December 29, 2025
File No. 27224515.26

Mr. Mike Smith, P.E.
Iowa Department of Natural Resources
Land Quality Bureau
6200 Park Avenue
Des Moines, Iowa 50321

Subject: Methane Mitigation Plan
             Henry County Sanitary Landfill
             Permit No. 44-SDP-01-75C

Dear Mike:

SCS Engineers (SCS), on behalf of the Henry County Solid Waste Commission (Commission), proposes this methane mitigation plan for the Henry County Sanitary Landfill (Landfill).

Background

In email correspondence dated September 5, 2024 (Doc #110838), the Iowa Department of Natural Resources (DNR) was notified of an exceedance of the action level of greater than 25% of the lower explosive limit (LEL) for methane measured in the on-site office building (not owned by the Commission) on September 5, 2024. The gas exceedance was measured in a storage closet used to store business records next to the building's kitchen. The initial reading was 43% of the LEL and a recheck was 39% of the LEL. During the September 5, 2024, monitoring event, monitoring throughout the rest of the building, including areas near the closet, did not detect methane. Subsequent monitoring events detected methane in the closet and the void space beneath the closet, but not in the rest of the building.

A summary of methane measurements in the closet and the void space beneath the floor of the closet since September 5, 2024 is shown below. The void space beneath the closet floor was unknown during the September 2024 monitoring event.

Date	Closet % LEL	Void % LEL
September 5, 2024	43	NM
December 18, 2024	2	23
March 11, 2025	33	>99
May 7, 2025	10	77
July 16, 2025	11	>99
November 25, 2025	0	>99

In response to the methane exceedance, the DNR required a mitigation plan as noted in correspondence dated September 24, 2024 (Doc #110923). To identify the source of the gas in the void space, a gas sample was collected on March 11, 2025. The results of the first sample were

inconclusive as to the source of the gas, as discussed in correspondence dated May 13, 2025 (Doc #113049). The May 13 correspondence included a picture of the warning signs posted on the closet door, notifying building users to keep out due to flammable gas. The closet door is kept locked other than when being accessed for monitoring purposes. The closet is currently not used, including no longer used for the storage of business records.

To allow time for additional gas sampling to identify the source of the gas in the void space and prepare the mitigation plan, a submittal date of December 31, 2025, was established for the mitigation plan (Doc #113062). On July 16, 2025, gas samples were collected from the void space beneath the closet and from a leachate piezometer to obtain a gas sample directly from the waste mass. A tritium analysis was completed on the July 16 sample from the closet void area. The March 11 sample from the closet void space and the July 16 sample from the leachate piezometer did not contain sufficient methane concentrations to perform tritium analysis.

An interpretative report from the laboratory, dated September 4, 2024, concluded that the source of the gas in the void space below the closet was the Landfill, as stated below:

> *The tritium concentration of the methane from the Office Closet sample was significantly greater than expected for normal surface water or shallow groundwater and fell within the range expected for municipal landfills. Thus, the molecular and isotopic results of the FOMW2-LE and Office Closet gas samples indicate the source of the gas in the void space of the closet area is consistent with landfill gas originating from the Henry County Sanitary Landfill.*

The analytical results and interpretive report for the July 16, 2025, sampling event are attached.

Comment Letter Response

The items from the DNR comment letter dated September 24, 2024 (Doc #110923), are addressed by number below.

1. An understanding of local geology and groundwater levels that impact gas migration pathways,

The local geology at the Landfill is well understood and is described in the *Groundwater Quality Assessment Plan*, dated February 14, 2013 (Doc #75791), prepared by Barker Lemar Engineering Consultants. In summary, the geology in the western part of the Landfill is weathered glacial till with sand seams underlain by an extensive sand layer. The boring log for monitoring well MW-27, located adjacent to the building, indicates that both the weathered till and the deeper sand layers were encountered in the boring. Water levels measured in monitoring well MW-27 from 2020 through 2025, relative to the ground surface, indicate a vadose zone approximately 18 to 22 feet thick.

2. The necessity of the installation and management of a gas collection system under the affected building,

The proposed remedy is to install a passive gas venting system that includes sealing the floor of the closet above the void space and venting the void space to the exterior. The floor above the void space will be sealed with 8-mil plastic sheeting, a layer of underlayment, and HDPE sheeting, with the layers fastened by adhesive and/or screws, as appropriate. A hole will be drilled through the floor and plastic layers to install a 3-inch HDPE exhaust pipe. The edges of the closet and screw holes will be sealed with caulk, and flanging will be installed around the pipe to make the seal as airtight as practical.

