.005	8.08	0.579

Samples analyzed using method RSK 175

Data collected by Range Resources, except 9/26/2013 and 9/27/2013 data collected by RRC.

NA = not analyzed

ND = not detected

Table 3
Calculation of Nitrogen Content
Well Nos. 2, 8, 8A and 26
Silverado on the Brazos Neighborhood
Parker County, Texas

<i>argon corrected</i>							
$N_{2True} =$	$N_{2Sample} - (N_{2Air} / Ar_{Air}) \times Ar_{Sample}$						
	$N_{2Sample}$	N_{2Air}	Ar_{Air}	Ar_{Sample}	N_{2True}	Date Collected	
Well No. 8	4.69	78.1	0.934	0.0426	1.13	Oct-10	
Well No. 8	37	78.1	0.934	0.424	1.55	Jan-11	
Well No. 8	6.41	78.1	0.934	0.0642	1.04	Sep-13	
Well No. 8A	78.78	78.1	0.934	0.888	4.53	Sep-13	
Well No. 2	63	78.1	0.934	0.742	0.95	Dec-10	
Well No. 2	26.03	78.1	0.934	0.312	-0.06	Sep-13	
Well No. 26	77.94	78.1	0.934	0.924	0.68	Dec-10	
Well No. 26	74.28	78.1	0.934	0.843	3.79	Sep-13	

Table 4
Summary of Gas Data - Isotech
Additional Samples
Silverado Neighborhood and Surrounding Areas
Parker and Hood Counties, Texas

