Gas Safety Incorporated
16 Brook Lane
Southborough, Massachusetts 01772
774-922-4626
www.gassafetyusa.com

Report to Damascus Citizens for Sustainability
and
Mr. Don Williams
on
25 July 2012 Field Inspection and Methane Sampling Survey
of
Parts of Leroy, Granville and Franklin Townships
Bradford County, Pennsylvania

Union and Liberty Townships, Tioga County

McNett and McIntyre Townships
Lycoming County

SUMMARY
This, the second, methane survey in the Leroy Township area confirmed surface emissions of likely ≥94% methane (100% natural gas) over an area at least 600 meters by 200 meters, and at least two substantial methane plumes in the air. The survey data confirmed the conclusion of our 8 June 2012 survey that methane emissions were occurring in an area near and to the west of H Rockwell Road[1] and Route 414. The methane plume found on 8 June was still in place on 25 July, though the location was slightly different due to wind conditions. The data suggests methane may be entering the local fault/fracture system at a considerable depth and traveling laterally potentially thousands of meters before reaching the surface or residential water wells.

[1] The names Rockwell Road and H Rockwell Road are both used for the same road in Leroy Township, depending on the map or mapping reference source consulted and are used interchangeably in this report.

A portable laser-based methane measurement system[2] and a combustible gas indicator (CGI)[3] were used to survey shallow soil and above-ground ambient air methane levels in Leroy Township, Bradford County, Pennsylvania and adjacent parts of other Townships and Counties (see title) on 25 July 2012. The laser-based methane system reports methane levels in air to the nearest part per billion (ppb) every 3-4 seconds. During the survey over 12,000 methane measurements were made with the laser-based system. Whenever methane levels were too high (>1000 ppm) for the laser-based system, the CGI unit was used.

Methane concentrations as high as 94% were found at 2 to 18 inches below the soil surface, with gas bubbling from the soil surface and audible gurgling of gas underground. The linearity of the gas emission points suggests flow along a fault/ fracture in local rock. Bubbling gas continued in Towanda Creek also suggesting fugitive gas from shale gas wells may be travelling through faults and fractures, which also carry local ground water, hence, impacting local water wells. Collectively the data and observations clearly indicate natural gas has pervaded an extensive subsurface area and that surface emissions and ground water methane contamination problems are likely to continue for unforeseeable times. The issues and concerns presented in this report require more thorough investigation. In addition, another larger plume was encountered extending over a straight-line distance of 17 kilometers (10.5 miles) from the area NE of Canton along Route 14 to N of Ralston. Presumably that plume was originating in the uncontrolled gas flows associated with another strong methane migration event that reportedly began on 20 June 2012 in Union Township, Tioga County.

BACKGROUND

A number of dramatic fugitive methane emissions were reported to have begun in Leroy Township on 19 May 2012. Reports suggested a substantive loss of control of natural gas flows from one or more of the shale gas wells in the Township may have occurred. In the interest of verifying and developing independent documentation of the reportedly large increases in natural gas emissions, the Clean Air Council ("CAC", Philadelphia, PA) contracted Gas Safety, Inc. ("GSI", Southboro, MA) to do a one-day sampling and area visit to ascertain the locations of observed or suspected natural gas emissions. The intention was for GSI to use a customized, portable Cavity Ring-Down Laser Spectrometry (CRDS) methane measurement system to investigate and document the occurrence (or not) of the reported emissions. Data from that survey clearly indicated the presence of a methane plume that appeared to be originating to the west of Rockwell Road (Figure 1). [Documents from June 8 are posted with this report on DamascusCitizens.org.]

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[2] A customized, proprietary Cavity Ring-Down Laser Spectrometry system .

[3] Bascom-Turner Instruments, Gas-Sentry CGO-321, Calibrated 7-5-12

This report documents a second methane survey in the same area carried out on 25 July 2012 by GSI supported by Damascus Citizens for Sustainability and Don Williams, an environmental advocate, as a follow up investigation on the 8 June survey.

Weather conditions for the second methane survey were mild and favorable. Variable westerly winds were negligible to light. Wind conditions are important because methane is less dense than air. Consequently when there is no wind, surface emissions of high concentrations of methane will tend to rise directly upward, restricting the extent of any ground level plume to the immediate vicinity of the methane emissions area. Light to moderate winds are optimal for detection of emissions because they cause measurable ground level concentrations to plume downwind up to several kilometers (several miles). Strong winds dilute and disperse methane rapidly making ground levels concentrations harder to detect.

