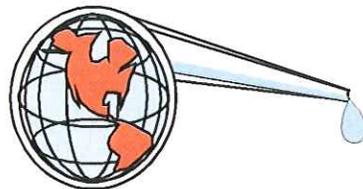


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Analysis of the West Divide Creek Seep

Prepared for Garfield County by Science Based Solutions LLC



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Executive Summary

The recent complaint by Lisa Bracken stated that there has been continued seepage from the West Divide Creek (WDC) site with an additional seep or increased activity associated with the existing seep in summer of 2008. Ms Bracken asks to have the drilling moratorium re-instated until more study can be completed to better understand impacts from further drilling activity in the area. Olsson Associates (formerly Cordilleran) has continued to sample the monitoring wells quarterly since 2004, with a few wells that have been sampled more frequently. In order to evaluate the situation with regard to the WDC seep all the available data on the COGCC website related to the SDC seep and submissions by Ms. Bracken were examined.

The data show that the West Divide Creek seep levels of methane and benzene started to decline in early 2004 with the initiation of remediation activities. Active air-sparging is currently continuing. The benzene levels in the groundwater wells have continued to decline overall within an overall seasonal cycle. Projection of the continued decline in benzene shows that remediation activity will likely need to continue past 2012 to reach the regulatory maximum (5µg/l). The methane levels in the monitoring wells have remained essentially constant within the seasonal cycles. Both methane and benzene levels become depressed during the spring runoff, and then increase to peak in the winter samples. The isotopic data for methane and the presence of associated hydrocarbons with most methane samples indicate the source is thermogenic with little or no contribution from biogenic sources.

The data support the basic observations of Ms. Bracken. In fact, the data indicate there has been continued seepage of methane and associated hydrocarbons with the only significant decreases in gas and associated hydrocarbon concentrations in groundwater and stream samples during peak stream flow. The high flow periods (early summer) dilute the surface and groundwater levels and likely account for the seasonal pattern. The high surface and groundwater levels of methane and benzene in the winter coincide with low flows, ice in the stream and low vegetative and animal activity levels tending to mask the visible impact from high continuous discharge of hydrocarbon seepage.

The original conceptual model of the seep as a single source that was sealed off by the remedial cement in the Schwartz 2-15B well is not entirely supported by the data. The continued declining trend in benzene is as expected assuming all the benzene was emplaced by the original leak in the stream sediments, and thus represents a limited source declining over time as mass is removed. The continued discharge of thermogenic methane does not appear to be consistent with this model. The continued leaking of C1-C6 hydrocarbons without a declining trend could indicate a slow leak from a large source, continued leaking from the Schwartz 2-15B well, or other sources that continue to vent through the path established in 2004 by the original seep. The precise location of any additional gas sources cannot be positively identified with the current data other than as thermogenic.

Introduction

In response to the recent complaint by Garfield County resident Lisa Bracken, the Board of County Commissioners directed Science Based Solutions LLC to conduct an independent review of the available information to evaluate the validity of Ms. Bracken's complaint concerning the West Divide Creek (WDC) seep site and the renewed activity on her property. The available data from the Colorado Oil and Gas Conservation Commission (COGCC) included methane and BTEX data for the monitoring wells and stream sampling locations at the historic seep on a quarterly basis and includes surface water parameters taken during sampling. The data also includes isotopic data for gas samples from some of the groundwater and surface water sampling sites for some sampling times. The most current sampling round is from March 2009 and this report is based on that data.

The COGCC website did not have all data related to the WDC seep site publicly available. None of the data is available in electronic tabular form. The data available was included as text or image appendices in the quarterly reports. There were numerous reports missing and the reports were either not consistent in data reported in the appendices, or reported no data. The most difficult data to obtain from the WDC seep site was the inorganic water quality data, followed by the isotopic data. There was also limited chemical data from surface and groundwater samples as well as limited data from homeowner wells. All the available data from the COGCC website's library is compiled in Appendix 1 and included as a Microsoft Excel file. There is additional data under the images portion of the website, but access requires a unique identification number. Without all the information this report is limited in scope.

The COGCC allowed the number of sample locations and the list of analytes to be reduced in 2006 (COGCC, 2006), therefore not all parameters are available for the full duration. Very limited homeowner water well sampling data is available as the original order did not specify that this data be publicly available. The County may wish to request homeowners to supply any information related to the WDC seep and remediation be submitted for County review and evaluation so the County can independently provide assessment. The County may also wish to request all the data available regarding the WDC seep monitoring program and associated COGCC staff reports and letters.

Ms Bracken reported to COGCC that in spring and summer 2008 several indicators of increased seep activity were observed. Some of these areas of increased activity were at the original seep, while others were slightly downstream of that location. These included areas of dead vegetation, biofilm sheen in portions of the stream, increased iron-reducing microbial activity, bubbling, and dead invertebrates and reptile. These are all indicators of the normally oxygen-rich environments becoming more reducing, many of which were observed in the 2004 seep. Figure 1 is the map submitted by Ms. Bracken detailing her observations of the 2004 and 2008 activity at or near the WDC seep.