Sample	Media	Date	Compositional Analysis													Isotopic Analysis					
			Helium He	Hydrogen H ₂	Argon Ar	Oxygen O ₂	Nitrogen N ₂	Carbon Dioxide CO ₂	Carbon Monoxide CO	Methane CH ₄	Ethane C ₂ H ₆	Propane C ₃ H ₈	iso- Butane iC ₄ H ₁₀	n- Butane nC ₄ H ₁₀	iso- Pentane iC ₅ H ₁₂	n- Pentane nC ₅ H ₁₂	Hexane+ C ₆ +	Methane δ ¹³ C ₁	Ethane δ ¹³ C ₂	Propane δ ¹³ C ₃	
PWS (Lake Country Estates)	Dissolved Gas in Water	7/7/2011	0.0062	ND	0.0694	0.032	0.623	0.037	ND	86.32	5.32	1.32	0.315	0.214	0.091	0.0246	0.0256	-48.3	-189.9	-33.76	-28.84
WW03 - Camzo	Well Head Gas	8/24/2011	0.0777	ND	0.586	11.77	0.91	ND	36.92	2.39	0.0652	0.0176	0.0075	0.0035	0.0012	0.0047	-49.47	-203.7	-33.75	NA	
WW05 - Camzo	Well Head Gas	8/25/2011	0.0696	ND	0.549	12.25	0.057	ND	36.06	3.03	1.37	0.21	0.316	0.0883	0.0556	0.0499	-47.24	-180.6	-34.34	-30.68	
Camzo Production Tubing	Barnett Production Gas	3/22/2011	0.0815	0.969	ND	ND	1.59	0.18	ND	78.22	12.88	4.24	0.444	0.94	0.172	0.184	0.0963	-47.51	-194.5	-36.83	-32.5
Camzo Casing Gas	Barnett Production Gas	3/22/2011	0.0781	0.045	ND	ND	1.5	0.37	ND	77.93	13.25	4.61	0.51	1.12	0.216	0.236	0.13	-47.67	-192.7	-36.92	-32.63
Teal PNG	Barnett Production Gas	1/4/2011	0.0857	0.0258	ND	ND	1.17	0.38	ND	77.33	13.08	4.6	0.66	1.31	0.356	0.402	0.605	-46.53	-184.1	-35.17	-31.03
Teal PNG Dup	Barnett Production Gas	1/4/2011	0.0857	0.0165	ND	ND	1.17	0.39	ND	77.37	13.09	4.59	0.658	1.3	0.351	0.393	0.587	-46.51	-183.4	-35.16	-31.02
Teal INJ	Barnett Production Gas	1/4/2011	0.0881	0.0074	ND	ND	1.18	0.44	ND	78.22	12.99	4.41	0.604	1.17	0.286	0.308	0.297	-46.53	-182.9	-35.19	-31.02
Butler PNG	Barnett Production Gas	1/4/2011	0.0868	0.0112	ND	ND	1.16	0.43	ND	77.6	13	4.5	0.638	1.27	0.341	0.383	0.585	-46.52	-184.4	-35.26	-31.2
Butler PNG Dup	Barnett Production Gas	1/4/2011	0.0873	0.0371	ND	ND	1.16	0.36	ND	77.57	13.01	4.51	0.641	1.2/8	0.346	0.391	0.605	-46.54	-183.7	-35.17	-31.02
Butler INJ	Barnett Production Gas	1/4/2011	0.0873	0.0073	ND	ND	1.17	0.44	ND	78.19	13	4.42	0.607	1.17	0.289	0.311	0.304	-46.5	-182.4	-35.15	-31.02
Butler INJ Dup	Barnett Production Gas	1/4/2011	0.0871	0.0071	ND	ND	1.18	0.42	ND	78.25	13	4.41	0.604	1.17	0.284	0.303	0.283	-46.55	-185.6	-35.17	-31.04
Butler 1-H	Barnett Production Gas	10/26/2010	0.0812	0.0062	0.0841	1.86	7.93	0.42	ND	71.28	11.79	4.04	0.551	1.09	0.276	0.296	0.282	-46.6	-183.9	NA	NA
Butler BNH	Bradenhead Gas	1/4/2011	0.385	0.0123	0.0281	0.054	6.55	0.023	ND	91.75	0.634	0.22	0.0395	0.0919	0.0345	0.0447	0.132	-61.55	-192.4	-40.18	-31.57
Butler BNH Dup	Bradenhead Gas	1/4/2011	0.383	0.0131	0.0281	0.043	6.55	0.024	ND	91.9	0.614	0.199	0.0342	0.0762	0.0268	0.0339	0.0755	-61.48	-196.8	-40.16	-31.48
Teal BNH	Bradenhead Gas	12/27/2010	0.152	0.0155	0.0815	0.094	70.18	0.007	ND	28.23	0.252	0.113	0.0237	0.0494	0.0167	0.0176	0.262	-75.09	-241.9	-35.45	-30.79
Well No. 1 (Silverado Neighb)	Dissolved Gas in Water	12/27/2010	ND	ND	1.49	0.29	78.37	0.3	ND	19.03	0.519	ND	ND	ND	ND	ND	ND	-46.53	-166	-20.61	NA
Well No. 1 (Silverado Neighb)	Dissolved Gas in Water	5/14/2012	NA	ND	1.59	0.069	79	0.33	ND	18.47	0.541	ND	ND	0.0004	ND	ND	ND	-46.24	-178.2	-20.5	NA
Well No. 1 (Silverado Neighb)	Dissolved Gas in Water	8/17/2012	NA	ND	1.44	0.029	80.01	0.3	ND	17.7	0.518	ND	ND	0.0004	0.0004	ND	ND	-46	-174.9	-20.3	NA
Well No. 1 (Silverado Neighb)	Dissolved Gas in Water	11/30/2012	NA	ND	1.44	0.15	75.39	0.33	ND	21.99	0.701	ND	ND	0.0013	ND	ND	ND	-46.36	-179.5	-21.9	NA
Well No. 1 (Silverado Neighb)	Dissolved Gas in Water	2/15/2013	NA	ND	1.39	0.12	76.2	0.3	ND	21.31	0.681	ND	ND	0.0003	ND	ND	ND	-46.44	-180.9	-21.2	NA

NA = not analyzed
 ND = not detected
 % = per mill
 % = mol %

Table 5
Water Well Completion Information
Complainants' Water Wells
Silverado on the Brazos Neighborhood
Parker County, Texas

Well No.	Total Depth (ft)	Screened Interval (ft)	Gravel Pack (ft)	Depth to Red Bed Marker (ft)
2	380	NA	NA	235-250 ⁽¹⁾
8	200	180-200	60-200	190
8A	120	100-120	60-120	not penetrated
9	225	160-225	120-225	210
11	NA	NA	NA	NA
13	200	NA	91-200	180
18	200	NA	92-200	180
24	300	220-260, 280-300	170-300	250
26	260	250-260	150-260	255

NA = information not available

⁽¹⁾ based on nearby well logs

Table 6
Annular Pressure Threshold compared with Bradenhead Pressures - Butler 1-H and Teal 1-H Gas Wells