The group involved in the methane sampling survey is listed below. Natt, Ackley and Payne met at the junction of Routes 414 and 514 in the northwest corner of Franklin Township at approximately 2:00 PM on 25 July 2012, then drove to Rockwell Road where they met two local residents. All participated in the soil surface emissions survey. Ackley and Payne conducted the broad area, ambient air methane survey.

Dan Natt, Bradford County resident
Local residents (preferred to remain anonymous)
Bob Ackley, Gas Safety, Inc.
Dr. Bryce F. Payne Jr., Gas Safety, Inc.

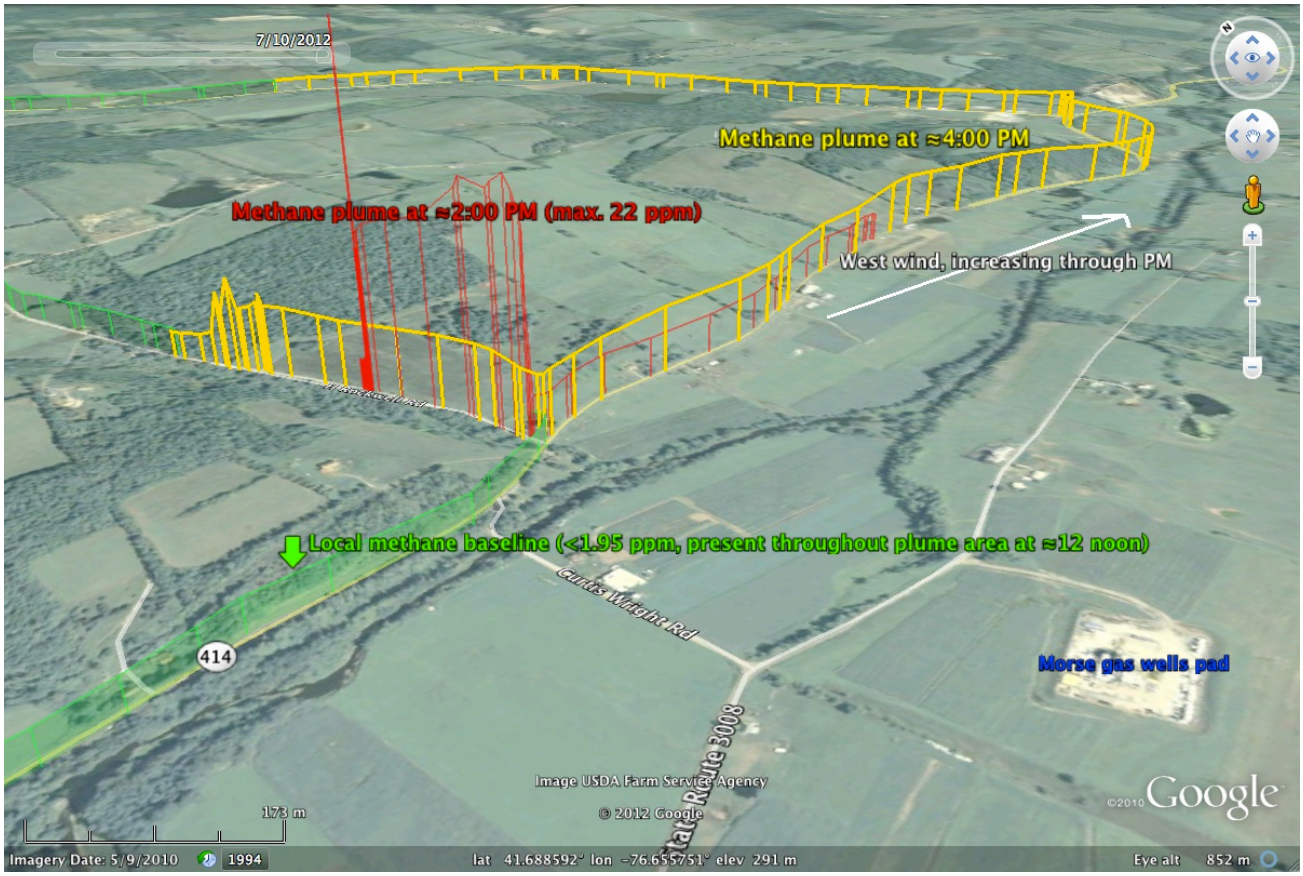

Figure 1. Showing the 8 June 2012 Rockwell Road (below red methane spike in image above) methane plume. Methane levels were normal (indicated by green methane level markers in image above) on Rt. 414 until reaching
H Rockwell Road, where slightly elevated levels were encountered (average of 32 readings = 2.068, range = 1.967 to 2.184ppm, not shown) northbound along the first approximately 500 meters of that road. About an hour later, on the return trip south on H Rockwell Road and east on Rt 414 the methane levels (red methane level markers in image above) had risen substantially and the affected area expanded south and east. Methane levels began to rise relatively suddenly about 500meters north of Rt 414 from 2.01 ppm to a maximum of 21.979 ppm, then settled into a range of 10 to 14 ppm. The area of elevated methane levels had expanded to the south and east as indicated by measurements along Rt 414 showing levels descending from 4.620 ppm at H Rockwell Road to 2.049 ppm approximately 1 kilometer to the east. Another survey pass was made through the area approximately 1 hour 50 minutes later driving eastbound on Rt 414 (yellow methane level markers in image above). The elevated methane levels were then found to have expanded to cover an area from Rockwell Road east along Rt 414 for 2.8 kilometers then north along Rt 514 (2.8 kilometers) at an overall average concentration of 3.8 ppm. The measured plume covered an area of approximately 4.2 square kilometers, however, methane data and wind direction indicate the plume probably extended considerably farther to the south and east. Time was insufficient to measure the full extent of the plume to the south and east.