The exhaust pipe will extend up through the ceiling, exit through the side of the building, and be sealed with a flange. The pipe above the ceiling will be attached with a slight drop so that condensate flows back down the pipe rather than to the outside of the building. The end of the pipe outside the building will be covered with a screen to prevent material from entering the pipe.

If the passive vent is insufficient to reduce methane concentrations below action levels in the closet (25% of the LEL), a powered exhaust fan will be installed in the passive vent pipe to increase gas extraction.

As methane has not been detected in the office building outside the closet and the void space, a targeted approach of venting the void space is anticipated to mitigate methane accumulation sufficiently. The sealed floor of the closet would keep the methane from entering areas of the building that may be accessed or occupied. The closet will remain locked with the existing warning signs remaining in place.

Methane monitoring in the closet will be conducted within 24 hours of installing the venting system. Monthly monitoring of the closet will be conducted for 3 months, followed by the resumption of the routine quarterly monitoring schedule.

3. The necessity of source control in lieu of or in conjunction with a building collection system,

At this time, source control is not being pursued as the concern appears to be limited to the void space beneath the closet, which is being addressed by sealing the floor coupled with passive venting of the void space. Historical records indicate former surface water drain pipes along with up to two connected former septic system discharge pipes present in the area of the building, as described in the August 1994 *Groundwater Assessment Report* prepared by Shive-Hattery:

> *The building was constructed by Don Whaley, Sr., the contract operator for Phase I and Phase II fill areas and used for equipment maintenance and storage during Phase I and II operations. A septic tank which serves the building is reportedly located immediately west of the building. Effluent from the septic tank reportedly discharges into the upper portion of a gravel filled trench approximately 50 feet in length and 24 to 30 inches deep. A perforated collection pipe at the base of the trench is connected to the tile drain. The tile drain runs through the earthen berm separating the Phase I and Phase II fill areas and discharges northeast of the Phase I area. The tile drain is also connected to two drainage tiles located at the base of the depression immediately north of the old maintenance building. Septic tank effluent from an old farm house formerly located east of the maintenance building also reportedly discharged to this tile drain.*

A topographic map (Figure 1) from the August 1994 Shive-Hattery report is attached.

The drainage pipes were used to drain the subgrade area on the north side of the Landfill building at the time of active landfilling where a dump truck could be parked, allowing for a public drop-off area from surface grade. This subgrade area was filled in (with the exception of at least the void space beneath the closet) in the 1990s when the building was expanded north under new ownership and use. Source control would entail either an interceptor trench intended to intercept and vent the gas migration pathway, which is likely the former stormwater drainage pipes and/or the subgrade backfill materials, or active gas control installed in the waste mass. Either of these actions remain options if adequate methane control within the building cannot be achieved by the passive system proposed herein or, if necessary, by the next step of adding active venting to the proposed passive system.

4. The need for continuous monitor(s), alarm settings and a monitor maintenance program,

A method for continuous monitoring of the building is currently under development and will be completed following an initial period of periodic monitoring following implementation of the actions proposed herein. Two options for continuous monitoring are being considered; 1) a system which will alarm at the building, both internal and external at appropriate building access points or 2) a system which alarms as indicated in Option 1 combined with external communication via text and/or email to select individuals including management personnel of the building occupant, the building owner, and the Commission. The continuous monitor(s) would be maintained in accordance with the manufacturer's recommendations.

5. And an emergency response plan if gas is detected in the affected building.

Methane gas is a by-product of waste decomposition and can be explosive in specific concentrations. Methane gas is colorless and odorless; the odor comes from other gases mixed with it.

If methane gas is detected by electronic monitoring or by detecting an odor:

- Evacuate immediately.
- Contact the Fire Department (911).
- Contact the Henry County Solid Waste Commission representative. Mt. Pleasant City Hall will have contact information (319-385-1470).
- Contact the building owner. As of December 2025, this is Mr. Tim Batey (319-750-5525).
- Contact DNR Field Office #6 (319-653-2135).
- If directed by the Field Office, contact the DNR Emergency Reporting Hotline (515-725-8694).
- Do not return to the building until it has been properly ventilated and the gas concentrations have been checked with an electronic meter.
- A second check of gas concentration levels with newly calibrated equipment may be required.
- If the venting system lines are malfunctioning, contact a professional engineer for repair assistance.

After an incident such as fire, severe thunderstorm, tornado, flooding, etc.:

- Check methane venting systems.
- Monitor methane gas soon after the incident to check for hazardous methane levels.
- If you smell gas, evacuate immediately.
- Contact the representatives listed in the previous section.
- If the venting system lines are malfunctioning, contact a professional engineer for repair assistance.