The original findings by the COGCC were that the EnCana Schwartz 2-15B well suffered a loss of cement that allowed the well to vent gas in an uncontrolled fashion for approximately 55 days until a remedial cement job stopped the gas venting. The uncontrolled gas moved vertically up the well bore until it encountered a near-vertical fault at about 3000 feet below the surface that terminated in the West Divide Creek. The estimated 100 million cubic feet of gas and associated hydrocarbons contaminated the sediments of the creek and surface water in the stream exceeded

the Colorado State standard for benzene. The site was fully characterized and the remediation plan for air sparging downstream of the impacted area was approved and equipment installed in early 2004. Active remediation and quarterly monitoring has continued to the present (Cordilleran, 2008). Figure 2 is the map from the report by Olsson Associates showing the surface sample and groundwater sampling locations and the air sparging installations. Ms. Bracken's property is approximately 1450 feet north of the historic seep. The water level (potentiometric) contours show that the subsurface streambed and shallow groundwater flow moves roughly parallel and slightly west of the active stream channel. The stream system includes the surface stream and the alluvial stream channel. Groundwater in the stream channel is closely connected with the surface flow, while groundwater in the underlying consolidated Wasatch Formation is poorly connected.



Figure 1. West Divide Creek seep activity in 2004 and 2008 submitted by Lisa Bracken.

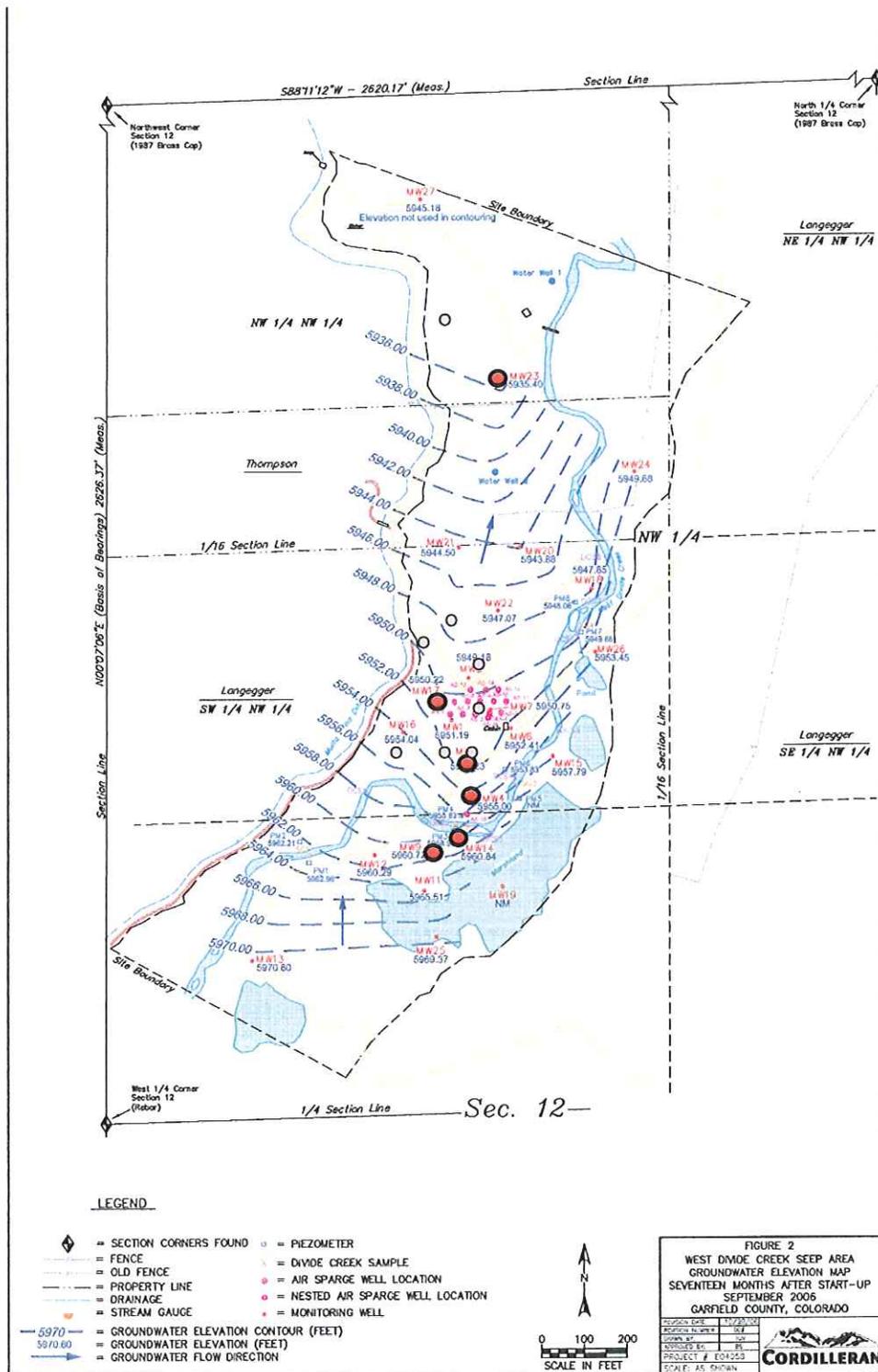


Figure 2. Base map from Olsson Associates showing water table levels and locations for surface and groundwater sampling and remediation wells. Gray dots highlight the locations of wells shown in graphs (MW2, MW04, MW09, MW14, MW17, and MW23).

Analysis

The historic database from the most current Cordilleran (now Olsson Associates) report of April 23, 2009 was downloaded from the COGCC website in order to evaluate the current state and any changes in seep activity. All historic samples had methane and BTEX data. Figure 3 shows the most recent delineation of the seep based on the methane data. The center of the seep is approximately 1500 feet south of the Bracken domestic water well. The dimensions of the seep are essentially unchanged over the last three years. Appendix 2 shows the seep maps of methane contours for December 2006-2008 for comparison.