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METHANE IN HOMES AND RESIDENTIAL WATER WELLS

Two residences (referred to as house7 and house8 to distinguish from those in the 8 June survey) were visited. Both are served by on-site domestic water wells heavily contaminated with methane. The house7 well had been equipped with a wellhead vent, and water treatment system to remove methane. Recent test results (by others) indicated pretreatment methane concentrations were near saturation (26 mg/liter) with the treatment system reducing the methane concentration to around 6 mg/liter. At house8 a water treatment system including reverse osmosis had been installed to control the contamination. The occupants of the house expressed no concerns about water quality at the time of the 25 July methane survey.

The general area of houses 7 and 8 are, of course, within the area predicted to be the source of the plume detected on 8 June and still present during the 25 July survey (Figure 2). In fact, the plume was confirmed on 25 July with survey runs in three different directions at three different times over the 9.5-hour work period. In the general area, ambient outdoor air methane levels ranged from 2 to 22 ppm. Ambient interior air methane levels in house7 were normal (around 2 ppm), but those in house8 were elevated (≥ 6 ppm) . The elevated methane in house8 was present despite open windows and doors, and a positive pressure ventilation system in the basement, which suggests methane levels may rise further when cool weather returns, doors and windows are closed, and heating systems activated. The methane levels in house8 were inevitable given the methane concentrations in the exterior air (approaching or >6 ppm) and soils in the area (see below DISCUSSION OF SOIL AIR METHANE RESULTS).