If you have any questions regarding this mitigation plan, please contact Nathan Ohrt at (319) 331-9613.
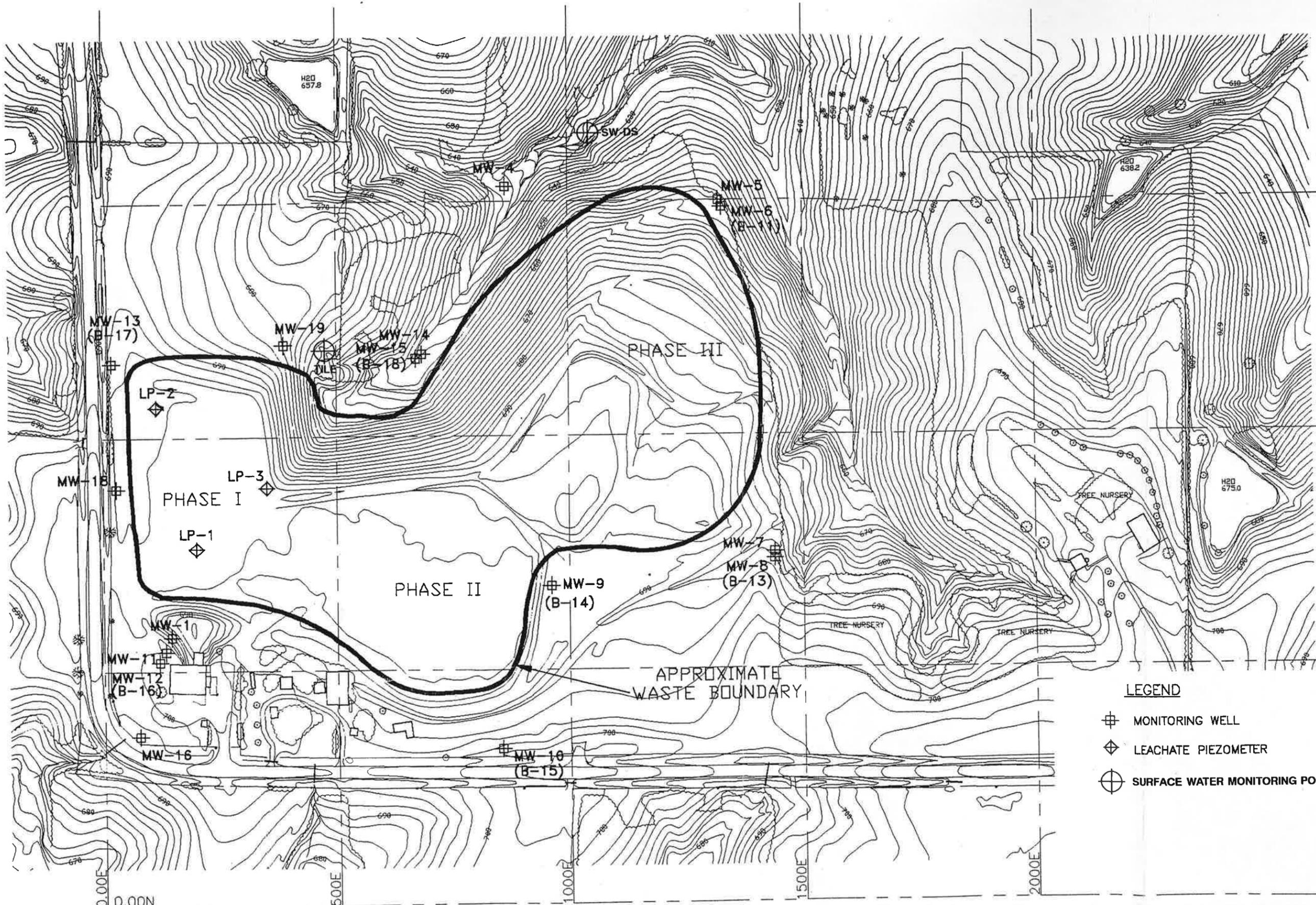
Sincerely,

Nathan Ohrt
Senior Project Professional
SCS Engineers

Timothy C. Buelow, P.E.
VP - Senior Project Advisor
SCS Engineers

NPO/TCB

Copies: Mr. Steve Brimhall, Henry County Solid Waste Commission

PHASE III

PHASE I

PHASE II

APPROXIMATE
WASTE BOUNDARY

MW-13
(B-17)