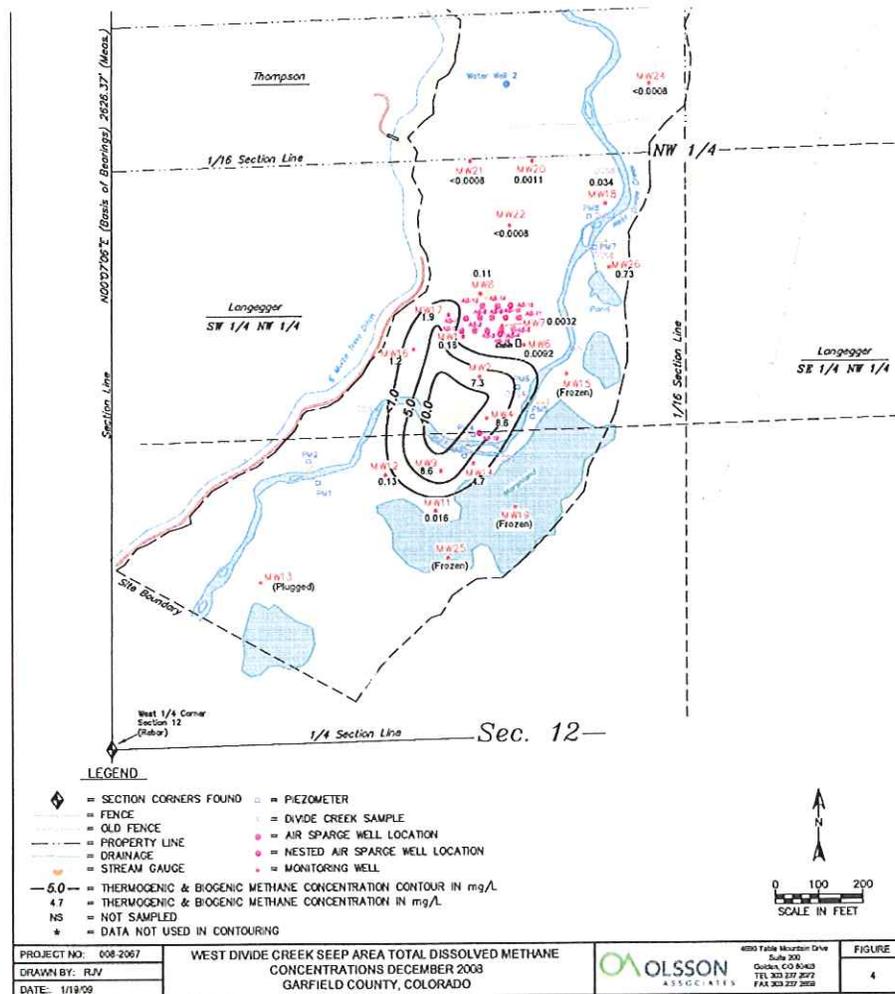


Figure 3. Benzene versus time in selected monitoring wells. See Figure 2 for well locations.

The pattern of emission from the West Divide Creek seep has been one of declining benzene from an initial value of approximately 300µg/L to about 150µg/L (see Figure 4).

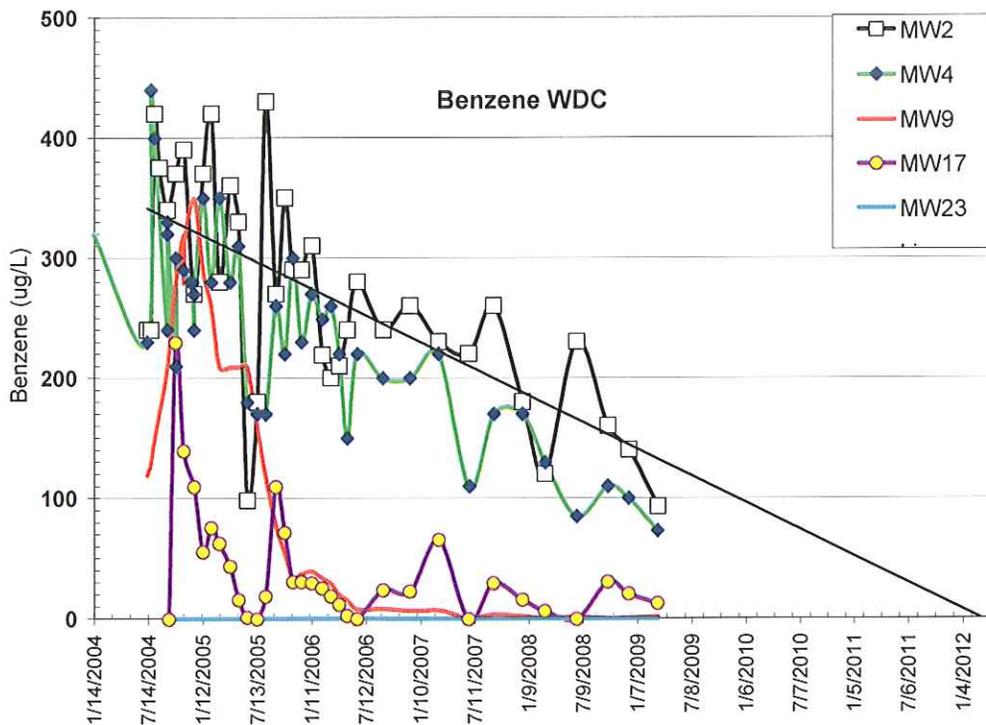


Figure 4. Benzene versus time in selected monitoring wells. See Figure 2 for well locations.