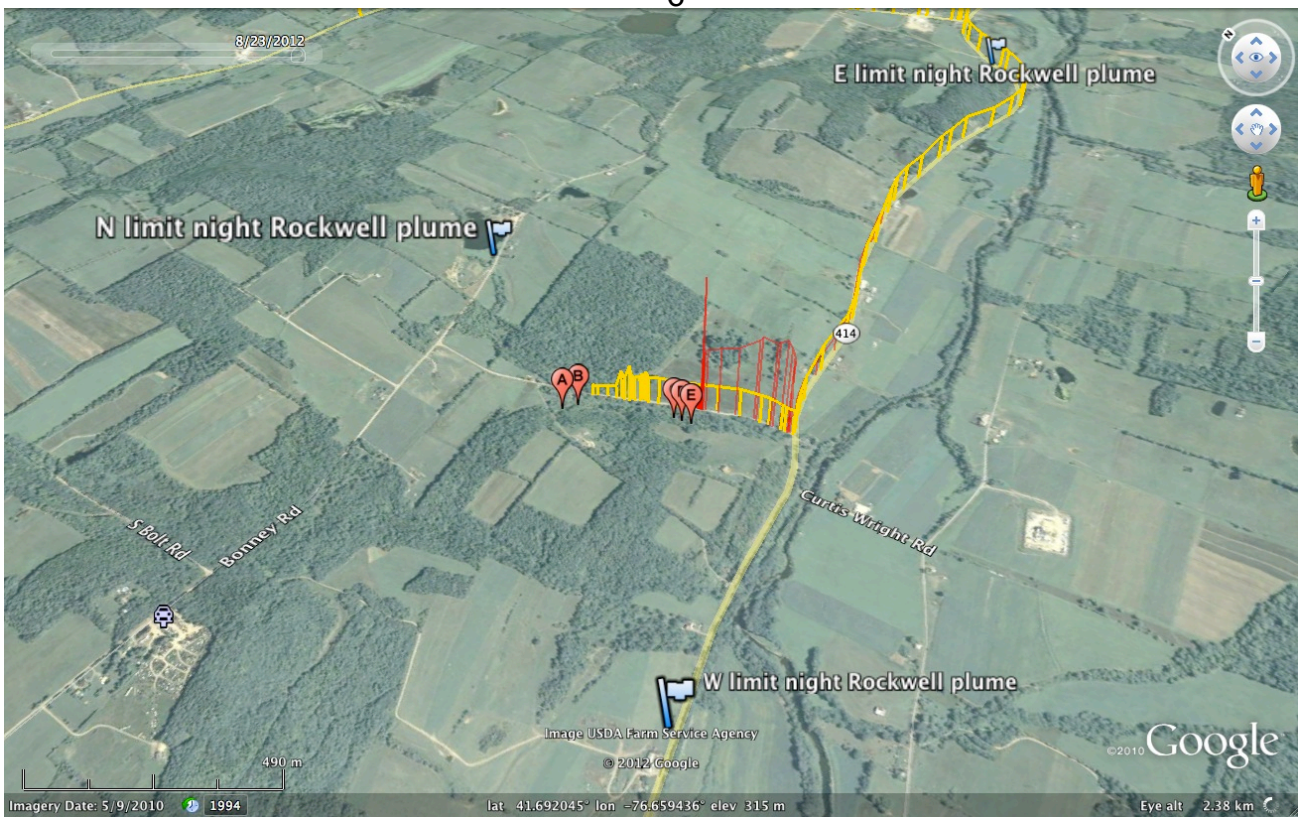

Figure 2. Locations of soil gas sampling points on 25 July 2012 (red markers A-E) with respect to 8 June 2012 methane plume (yellow and red "fences"). (see also Figure 1 above).

METHANE IN SOIL AIR IN THE IMPACTED AREA

Sampling Methods and Considerations

Surface soils in the vicinity of house7, mostly around the small creek that runs south along the west of Rockwell Road, were sampled. Initial efforts using the laser-based system indicated methane levels were too high for that instrument. A combustible gas indicator (CGI) was brought on scene and used for most of the soil air sampling done on 25 July. A steel probe was driven into ground using an attached slide hammer (referred to as a "plunger bar"). The nominal depth of the plunger bar penetration is 18", but this is adjusted to shallower depths as necessitated by rocks or other hindrances to probe penetration. The driven-in probe is withdrawn from the soil. The CGI sample intake probe is then inserted into the plunger bar hole. The CGI probe draws air faster than air can move out of the soil into the sampling hole causing the sample in the hole to be diluted with atmospheric air during the process. Consequently, the highest value detected by the instrument is reported as the methane (combustible gas) concentration for that sample hole.

Soil conditions impact the effectiveness of the plunger bar sampling method. Two such conditions were in effect in the area sampled on 25 July. The plunger bar

method works best in dry to slightly moist soils as these conditions promote soil cracking around the hole, promoting gas movement from the soil into the hole. When soils are wet the response to the penetration of the plunger bar probe is less reliable. During penetration the probe can compress the soil around the hole and seal the walls. The extent to which that seal will be broken when the probe is withdrawn is not predictable. This problem is worst in wet, clayey soils, which were the conditions in the sampling area on 25 July. When the walls of the hole seal, atmospheric air fills the hole, and the CGI does not draw a sample representative of the air in the surrounding soil. Consequently, the soil conditions on the site on 25 July favored falsely low readings. In addition the gas rising to the surface in the area had brought water up with it, forming mud and leaving free water on areas that were previously dry. Due to the free water in the area, the walls of the sample holes were soft or unstable, which, along with intrusion of surface water, caused problems with plugging or drawing water into the CGI probe. Most of the zero to moderate readings were due to such plugging problems.