MW-19

MW-14

MW-15
(B-18)

LP-2

LP-3

MW-18

LP-1

MW-4

SW-DS

MW-5

MW-6
(B-11)

MW-7

MW-8
(B-13)

MW-9
(B-14)

MW-1

MW-11

MW-12
(B-16)

MW-16

MW-10
(B-15)

H2O
657.8

H2O
638.2

H2O
675.0

TREE NURSERY

TREE NURSERY

TREE NURSERY

NORTH

0.00N

500E

1000E

1500E

2000E

LEGEND

⊞ MONITORING WELL

◇ LEACHATE PIEZOMETER

⊕ SURFACE WATER MONITORING POINT

SHIVE-HATTERY
ENGINEERS AND ARCHITECTS, Inc.

TITLE	HENRY COUNTY SANITARY LANDFILL SITE PLAN
SCALE	1" = 200'
FIELD BOOK	
REVISION	
DATE	6-9-94
DRAWN	B.G.
APPROVED	W.C.
PROJECT NO.	194140-0
SHEET NO.	FIGURE 1

Gas Geochemistry of samples from Henry County Sanitary Landfill, Mt. Pleasant, Iowa

(Isotech Job No. 61776 & 63126)

Interpretive Report

By

Keith C. Hackley, Ph.D.

Prepared for

SCS Engineers

September 4, 2025

CONFIDENTIAL

Isotech a Stratum Reservoir Brand
1308 Parkland Court
Champaign, IL 61821

Phone: 217-398-3490
e-mail: keith.hackley@stratumreservoir.com

1

Table of Contents

I. EXECUTIVE SUMMARY

Introduction

The following is an interpretation of the analytical results of gas samples collected from the Henry County Sanitary Landfill site near Mount Pleasant, Iowa (Figure 1). The landfill is closed, but, according to SCS Engineers personnel, the landfill was in operation from 1975 to 1990, and an official closure permit was issued in 1994, after which the site and operations building were purchased by a third party. Methane was detected in a void space beneath the wooden floor of a closet in the building that had previously been part of the landfill operation. Three gas samples were collected: one sample ("LP-3") from a landfill probe (collected 7/16/2025) and two samples ("FOMW2-LE" and "Office Closet") from the void space beneath the floor of the closet area (collected 3/11/2025 and 7/16/2025). Besides the landfill, the other primary source of methane at the site would be a septic system on site.

The analyses completed to help determine the source of methane from the closet area include molecular analyses via gas chromatography (GC), stable isotope analyses via isotope ratio mass spectrometry, radiocarbon analysis via accelerating mass spectrometry, and tritium analysis via liquid scintillation counting. The GC compositional analyses included the major atmospheric gases plus helium, hydrogen, and hydrocarbons from methane to hexanes+. The GC results are summarized in Table 1. The stable isotope analyses included the carbon and hydrogen isotope analyses ($\delta^{13}C$ and δD) of methane (CH_4, or C_1), and the $\delta^{13}C$ of the carbon dioxide (CO_2). Radiocarbon (^{14}C) analyses were completed on the methane component of the samples. A tritium analysis was completed on the methane in the second sample from the closet void area (Office Closet). The FOMW2-LE and LP-3 samples did not contain sufficient methane for tritium analysis. Background information on isotopes is given in Appendix I. The results of the isotope analyses are summarized in Table 2. Copies of the analytical data reports are included in Appendix II. Several figures are enclosed to help illustrate the data and show how these samples compare with one another and with compositions typically observed for various sources of methane.

Objectives

The main objective was to determine if the gas sampled from the closet area, represented by the samples "FOMW2-LE" and "Office Closet", originated primarily from the landfill, represented by the sample "LP-3", or perhaps from an alternative source such as the septic system or anaerobic degradation of something else in the void below the closet floor.

Conclusions

- The molecular composition of the FOMW2-LE and Office Closet samples showed higher concentrations of CO_2 relative to methane. Typically, unoxidized landfill gas has high CO_2 concentrations but greater methane, with a CO_2/CH_4 ratio of around 0.7. However, as landfill gas migrates, the CO_2/CH_4 ratio often increases to 1.0 or above due to oxidation of methane and other organic compounds increasing the concentration of CO_2 (*Bogner et al., 1996*).