The current benzene concentrations in groundwater are still 30 times the Colorado State limit ($5\mu\text{g/L}$) for this watershed. Projection of the continued decline in benzene was made assuming the most rapid relationship (linear). The result shows that remediation activity will probably cause benzene to continue to decline and meet the regulatory maximum ($5\mu\text{g/l}$) by early 2012 at the earliest.

After the initial peak values, methane concentrations were stabilized and have remained essentially constant (see Figure 5). The methane activity shows a seasonal trend with increasing concentrations after spring runoff with peak values in the winter-to-early spring samples. This pattern is consistent with the highest values occurring when stream flow (and dilution) is lowest. The figure also shows the times that activity in the creek noted by Ms. Bracken and the times that Mr. Eubanks noted unusual activity in his well for reference during later discussion. Stream values follow the same seasonal pattern of variation, but at much reduced levels since the stream samples are in contact with the atmosphere (see Figure 6).

Isotopic data was not available from the COGCC website for the period between 2004 and September 2006. In addition, there was no isotopic data available for the March, June and December 2006 sampling rounds, March and June 2007 sampling rounds and March 2008 sampling round. However, the available data from the established seep show almost no variation in carbon isotopic values with time. All the samples are clearly thermogenic. The isotopic data for the sampled methane gas included 3 samples from 2006, 21 samples from 2007, 12 samples from 2008 and 7 samples from 2009 (see Figure 7). The data is also compiled in Appendix 1.

All the gas samples available for this three year period were from groundwater monitoring wells except one surface water sample in 2007 (location DCS2). All the samples plot squarely within the thermogenic methane field excepting 2 from MW23 (northern-most well used in analysis, see Figure 2 for location). The isotopic values for the monitoring wells are almost identical to gas samples taken from producing wells in the Mamm Creek field (URS 2006, PPA 2008).

Most of the wells with methane isotopic thermogenic signatures sampled between June 2007 and March 2009 also had ethane, ethane and propane or the entire homologous alkane series detected reinforcing the interpretation as thermogenic. Specifics for associated hydrocarbon presence are compiled in Appendix 1. The detailed gas phase analyses can be found in the quarterly reports submitted to COGCC by Olsson Associates.

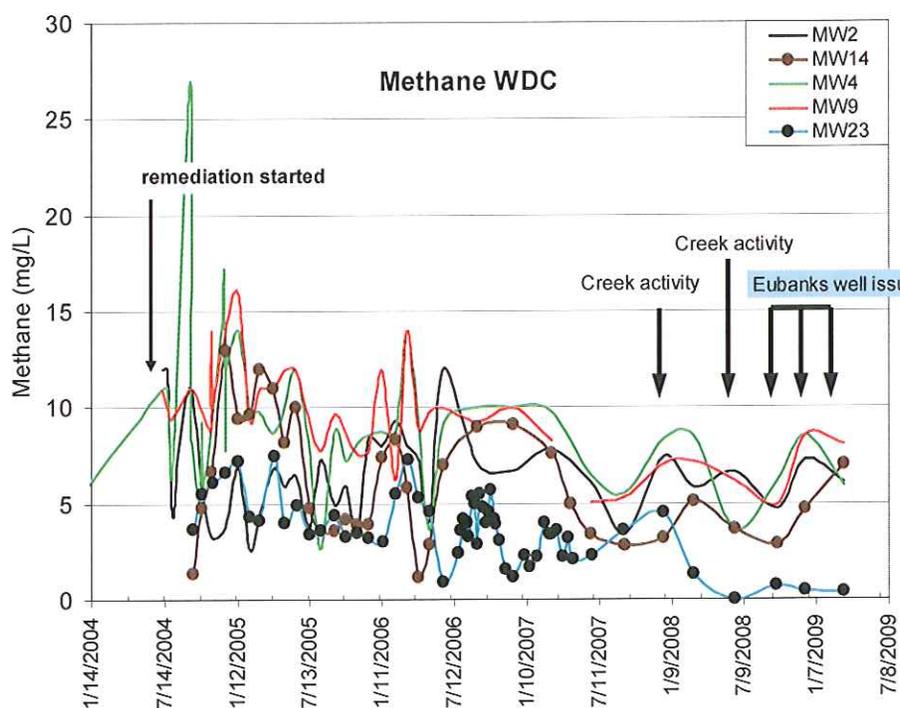


Figure 5. Methane versus time in selected monitoring wells. See Figure 2 for well locations.