Sampling Locations and Results

Seventeen plunger bar holes were sampled in five locations, A through E, indicated in Figure 1. At location A there was audible subsurface gurgling in an area with moist, but not wet soil surfaces. Three holes gave results of 0, 8, and 83% methane. At location B water had been brought up by rising gas, which bubbled through water left on the surface. Four holes gave readings of 0 to 3.9% methane. Location C was somewhat elevated, drier ground with moistened soil areas, where 0, 12 and 94% methane was encountered in holes 2" to 15" deep. At location D gas was bubbling up through mud near the stream bank, 22 and 56% methane was measured in two holes. Location E was a recently noticed area with a clearly audible subsurface gurgling sound near the stream bank. The area was very rocky, and could not be penetrated to the point of origin of the gurgling sound. Five holes gave methane levels from 8-42%.

DISCUSSION OF SOIL AIR METHANE RESULTS

Point or Non-Point Emissions?

It was clear from the field observations that natural gas has pervaded the entire sampling area and is rising continuously to the surface. Our sampling locations only covered a fraction of the likely methane surface emissions area. The plume concentrations on Rockwell Road indicated the strongest emissions were occurring farther south than the impacted area sampled on 25 July. Along the stream course, specific emissions points were easily identifiable (surface bubbling, underground gurgling) and the emissions points seemed to be distributed in a roughly linear pattern. These observations suggested the gas is moving through underground faults/fractures until it finds a water- and structure-confined pathway to appear at the surface in specific, confined areas. On the other hand, on the higher ground closer to house8 the concentrations of methane in air indicated a more diffuse pattern of surface

emissions may have been occurring. This would seem reasonable in light of three local conditions.

First, the lower lying areas near the stream (house 7 area) probably overly a fault that is conducting gas to the surface, hence, surface gas release points occur in areas that lie in locations along roughly straight lines. In contrast, the suspected fault presumably underlying the stream area becomes more distant as one moves uphill toward house8 away from the stream.

Second, ground water is presumably shallow in the low-lying areas as there are artesian wells and springs. The head pressure of ground water likely affects the pathways and flow rates of gas below ground by blocking many pathways that gas would otherwise follow. The surface-to-groundwater depth increases consistently as one moves uphill from house7 toward house8, so the tendency of ground water to direct gas flows becomes continuously less important as one gets closer to house8.

Third, sedimentary rock (presumably a shale) lies under the soil in the area. That sedimentary rock is fractured into relatively thin (1/4" or so thick) square-ish plates (1-3" across) that lie in an arrangement reflecting the strata in the original rock. This fractured, platy rock is riddled with clear open spaces between the small adjacent plates of rock. The original rock formation was tilted to nearly vertical so the fractured rock plates are standing nearly on end and pointing roughly SE-NW.

So, as the methane from the gas well moves through the local rock toward the surface it first finds its way through the local fault/fracture system up through water-laden platy sedimentary rock near the surface. As it continues to rise, some escapes into the air, but some escapes into the network of continuous empty spaces among the small plates of rock under the surface soil on the higher ground. Once it finds those spaces it flows and pushes through them, moving preferentially upward and to the NW (or SE). No longer confined to move through channels determined by water pressure and tension, in the higher, drier ground, the gas moves relentlessly upward and outward, pushing out the natural soil air. The result is gas widely distributed over broad areas on the higher ground near house8 while appearing confined to distinct localized emissions points in the low-lying, wetter areas, as in the vicinity of the stream, and house7.