- The FOMW2-LE and Office Closet samples showed low concentrations of oxygen (O_2) but elevated nitrogen (N_2) and argon (Ar). The N_2/O_2 ratios for the FOMW2-LE and Office Closet samples were 43.1 and 44.5, respectively, much greater than the ratio for air (3.73), suggesting the O_2 has been consumed in the gas sampled from the void space beneath the closet floor. Whereas the N_2/O_2 ratio for the LP-3 sample was 3.78, nearly identical to the atmosphere. Thus, molecular results of the FOMW2-LE and Office Closet gas samples indicate the gas has been oxidized, which is consistent with the carbon isotope ($\delta^{13}C$) results of the CO_2 from these two samples.

- The $\delta^{13}C$ values of the CO_2 from the FOMW2-LE and Office Closet gas samples were isotopically quite negative, -33.84 ‰ and -30.31 ‰, respectively. Such $\delta^{13}C$ values are significantly more negative compared to normal soil gas, which is typically close to -23 ‰ (*Cerling et al., 1991*). Thus, the negative $\delta^{13}C$ values of the CO_2 indicate oxidation of a reduced carbon source with a very negative $\delta^{13}C$ value such as methane. The $\delta^{13}C$ value of the methane for the LP-3 sample was -50.14 ‰, while the $\delta^{13}C$ of the CO_2 for the LP-3 gas sample was positive, 4.93 ‰, characteristic of that expected for landfill gas.

- When graphing the $\delta^{13}C$ values of CO_2 versus the $\delta^{13}C$ values of methane from the FOMW2-LE, Office Closet, and LP-3 gas samples, the results for the FOMW2-LE and Office Closet samples plot on a trajectory expected for the effects of partial oxidation relative to the isotopic composition of the CO_2 and methane for the LP-3 sample. This is consistent with what would be expected for migration of landfill gas away from the waste repository area.

- The $\delta^{13}C$ and δD values of the methane for the FOMW2-LE and Office Closet gas samples were more positive than the $\delta^{13}C$ and δD values of the methane for the LP-3 landfill gas sample. When plotted on a δD versus $\delta^{13}C$ graph for methane, the isotopic composition of the results for the FOMW2-LE and Office Closet gas samples are consistent with expected trajectory for partial oxidation of the landfill gas methane (LP-3), suggesting the gas samples from the closet void area originated from the landfill.

4

- The ^{14}C activity of the methane for the Office Closet gas sample (122.66 pMC) was nearly identical to the LP-3 landfill gas sample (122.30 pMC, within one standard deviation). The ^{14}C activity of the methane for the FOMW2-LE gas sample was 121.53 pMC, within two standard deviations of the ^{14}C activity of the methane for the LP-3 landfill gas sample. Such elevated ^{14}C activities for the methane from the Office Closet and FOMW2-LE samples are consistent with that expected for landfill gas and similar to that observed for the adjacent landfill gas, suggesting the gas from the closet void area originated from the landfill gas. Although there is a septic system near the building where the closet void exists, and sewage may also have elevated ^{14}C activity compared to groundwater, published results of ^{14}C activity of organic matter from sewage treatment plants are typically lower than that observed for landfill gas.

- The tritium concentration measured on the methane from the Office Closet sample showed 56.6 tritium units (TU), a significantly greater concentration than normally expected for shallow groundwater. Septic systems would be expected to contain a similar tritium concentration as that observed in its source water, which is typically shallow groundwater or a local surface water reservoir. According to the literature, most surface water and shallow groundwater contain tritium concentrations around 11 TU or less in this region. Landfills typically contain elevated tritium, often several times, to orders of magnitude times greater than the local groundwater. Thus, the tritium concentration of the methane from the Office Closet sample suggests the methane originated from the landfill.

II.   BRIEF DESCRIPTION OF THE SITE AND SAMPLES

The Henry County Sanitary Landfill is a municipal solid waste disposal landfill, located approximately four miles south of Mount Pleasant, Iowa (Figure 1). According to SCS Engineers personnel, the landfill opened in 1975 and began closure activities in 1990. The Iowa Department of Natural Resources issued a closure permit in 1994. The landfill is an unlined ravine-fill repository, covering about 19 acres with no gas collection system (Figure 2).

An elevated methane reading was measured in the closet area of one of the buildings on site in the fall of 2024. The building with the closet void area had previously been part of the landfill operation. It is understood that when the landfill was in operation, the building originally was adjacent to a subgrade area where a landfill truck could back into and residential customers could throw their trash into the back of the truck and not have to drive out to the working face of the waste repository area. When needed, landfill personnel would empty the truck at the working face of the landfill. After the site was closed and purchased by a third party in the

1990's, the site building was expanded over a portion of the subgrade area which was mostly filled except a small part where a closet was constructed during the building expansion.