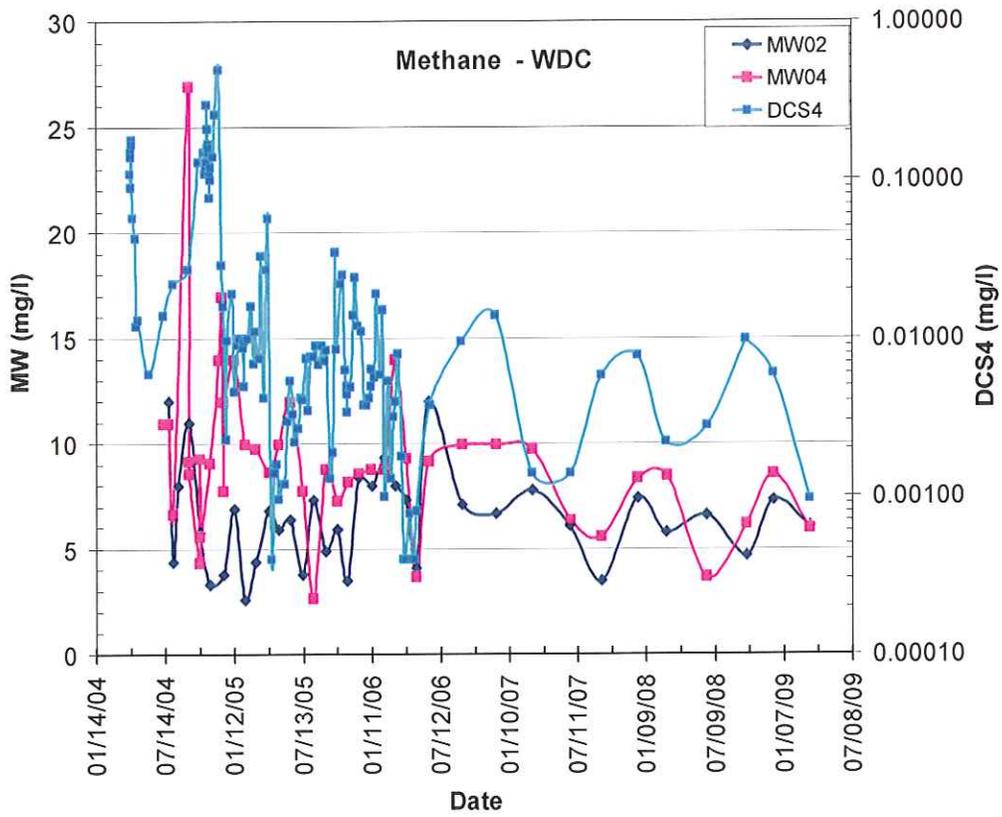


Figure 6. Methane values versus time from selected wells and surface samples.

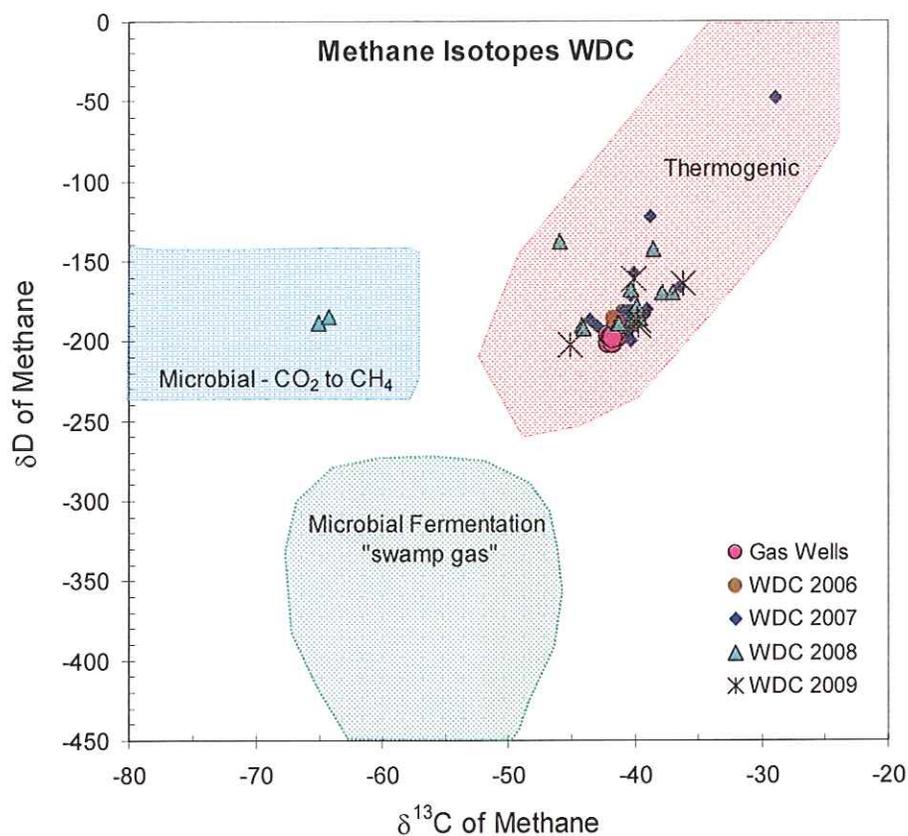


Figure 7. Carbon versus hydrogen isotopic values for methane samples from available locations.

Discussion

Methane emissions have stabilized since 2005, but do not show an overall decline. The methane source is thermogenic with little or no evidence for a biogenic component with the exception of MW23. This well is farthest away north of the seep center, but that well does have detections of higher hydrocarbons indicating a thermogenic component to the methane or extremely reducing conditions. All the wells show almost no variation in carbon isotopic values with time and are consistent with continued emission from the original seep that is affecting the surrounding area. Figure 8 uses the recent and historic data from the seep to show there has been almost no change in the isotopic content of the carbon isotopes with time.

