

**SUMMARY REPORT OF BRADENHEAD TESTING, GAS WELL REMEDIATION,
AND GROUND WATER INVESTIGATIONS
SAN JUAN BASIN, LA PLATA COUNTY, COLORADO**

**PREPARED FOR
COLORADO OIL AND GAS CONSERVATION COMMISSION
BY
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INTRODUCTION:

Geologic reports, newspaper accounts, and sworn statements taken from old time residents of La Plata indicate that methane seepage occurred at most of the current seep locations along the outcrop of the Fruitland Formation and that many water wells contained methane prior to either conventional or coalbed methane development. In the early 1990's, however, these conditions appeared to worsen in some areas. In response to these changes the Colorado Oil and Gas Conservation Commission ("COGCC") and the Bureau of Land Management ("BLM") in cooperation with the Southern Ute Indian Tribe ("SUIT"):

- Have undertaken numerous large scale ground water investigations;
- Have responded to individual landowners complaints to verify and to determine the nature, extent, and cause, if any, of these changes; and
- Have adopted aggressive procedures to ensure that older gas wells that may have been acting as conduits for migration of gas into ground water aquifers were remediated and that new and future gas wells can not act as conduits.

There are 4 main areas where high concentrations of methane have been detected in the ground water. The methane in 2 of these areas appears to be created by bacterial activity (biogenic gas) and not related to gas operations. Both existing and new water wells in these areas have a high likelihood of containing methane because biological processes are still generating it. Methane in the other 2 areas appears to be thermogenic and probably has migrated into ground water aquifers via natural features such as fractures or pre-1988 conventional gas wells in which the aquifers and/or Fruitland Formation were not isolated. Although remediation or plugging of the offending conventional gas wells has eliminated the manmade conduits for gas migration, water wells in these areas may contain methane that is still entrained in the water.

Based upon current analytical data, methane concentrations in ground water in La Plata County appear to be relatively stable. Comparison of data from 198 water wells that have been sampled at least twice indicate that the methane concentrations in 129 wells have not changed significantly, in 50 wells the concentrations have decreased, and in 19 wells the concentration have increased.

One factor that is changing is the number of domestic water wells being drilled. Approximately 45% of all water well permits issued by the State Engineer's Office in La Plata County were issued in the last 10 years. The obvious result of this is that more water wells could encounter methane that is already in the ground water.

The rigorous requirements for gas well completion, routine bradenhead testing, and rapid remediation of any downhole problems that have been in place for about ten years have greatly reduced or eliminated the potential for existing and future gas wells to act as conduits for gas migration into ground water aquifers.

BRADENHEAD TESTING AND GAS WELL REMEDIATION

The COGCC and the BLM have implemented bradenhead testing and gas well remediation programs that pertain to our respective jurisdictional wells. The purpose of these programs is to identify and remediate any wells that have the potential to contaminate ground water. Remediation of a well failing a bradenhead test proceeds even though there is usually no evidence that the particular well is contaminating ground water.

- There are 2150 wells in La Plata County. Approximately half of these wells are Fruitland Coal Wells and the other half are conventional gas wells usually completed in the deeper Pictured Cliffs, Mesa Verde or Dakota Formations.
- All gas wells in La Plata County have been tested annually since January 1991 to ensure that methane gas is contained in the well bore. Since that time approximately 254 wells have failed this test and have been repaired. Although most wells only need to be repaired once, some wells have been repaired twice making a total of 269 repair procedures.
- These repair procedures are of two types. One type of procedure replaces the well head seals. This is a mechanical repair that isolates gas leaking from the production casing to the surface casing at the surface. The other type of procedure requires placing cement outside of the production casing at depth to isolate ground water aquifers and other geologic zones from leaking gas.
- The number of wells requiring repairs has steadily dropped since the start of this program. In 1994 a high of 69 wells were repaired. The number of repairs in 1998 (the last complete year of statistics) was 18 wells.
- Only approximately 36 repairs of the total 269 repair procedures have been performed on Fruitland Coal wells. The remaining procedures have been performed on Dakota and Mesaverde wells. Dakota and Mesaverde wells are generally older wells which did not have the casing cemented through the Fruitland Formation to prevent coalbed methane migration.
- Since August 1988, COGCC rules (in cooperation with the BLM and the SUIT) have required that all Fruitland Coal wells have production casing cemented to surface. Cementing this casing to surface greatly reduces the possibility of methane gas collecting outside of the casing and migrating into

ground water aquifers.