Elevated methane was detected in the closet area of the expanded building at Henry County Landfill in the fall of 2024. The building was vacant when the first elevated gas reading in the closet area was detected however, since gas readings were not checked in the closet area prior to the fall of 2024, it is not known whether elevated methane was previously present. According to SCS personnel, the void, or cavity, beneath the floor of the closet area is possibly 8 to 10 ft deep and appeared to have liquid and other debris present.

Two samples were collected from the void are beneath the closet floor, "FOMW2-LE" on 3/11/25 and "Office Closet" on 7/16/2025. A third sample was collected from a landfill gas extraction probe, "LP-3", on 7/16/25 (Figure 3). The FOMW2-LE gas sample was collected in an IsoBag®. The other two gas samples were collected in pre-evacuated liquid propane tanks in the attempt to obtain enough gas for tritium analysis of methane. All three samples were analyzed for molecular composition using gas chromatography (GC), for the stable carbon and hydrogen isotopes ($\delta^{13}C$ and δD, respectively) of methane, the $\delta^{13}C$ of carbon dioxide (CO_2) using isotope ratio mass spectrometry (IRMS), and for carbon-14 (^{14}C) of the methane ($^{14}C_1$) using accelerating mass spectrometry (AMS). The Office Closet sample was analyzed for tritium (^3H) on the methane (Tritium C_1) using beta liquid scintillation counting (LSC). Only the Office Closet sample collected on 7/16/25 contained enough methane for the ^3H analysis.

III.   RESULTS AND DISCUSSION

Enclosed are copies of the analytical data reports for the gas sample FOMW2-LE associated with Job 61776 and the gas samples Office Closet and LP-3 associated with Job 63126 (Appendix II). Multiple figures are included to help illustrate the molecular and isotope results and to compare the data from the closet void area (FOMW2-LE and Office Closet) to the landfill gas (LP-3) and with compositions commonly observed for different sources of gas.

Molecular Composition

The GC results show that the samples from the closet void area (FOMW2-LE and Office Closet) contained significant amounts of methane (7.13% and 17.93%, respectively) and elevated CO_2 (11.59% and 19.99%, respectively) (Table 1). Such high CO_2 concentrations are consistent with that expected from near surface microbial methane production like that from landfill gases and/or septic and swamp environments. These two samples also contained significant concentrations of nitrogen (N_2) (78.52% and 60.01%, respectively) and argon (Ar)

(0.947% and 0.717%, respectively) suggesting the presence of air which contains 78.08% N_2 and 0.934% Ar. However, the oxygen (O_2) concentration was rather low in the FOMW2-LE and Office Closet samples, 1.82% and 1.35%, respectively. Such results suggest oxygen has been consumed in closet void samples due to oxidation reactions. The landfill gas sample (LP-3) contained only 1.08% methane and 0.63% CO_2 but had 77.02% N_2, 20.36% O_2, and 0.913% Ar, indicating the sample was diluted with air. The ratio of CO_2/CH_4 for the landfill gas sample was approximately 0.6 similar to that expected for unoxidized landfill gas (~ 0.7, *Bogner et al., 1996*). The ratios of CO_2/CH_4 for the FOMW2-LE and Office Closet samples were 1.6 and 1.1, respectively. These CO_2/CH_4 ratios are greater than typically expected for landfill gas but similar to that observed for oxidized landfill gas (*Bogner et al., 1996*). The very low oxygen concentrations compared to the high nitrogen concentrations for the FOMW2-LE and Office Closet samples are consistent with oxidation of the gas in these samples.

The Office Closet sample contained a trace of iso-butane which is not normally expected with microbial gases although, traces of heavier alkanes than methane have been observed in landfill gases (*Eklund et al., 1998*). No iso-butane was reported for the molecular analysis of LP-3, the landfill gas sample for the Henry County Landfill, however, this sample was very diluted with air which may explain why no other alkanes besides methane were observed.

Isotopic Composition

The $\delta^{13}C$ and δD results of methane for the LP-3 landfill gas sample were characteristic of near-surface microbial gas such as that produced in landfills and other near-surface environments such as swamps and septic systems (Figure 4). The $\delta^{13}C$ and δD results of methane for the FOMW2-LE and Office Closet samples were more positive compared to results for the LP-3 sample and follow a trajectory like that expected for partial oxidation of the methane from the LP-3 sample. During oxidation, the methane molecules containing the lighter isotopes (^{12}C and ^{1}H) are preferentially oxidized to CO_2, leaving behind methane with more of the heavier isotopes (^{13}C and ^{2}H), resulting in a positive shift in the isotopic composition of the residual methane (black-dashed arrow in Figure 4). The resulting oxidation product, CO_2, will have a more negative $\delta^{13}C$ composition compared to the CO_2 associated with the original gas composition.