<u>How Deep is a Likely Gas Source?</u>

Two conditions seem to suggest that the natural gas found rising to the surface is entering the local fault/fracture system at a considerable depth: (1) the impacted areas appear to be extensive, and (2) methane is not apparent close to the gas wellheads. The sampled emission area is extensive, covering at least 600 meters along and 200 meters to the west of Rockwell Road, and almost certainly extends further. There is another no-access-allowed methane emissions area 1100 meters east of Rockwell Road, and, there is the visually obvious bubbling in Towanda Creek that appears likely to extend hundreds of meters. If the gas were entering the fault/fracture system at a shallow depth, then

the gas would likely find its way to the surface quickly, resulting in more confined, and intensive, emissions areas closer to the gas well itself. The actual impact areas are relatively distant from the vertical bores of the suspected source gas wells (Morse 3H and 5H). The apparent shortest distance from the Morse wells pad to the Rockwell Road surface emissions area is 600 meters (2000 feet or 0.4 mile), with the no-access emissions area at 1300 meters (4400 feet or 0.8 mile) and the observed bubbling area in Towanda Creek at 2300 meters (over 7,000 feet or 1.3 miles) from the gas well pad. It seems unlikely that a shallow geological feature would conduct methane over such distances without at least some readily observable or measurable gas rising in closer proximity to the gas wellhead.

A Noteworthy Site

The identified area of methane surface emissions along Rockwell Road presents an exceptional opportunity to investigate how methane moves under different underground scenarios, and broad area methane flow rates. It is large enough and has enough ground water and rock/soil structure variations to provide a broad range of conditions, yet small enough to be nearly fully investigated and documented. Gas Safety Inc. would welcome opportunities to perform or collaborate on such investigative work.

ROAD SURVEYS OF THE AREA FOR METHANE IN THE AIR

Cavity Ring-Down Spectrometry and Baseline Ground-Level Methane Data

The CRDS instrument is extremely sensitive, runs continuously, and is robust. Consequently the unit quickly generates large volumes of highly reliable methane measurements on a continuous basis. During the one-day area survey reported here, the instrument generated 12,657 methane measurements. In combination with similar quantities of data from prior surveys in the eastern Marcellus Shale region, GSI has determined that a reliable (99.99% confidence level) upper bound for background methane levels in ground level air is 1.95 parts per million (ppm). GSI also has identified thousands of gas leaks in commercial pipelines in a variety of settings and based on that experience has concluded that CRDS measured levels of methane in excess of 2.05 ppm reliably indicate a natural gas leak in the surrounding area. Based on these findings, GSI interprets methane levels above 1.95 ppm as presumptive, and above 2.05 ppm as highly probable methane contamination. There is potential for some biogenic sources to generate enough methane to cause such readings, but such potential biogenic sources are usually readily identifiable, and limited in both extent and intensity in comparison to fugitive natural gas from wells or infrastructure.

The areas in Leroy and other Townships surveyed and reported here had background levels and variations typical for the region, the lowest methane reading being 1.656 ppm (nominal accuracy of the CRDS is 0.001 ppm). Some areas of elevated methane

in the air occurred near areas on farms with long-term animal manure loads. No elevated methane levels were found for other agricultural areas that might be conventionally considered suspect for biogenic methane production. As on 8 June, no elevated methane levels were measured at the nearest access (≥150 meters) to the natural gas well pads within the area covered by this survey.

The Rockwell Road Plume

Elevated methane levels were detected shortly after the instrument was initially activated at the junction of Routes 414 and 514. **The methane plume was present in the same general area as on 8 June, though it extended only about half as far to the north toward the east end, but farther north toward the west end, most likely due to lighter and less northerly winds on this (25 July) survey.** Data collected on the initial drive west on Rt. 414 confirmed the plume was present to, and northward along, Rockwell Road to house7. The Rockwell Road area was departed about 3 hours later. Data from the drive back to the junction of Rts. 414 and 514 again confirmed the plume was present, as did two more passes through the area later that night. **It appeared likely the plume is continuously present, being fed by the confirmed surface emissions along Rockwell Road.**

Bubbling at Cross Road Bridge

Gas bubbling up in Towanda Creek beneath the Cross Road bridge was again visually confirmed, but no attempt was made to collect or measure methane concentrations due to accessibility problems. **The rate of bubbling appeared to be similar to that observed on 8 June.** Again, the volume and spatial distribution of the bubbling locations make other potential explanations, e.g., a solely biogenic methane source in the creek bottom, seem implausible and suggested the possibility that methane emissions may have been occurring along a fault line.

The Canton-Ralston Plume

A wide area road methane survey was then conducted over the next several hours farther to the west, reaching into Tioga and Lycoming Counties. Two important observations were made.