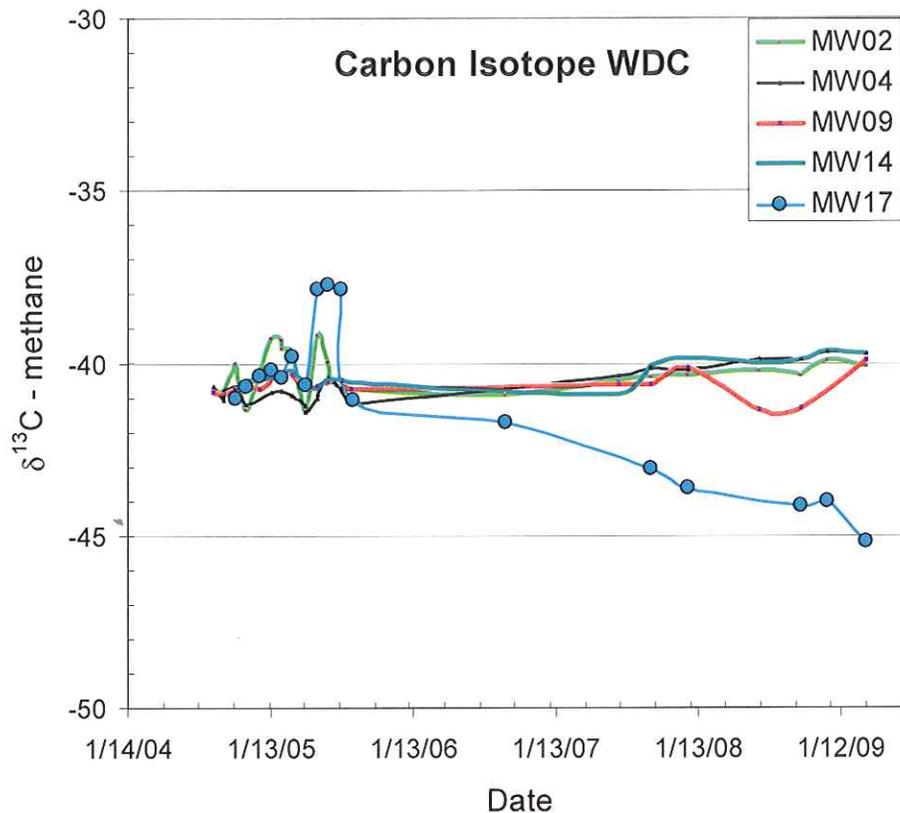


Figure 8. Carbon isotopic values for methane samples versus time from available locations.

The source of the methane at well MW23 is open to interpretation. While it is microbial, the source of the CO₂ is unknown. Based on established fractionation during methane formation the δ¹³C value of the carbon dioxide is between -9 and +15. This suggests the source is local decay of organic matter rather than thermogenic activity is the source of the carbon dioxide. However, the December 8, 2008 sample reported both ethane and propane detected. While ethane is rarely detected in biogenic samples, the presence of propane supports a thermogenic component.

In contrast to the relatively constant methane values, benzene values show a continued decline. These data are interpreted as declining seep activity for benzene due to mass removal of the primary source and microbial degradation of the remaining benzene. The primary source of benzene is assumed to be the contaminated stream sediments with little or no continued additional source added from the fault. However, methane and associated hydrocarbons continued to be released at an essentially constant rate. If the original source from the Schwartz well was the sole supply of methane and associated hydrocarbon mass, it would be expected that a declining trend would have started for the C1-C6 hydrocarbons as the finite source is exhausted.

The constant rate of methane discharge suggests the original source is still supplying the seep with the gaseous hydrocarbons, another source or sources are venting through the pathway

established in 2004, or the mass of original hydrocarbons has not been significantly depleted over the past four years.

Ms. Bracken has made a number of specific observations to support her complaint. These are detailed in Appendix 3 with answers. While the data is lacking to evaluate many of the specific observations, the observations are consistent with continued or renewed seep activity in the vicinity of the historic seep. The observations are also supported by observations by Mr. Jim Eubanks who owns property adjacent to the seep. His observations concern the behavior of his water well and stock pond and are consistent with a strongly-reducing environment in the vicinity of his source of drinking and stock water.

Referring to Figure 4 we can see that the time when Ms Bracken noted unusual activity in the stream and Mr. Eubanks observations of unusual behavior in this well coincide with periods of relatively elevated methane emissions and lower stream flow. The majority of the observations collectively termed "increased seep activity" concern surface expressions of the seep including vegetation stress, surface bubbling and elevated abundance of reduced-environment microbes (iron-reducing bacteria). These observations are also consistent with the data that show continued seep activity and such impact would be more visible in the summer periods of low flow and higher vegetation stress.

The available data from the Bracken domestic well which is approximately 300 feet north of MW23 shows similar patterns of seasonal variation in hydrocarbons to the main seep, but at substantially lower levels (see Appendix 1). This is consistent with the decrease in seep impact with distance seen when comparing MW23 values with those near the center of the historic seep. The impacted area is coincident with or within 1500 feet of the original and still active seep, and continued hydrocarbon seepage appears to be creating reducing conditions in the area.

Conclusions

The data show that the West Divide Creek seep levels of methane and benzene started to decline in early 2004 with the initiation of remediation activities. Active air-sparging is currently continuing. The benzene levels in the groundwater wells have continued to decline overall within an overall seasonal cycle. Benzene levels become depressed during the spring runoff, and then increase to peak in the winter samples. Projection of the continued decline in benzene shows that remediation activity will likely need to continue past 2012 to reach the regulatory maximum (5µg/l).

Low-term quarterly monitoring data show there has been continued and relatively constant seepage of methane from the West Divide Creek (WDC) site since the initiation of remediation. The groundwater monitoring wells and stream measurements show cyclic patterns with the lowest concentrations in the monitoring wells during the highest flow in the stream.

The isotopic data for methane and the presence of associated hydrocarbons with most methane samples indicate the source is thermogenic with little or no contribution from biogenic sources.