The $\delta^{13}C$ of CO_2 for the FOMW2-LE and Office Closet gas samples (-33.84 ‰ and -30.31 ‰, respectively) were much more negative compared to the CO_2 for the LP-3 sample (4.93 ‰) (Table 2). Furthermore, the $\delta^{13}C$ of CO_2 for the FOMW2-LE and Office Closet samples were more negative than normal soil CO_2 (typically closer to -23 ‰, *Cerling et al., 1991*). Such

negative $\delta^{13}C$ of CO_2 values are consistent with partial oxidation of the gas associated with the FOMW2-LE and Office Closet gas samples and consistent with elevated CO_2 concentrations relative to CH_4 for these two samples. A plot of the CO_2/CH_4 ratios versus $\delta^{13}C$ of CO_2 shows the data for the FOMW2-LE and Office Closet gas samples plot in the direction expected for partial oxidation of the LP-3 landfill gas sample (Figure 5). Additionally, a plot of the $\delta^{13}C$ of the CO_2 results versus the $\delta^{13}C$ of methane also shows that the results for the FOMW2-LE and Office Closet gas samples are consistent with that expected for partial oxidation of the landfill gas represented by LP-3 (Figure 6).

The ^{14}C activities of the methane from FOMW2-LE and Office Closet gas samples (121.53 and 122.66 pMC, respectively) are basically the same as that obtained for LP-3, the landfill gas sample (122.30 pMC) especially considering the standard deviation of the $^{14}C_1$ measurement (Table 2). The ^{14}C activity of the methane from Office Closet gas sample is within one standard deviation of the LP-3 sample, and the ^{14}C activity of the methane for the FOMW2-LE sample is within two standard deviations of the LP-3 sample. As indicated in Figure 7, the ^{14}C activities from all three samples are typical of landfill gas. According to the literature, the ^{14}C activity of sewage waste ranges between approximately 70 to 105 pMC (*Law et al., 2013; Nara et al., 2010 and Griffith et al., 2009*), lower than that obtained from the void space beneath the closet area. Thus, the radiocarbon results of the methane in the samples from the void space in the closet area is consistent with the landfill gas.

A plot of the ^{14}C versus the $\delta^{13}C$ of the methane indicates the FOMW2-LE and Office Closet gas samples are consistent with partial oxidation of landfill gas as shown by the black-solid horizontal arrow in Figure 8. As mentioned previously, during microbial oxidation of methane there is an isotopic fractionation and the $\delta^{13}C$ of the residual methane will be shifted to more positive values. However, the ^{14}C activity is routinely normalized to a standard stable isotopic composition before being reported, thereby minimizing the effects that isotope fractionation, by processes such as partial oxidation, have on ^{14}C in a sample.

The measured ^3H concentration for the methane from the Office Closet gas sample was 56.6 TU (Table 1), much greater than expected for normal surface water or shallow groundwater. Studies in central Iowa (*Simpkins, 1995*) and southwestern Illinois (*Hackley et al., 2007*) showed the average tritium concentration in precipitation and shallow groundwater was 11 TU and 5.4 TU, respectively. The average concentration of ^3H in precipitation in the United States since the mid-1990's ranges between about 2 to 9 TU (*Eastoe et al., 2012*). Unfortunately, there was an insufficient concentration of methane in the LP-3 gas sample for ^3H analysis thus, we could not make a direct comparison of the ^3H in the methane from the Office Closet sample

with the landfill gas sample. However, a comparison of the ^{14}C activity with the ^3H concentration shows that the results from the Office Closet gas sample are consistent with the range of values expected for landfill gas (Figure 9). The tritium concentration that would be associated with septic systems would have the same concentration as the water source, which would be shallow groundwater or a surface reservoir. Thus, the tritium results for the Office Closet sample suggest the source of the methane in the void area beneath the closet area originates from the municipal landfill.