A large methane plume was encountered extending over a straight-line distance of 17 kilometers (10.5 miles) from the area NE of Canton along Route 14 to N of Ralston. Methane levels were consistently elevated over the entire distance. The plume was suspected of being the residual ground level methane moving with the wind from the area of the methane migration event that reportedly began in Union Township on 20 June 2012. Attempts to find the western and northern limits of the plume were frustrated by darkness and navigation (GPS signal) problems. Data indicated the full extent of this plume may have reached north of Alba on Rt. 14, or, alternatively, other presumably smaller plumes were present in that area.

Reference Baseline Conditions Needed

It was also noted during both the 8 June and 25 July methane surveys, that extensive areas have baseline methane levels that are consistently lower than the 1.95 ppm threshold Gas Safety Inc. currently uses to distinguish presumptively methane contaminated areas. In fairly extensive areas, usually more elevated areas or areas with standing forests or woodlands, the baseline seems to remain stable around 1.75 ppm for prolonged periods. **Since the GSI presumptive contamination baseline was developed from broad area surveys in drilled shale gas areas, it may be inappropriately high. If so, using the 1.95-ppm threshold would result in erroneously underestimating the broad area atmospheric methane impacts of shale gas development.** Baseline methane emissions data are needed for geologically similar areas before shale gas development begins. Without such baseline data it will likely be impossible to develop an accurate estimate of naturally occurring, pre-gas-drilling methane emissions levels. **Such accurate estimates of naturally occurring methane emissions would:**

- **Improve the accuracy of models and assessments of the rate of greenhouse gas emissions**
- **Allow simple, direct verification of methane releases or contamination from shale gas wells**
- **Permit better understanding of whether and how natural gas emissions are impacted by shale gas development.**

Additionally, such baseline data could:

- **Quantify natural methane emissions and their inherent variability**
- **May be diagnostic for locating faults that naturally conduct deep gas to the surface**
- **Thereby help to identify locations where gas wells, if drilled, will be more likely to develop methane migration problems.**

CONCLUSIONS

The methane survey data collected on 25 July 2012 in parts of Leroy, Granville, and Franklin Townships in Bradford County, Union and Liberty Townships in Tioga County, and McNett and McIntyre Townships in Lycoming County, Pennsylvania **confirmed the findings of the prior methane survey work done on 8 June 2012** in parts of Leroy, Granville, and Franklin Townships, Bradford County. Substantial methane emissions were occurring in an area along H Rockwell Road north of Route 414. The emissions area likely extended beyond the area actually sampled. The ground level plume detected on 8 June was still present and of similar size and apparent strength. Heavily methane contaminated residential water wells occurred in and around the same area. In one residence indoor methane levels were elevated. Ambient outdoor methane levels were elevated throughout the emissions area. In sampled areas intruding natural gas appears to have displaced all natural soil air. There is visible surface bubbling and clearly audible subsurface gurgling of gas. Bubbling of gas in Towanda Creek continued as on 8 June. Again, the data collectively suggested fugitive gas from shale gas wells might be travelling through faults and fractures, which also carry local ground water, hence, impacting local water wells. Collectively the data and observations also suggest natural gas has pervaded an extensive subsurface area beyond the area where elevated ground-level methane was found during this survey effort, and may be entering the fault/fracture system at considerable depth. If that is

correct, then more surface emissions should be expected. Further, even if the surface emissions subside, concerns about local ground water impacts will remain. A westward extension of the survey work detected a 17-kilometer (10.5-mile) long/wide methane plume from north of Canton to north of Ralston. It was presumed this plume was residual ground-level methane from the ongoing emissions associated with the methane migration event that reportedly began on 20 June 2012 in Union Township, Tioga County. The data and findings reported here stand, but the issues and concerns raised or supported by those data and findings require more thorough investigation for confirmation and quantification.

ACKNOWLEDGEMENTS

The support of Damascus Citizens for Sustainability and Don Williams for the 25 July 2012 methane survey work reported above is acknowledged and appreciated, as the support provided by the Clean Air Council for the previously reported 8 June 2012 methane survey. Numerous individuals provided support of time, information and effort, and we wish to acknowledge their help, especially that of Dan Natt who facilitated and accompanied us on both surveys and fell ill shortly after the 25 July 2012 survey was completed.