- Approximately 1050 Fruitland Coal wells have been drilled in La Plata County. Of these wells approximately 800 have been drilled since this cementing requirement was initiated.

ORPHANED WELL P&A – COGCC ERF and INDUSTRY FUNDS

COGCC identified 8 orphaned wells in La Plata County. These wells had been drilled from 1927 through 1963. In 1989 several active operators paid for the plugging and abandonment (“P&A”) of one of these wells. Between 1991 and 1998 COGCC used the Environmental Response Fund (“ERF”) to P&A the other 7 orphaned wells. Until plugged these wells were releasing gas in situations where aquifers were not properly isolated. The locations of these wells are shown as black dots on Map 1.

GROUND WATER QUALITY

Extensive ground water monitoring has been intertwined with this rigorous program of gas well testing, remediation, and plugging. Since 1990 numerous studies have been conducted to determine the concentrations of methane in water wells and the stable isotope composition of the methane. The analytical results have been used as a tool to identify the likely sources of the methane. Water wells have been resampled to determine whether changes in concentration have occurred as a result of gas well remediation. Additional information has been gathered about the ground water aquifers and the Fruitland Formation in La Plata County.

Ground Water and Gas Sampling and Analysis

Ground water samples have been collected from approximately 600 water wells and 26 gas wells in La Plata County. These data have been used to identify the potential sources of the methane gas detected in a number of water wells and to track changes in concentrations. In addition, an extensive database of other water quality parameters has been established. The largest single event occurred in 1994 when approximately 383 water samples were collected and analyzed. This work was co-sponsored by COGCC and BLM. The 1994 methane results are shown on Map 2.

The various ground water sampling and analysis events are summarized below:

- 1990 – USGS collected water samples from 70 domestic wells in the Animas River valley, south of Durango for chemical analysis.
- 1993 – BLM investigated domestic water wells in the vicinity of the HD Mountains as a follow up to the “HD Mountains EIS”. The study was expanded to include approximately 200 domestic water well tests.
- early 1990’s – Ignacio-Blanco Groundwater Task Force and the State of Colorado Division of Water Resources performed other methane in ground water studies, but the sampling and analytical techniques were different than those used by USGS and BLM so direct comparison of results was not possible.

- 1993 - Pine River Fruitland Coal Outcrop Investigative Team (IT) requested additional data gathering and technical assistance from BLM.
- 1994 – COGCC and BLM teamed up to evaluate methane occurrence in the aquifers of La Plata County beyond the Pine River Area and not previously investigated. The goal of the project was to acquire information to determine whether gas wells had impacted the shallow ground water aquifers in La Plata County. A total of 383 sites were sampled including, 320 water wells not tested in the 1993 BLM study, re-testing 49 sites visited in 1993, and 14 new sites in the Pine River Ranches Subdivision area. The methane results for this event are summarized on Map 2.
- 1995 – BLM conducted a further investigation of an area southeast of Durango in the Animas River valley near the junction of Highway 550 and Highway 160. Nine additional domestic water wells and 5 gas wells were tested plus several other domestic water wells were re-tested.
- 1996 – BLM sampled approximately 100 wells in the HD Mountains and Bondad/Sunnyside Areas to monitor how effective gas well remediation was on reducing methane concentrations.
- 1998 – COGCC and BLM collected water samples from approximately 140 wells. These wells had been previously sampled and were located near remediated gas wells.
- Analytical results of various sampling events were compared to determine whether gas well remediation was reducing the concentration of methane in the shallow aquifers. This type of comparison is difficult because a certain amount of fluctuation in methane concentration occurs normally in any water well containing methane. From this comparison it appears that the methane concentration has decreased in 50 water wells, increased in 19 wells, and remained about the same in 129 wells.

The results of this comparison are depicted as arrows on Map 1. Arrows pointing down indicate the concentration of methane appears to be less in the most recent sample than in the previous sample; arrows pointing up indicate the concentration appears to be more; and arrows pointing sideways indicate no significant change in concentration.

- Industry ground water sampling: BP Amoco monitors 20 domestic water wells for the Tiffany Project. J.M. Huber monitors 24 domestic water wells as part of their 1998 Development Plan.