The available data support the basic observations of Ms. Bracken. The high flow periods (early summer) will dilute the surface and groundwater levels of hydrocarbon emissions and likely account for the seasonal pattern. The high surface and groundwater levels of methane and

benzene in the winter coincide with low flows, ice in the stream and low vegetative and animal activity levels tending to mask the visible impact from high continuous discharge of hydrocarbon seepage.

The original conceptual model of the seep as a single source that was sealed off by the remedial cement in the Schwartz 2-15B well is not entirely supported by the data. The continued declining trend in benzene is as expected, but continued discharge of thermogenic methane is unexplained by this model.

The continued leaking of C1-C6 hydrocarbons without a declining trend could indicate a slow leak from a large source, continued leaking from the Schwartz 2-15B well, or other sources that continue to vent through the path established in 2004 by the original seep.

Recommendations

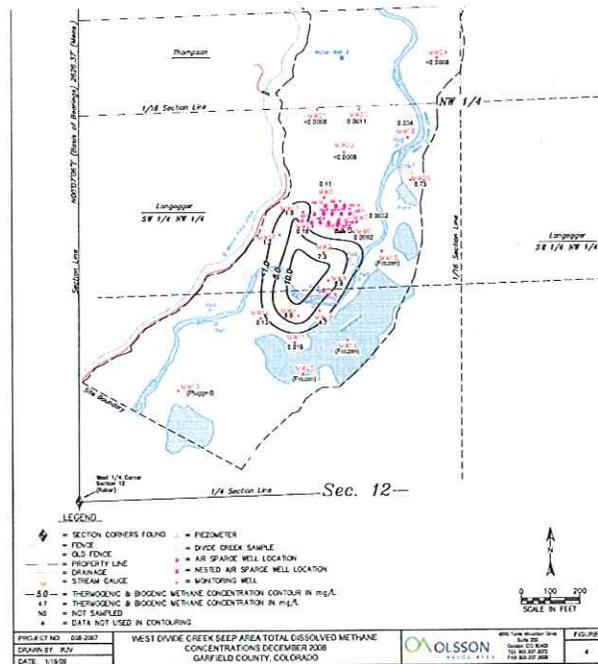
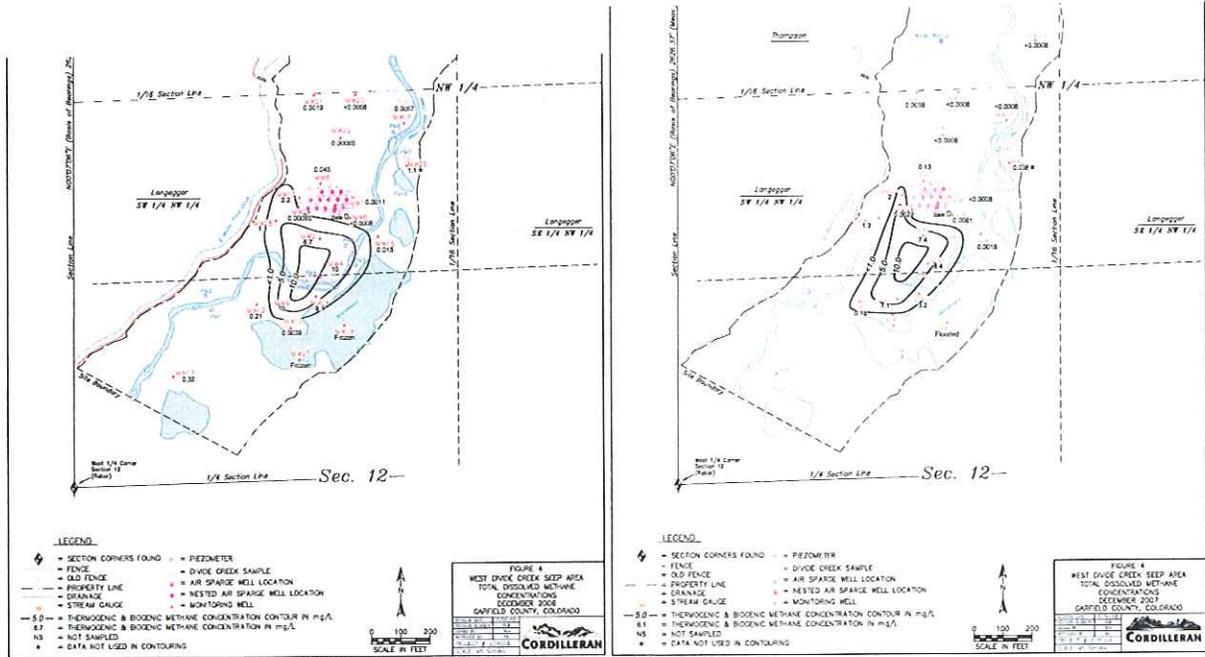
Garfield County should ask COGCC to supply all the data from the seep monitoring program, associated reports, and post-seep complaints and responses for the County to archive and for future review and analysis.

Garfield County should ask COGCC staff to prepare an evaluation of the continued seepage of methane and associated hydrocarbons to either estimate the likely duration of continued seepage if the source is the original discharge from the Schwartz 2-15b well or identify the additional source(s) of hydrocarbons and provide appropriate remediation.

Garfield County should ask impacted homeowners in the area to voluntarily provide data from their water wells that have been sampled by the State or gas producers to supplement the State data for future review and analysis.

Appendix 1 – provided as electronic files (MS Excel) of all publicly-available dissolved hydrocarbon and accompanying isotopic data for the Divide Creek seep.

Appendix 2. Methane contours at the West Divide Creek seep for December 2006, 2007 and 2008.



Appendix 3. Specific Complaints by Lisa Bracken with current answers in italics.

On five different occasions thermogenic methane has been detected in groundwater on our property. Those dates are: January 05, 2006 (MW23) / March 12, 2007 (MW23) / June 17, 2008 (MW27) / September 30, 2008 (MW23) / October 14, 2008 (MW23).

Thermogenic methane is identified by isotopic content. The only data publicly-available on the Bracken/Eicher property is for well MW23. Two samples from the COGCC website are available, September 2008 and December 2008. Additional pre-2006 analyses were available from the 2006 URS Phase I report. Both samples had isotopic signatures consistent with carbon dioxide reduction. This source of methane is biogenic, however, is not associated with fermentation, the common form of biogenic methane generation. The data do not currently support thermogenic sources for this gas. However, CO₂-reduction processes are only significant in reducing environments which are consistent with spatial proximity to hydrocarbon seeps. However, the sample from December 8, 2008 had both ethane and propane detected. While ethane is rarely detected in biogenic samples, the presence of propane supports a thermogenic component.

From December, 2006 onward, our domestic water well as well as MW23 and MW27 seem to have encountered spikes in chloride, sodium and TDS.

This data was not available except for a few sampling rounds and is insufficient to establish temporal trends.

On December 06, 2006 and again on March 13, 2007 (referring to two of the five dates where thermogenic gas was detected in the groundwater but negated by Cordilleran and the COGCC) methane, propane and ethane were detected in the ground water in an area near the seep discovered in June of 2008.

There were no publicly available isotopic samples from December 2006 or March 2007 to confirm these details. However, all publicly available samples of methane from the seep area groundwater monitoring wells had ethane, ethane and propane or the entire homologous series present with only a few exceptions.

ADDITIONAL SAMPLING: this occurred based on a dramatic increase in bubbling activity we observed in West Divide Creek. The sampling was conducted by EnCana/Cordilleran (ECA) in two different (in stream) beaver pond areas: Sample ID: "EDC1" and Sample ID: EDC2"
Sampling date: 11-02-07.

There is no publicly available tabular data or report from COGCC in the Piceance Basin portion of the Library this incident.

On June 30, 2008, I filed a complaint (Doc Num: 200191616) with the COGCC relative to our discovery of significant evidence of a methane seep occurring in areas all across our property and on Pepi Langegger's property in the area of the 2004 main seep. On Langegger's property, areas of the bank appeared as they did in 2004 when they were covered with iron-reducing bacteria and bio-film sheen, and were noted to be saturated with hydrocarbons and in near proximity to seeping benzene. Later in the summer we found evidence of the seep (iron-reducing

bacteria and biofilm sheen) on Steve Thompson's property also. By then, seep activity across all three properties seemed to be more prolific in certain relatively confined areas, while in other areas, only affected pockets were observed. Observations on our property included various environmental anomalies like: mineral/salt precipitate in soils; flammable bubbles accumulating abundantly in only one area of the creek (no longer a beaver pond); unusual sandstone erosion (1/8" holes in stone); soapy substances leaching to surface; a proliferation of bio-film sheen and iron-reducing bacteria in areas of spontaneous groundwater upwelling which occurred in two locations (approx. 20' N and approx. 150' S of creek bed); propane/butane-like odors, suddenly dead and/or distressed mixed-species vegetation; dead and/or partially paralyzed wildlife.

There is no publicly available tabular data from COGCC in the Piceance Basin portion of the Library this incident.

In response to our June 30, 2008 seep complaint, but nearly three months later, Margaret Ash (COGCC – enviro) sampled our property in several locations on three separate dates 09-25-08 / 10-14-08 / 12-04-08. Soil and water samples (including water from both upwellings on North and South sides of the creek) as well as one plant tissue sample were collected. Because of the difficult format of the data records, as well as confusion relative to sampling locations, we have been largely unable to comprehend the data. Ms. Ash compiled a useful synopsis, dated December 31, 2008 (Re: Alleged Gas Seep Investigation / COGCC # 200191771 and # 200200082 / Garfield County Colorado), of results including an engineering overview. Ms. Ash also pointed out that Lot # D8J50119 corresponds to our domestic water well.

There is no publicly available tabular data or report from COGCC in the Piceance Basin portion of the Library this incident.

EUBANKS: On July 16, 2008 – according to Mr. Eubanks (a neighbor – perhaps .5 mile SW) noticed his silver (ware) became tarnished when left in a pan of tap (well) water overnight. This effect lasted approx. 1 week – and in August, worsened.

This statement was confirmed by Mr. Eubanks.

As I understand it, between August and September, 2008 a red powdery substance began collecting in the bottom of and pitting the galvanized metal of Mr. Eubank's stock tank. Samples were collected by EnCana. This powdery substance was later collected in an empty sample bottle from the bottom of the stock tank by Mr. Eubanks and it "globed" together and exhibited adhesive-like properties.

This statement was confirmed by Mr Eubanks. The chemical analysis performed was not available.

EUBANKS: On 01-27-09, a microbiologic sample was collected from Mr. "Eubanks' Yard" hydrant. Whereas his water source had once shown a great degree of bacterial life, the analysis revealed a total absence of multiple forms (iron-reducing / sulfate reducing / slime forming) of bacteria. Other compounds were also tested for. Historic data for Mr. Eubanks property should be available in the COGCC database.

Some historic data for the Eubanks well was located. This statement was confirmed by Mr Eubanks. The chemical analysis performed was not available.