Sources of Methane Gas

In most instances where the concentration of methane in the ground water is sufficient to collect a separate gas sample, isotope analysis has been performed on the methane. This analysis has been used to determine the ratio of normal carbon (^{12}C) to the stable isotope carbon (^{13}C) and is referred to as delta carbon-13 ($\delta^{13}\text{C}$). The carbon isotope ratios determined for natural gas produced in the San Juan Basin are summarized below:

FORMATION	FROM $\delta^{13}\text{C}$	TO $\delta^{13}\text{C}$
Fruitland Coal	-41 $^0/_{00}$	-49 $^0/_{00}$
Pictured Cliffs	-39 $^0/_{00}$	-42 $^0/_{00}$
Mesa Verde	-33 $^0/_{00}$	-38 $^0/_{00}$
Dakota	-30 $^0/_{00}$	-34 $^0/_{00}$
Source: BLM		

$\delta^{13}\text{C}$ values such as these indicate a “thermogenic” origin for the methane. $\delta^{13}\text{C}$ values that are lighter than $-49 \text{ }^0/_{00}$ indicate a “biogenic” origin for the methane

The $\delta^{13}\text{C}$ values for samples from water wells are depicted on Map 3. The values can be grouped into 4 general areas:

- Bondad Area in the Animas River valley. $\delta^{13}\text{C}$ values suggest thermogenic sources, which probably included conventional wells, orphaned wells, and naturally occurring structural features such as fractures. Remediation of the conventional wells and P&A of 3 orphaned wells have eliminated a continuing man made source of gas. Natural conduits and methane already entrained in the ground water still exist.
- Los Pinos River Valley, predominately thermogenic. In the Pine River Ranches Subdivision the domestic wells with highest concentrations of thermogenic methane are no longer in use. South of the Pine River Ranches Subdivision, remediation of older gas wells and P&A of 1 orphaned well have eliminated the continuing man made vertical conduits for gas migration. Natural conduits and methane already entrained in the ground water still exist.
- Central Area, north of Ute Line (T34N R7W, T34N R8W, T35N R7W, and T35N R8W) predominately biogenic methane.
- Fruitland Outcrop Area, predominately biogenic methane.

The few samples with values that are more “thermogenic” in origin than those of produced gas from the formations shown above could be explained by either gas migrating up natural features from deeper formations or alteration of the sample.

Fluctuations in Methane Concentration

In 1994, several water wells in the Pine River Ranches Subdivision were sampled repeatedly over a 5 month period. The results showed that the concentration of methane in a water well fluctuate over time. Methane concentration in one of these wells fluctuated approximately + and – 7 mg/l methane. This natural fluctuation makes predicting trends difficult.

Ground Water Quantity Concerns

In addition to water quality concerns, there continue to be concerns regarding impacts from gas well completion activities to water quantity in domestic water wells. COGCC has investigated several of these types of complaints. To date we have not found any indication that activities associated with gas wells have impacted ground water levels or quantity of water.

In at least 2 instances the drillers logs for the wells indicated that the wells were completed in shales and only produced limited amounts of water during the initial well tests conducted by the water well contractor.

The generalized geology of the San Juan Basin (USGS, 1979) is shown on Map 2. Tertiary aged continental deposits underlie most of the area of ground water concern. The Animas Formation is a thick wedge of fluvial, composed of varicolored shale with interbedded breccia, conglomerate, and tuffaceous sandstone with some very thin coal beds. (These thin coal beds have been encountered and noted in domestic water wells completed in the Animas Formation. They are another potential source of methane in ground water.) The Nacimiento Formation is composed of interbedded sandstone and shale. The San Jose Formation is composed of interbedded sandstone, shale, and conglomerate. These fluvial deposits are extremely heterogeneous in nature and would account for localized variations in water quantity and quality.

In addition, seasonal fluctuations in ground water levels of more than 10 feet have been recorded in 1 of the 2 water wells continuously monitored by the USGS in the Florida Mesa area, southeast of Durango. Water wells in this 39 square mile area are completed in older gravels and alluvium that cap the mesa and could be expected to have seasonal fluctuations in water levels regardless of the wells' domestic usage. The primary sources of recharge to this ground water system is infiltration of irrigation water (80%) and seepage from unlined irrigation canals and ditches (15%). Only about 5% of recharge in this area comes from infiltration of precipitation on non-irrigated areas. Studies such as this of other areas would be useful for understanding the ground water resources and water balance elsewhere in La Plata County.

Increasing Number of Water Wells

Map 4 was constructed using records available from the State Engineer's Office for La Plata County. The dramatic increase in the number of water well permits is shown. 45% or 3,140 of the approximately 7,000 total water well permits were issued during the 1990's. The obvious result of this is that more water wells could encounter methane that is already in the ground water.