Summary of Observations

In summary, the molecular results for the FOMW2-LE and Office Closet gas samples contained elevated levels of CO_2 and very negative $\delta^{13}C$ values for the CO_2 which indicate the gas represented by these samples has been oxidized. The $\delta^{13}C$ and δD results of the methane for the FOMW2-LE and Office Closet gas samples were more positive compared to the LP-3 landfill gas sample and plotted in a manner aligned with partial oxidation of the LP-3 gas sample. The ^{14}C activity of the methane for both the FOMW2-LE and Office Closet gas samples were nearly the same as that observed for the LP-3 landfill gas sample. The tritium concentration of the methane from the Office Closet sample was significantly greater than expected for normal surface water or shallow groundwater and fell within the range expected for municipal landfills. Thus, the molecular and isotopic results of the FOMW2-LE and Office Closet gas samples indicate the source of the gas in the void space of the closet area is consistent with landfill gas originating from the Henry County Sanitary Landfill.

Cited References

Bogner, J.E., R.E. Sweeney, D. Coleman, R. Huitric, and G.T. Ririe (1996). Using isotopic and molecular data to model landfill gas processes. *Waste Management & Research*, **14**, 367-376.

Camarda, M., S. De Gregorio, R. Favara, and S. Gurrieri (2007). Evaluation of carbon isotope fractionation of soil CO2 under an advective-diffusive regimen: A tool for computing the isotopic composition of unfractionated deep source. *Geochimica et Cosmochimica Acta*, **71**, 3016-3027.

Cerling, T.E., E.K. Solomon, J. Quade, and J.R. Bowman (1991). On the isotopic composition of carbon in soil carbon dioxide. *Geochimica et Cosmochimica Acta*, **55**, 3403-3405.

Clark, I. and P. Fritz (1997). Environmental Isotopes in Hydrogeology. Lewis Publishers, Boca Raton, and New York, 328 p.

Coleman D.D., C.-L. Liu, K.C. Hackley, and S.R. Pelphrey (1995). Isotopic identification of landfill methane. *Environmental Geosciences* **2**, 95-103.

Eklund, B., E.P. Anderson, B.L. Walker, and D.B. Burrows (1998). Characterization of landfill gas composition at the Fresh Kills Municipal Solid-Waste Landfill. *Environmental Science and Technology*, **32**, 2233-2237.

Eastoe, C.J., C.J. Watts, M. Ploughe, and W.E. Wright (2012). Future use of tritium in mapping pre-bomb groundwater volumes. *Ground Water*, **50**, *1*, 87-93.

Griffith, D.R., R.T. Barnes, and P.A. Raymond (2009). Inputs of fossil carbon from wastewater treatment plants to U.S. rivers and oceans. *Environmental Science and Technology*, **43**, 5647-5651.

Hackley K.C., C.L. Liu, and D.D. Coleman (1996). Environmental isotope characteristics of landfill leachates and gases. *Ground Water,* **34**, 827-836.

Hackley, K.C., S.V. Panno, H.-H. Hwang, and W.R. Kelly (2007). Groundwater quality of springs and wells of the sinkhole plain in southwestern Illinois: determination of the dominant sources of nitrate. *Illinois State Geological Survey, Circular 57*0, 39 pg.

Law, Y., G.E. Jacobsen, A.M. Smith, Z. Yuan, and P. Lant (2013). Fossil organic carbon in wastewater and its fate in treatment plants. *Water Research*, **47**, 5270-5281.

Nara, F.W., A. Imai, K. Matsushige, K. Komatsu, N. Kawasaki, and Y. Shibata (2010). Radiocarbon measurements of dissolved organic carbon insewage-treatment-plant effluent and domestic sewage. *Nuclear Instruments and Methods in Physics Research B*, 268, 1142-1145.

Schoell, M. (1980). The hydrogen and carbon isotopic composition of methane from natural gases of various origin. *Geochim. Cosmochim. Acta* **44**, 649-661.

Simpkins, W.W. (1995). Isotopic composition of precipitation in central Iowa. *Journal of Hydrology*, **172**, 185-207.

Stuiver, M. and H.A. Polach, 1977. Discussion: Reporting of ^{14}C data. *Radiocarbon*, **19**, no. 3, 355-363.

Whiticar, M.J., E. Faber and M. Schoell (1986). Biogenic methane formation in marine and freshwater environments: CO_2 reduction vs. acetate formation - Isotope evidence. *Geochim. Cosmochim. Acta,* **50**, 693-709.

Table 1. Summary of gas chromatography (GC) results for the gas samples from the Henry County Sanitary Landfill near Mt. Pleasant, Iowa (Jobs 61776 and 63126).

Isotech Job No.	Isotech Lab No.	Sample Name	Sample Date	Container	He %	H_2 %	Ar %	O_2 %	CO_2 %	N_2 %	CO %	C_1 %	C_2 %	C_2H_4 %	C_3 %	C_3H_6 %	iC_4 %	nC_4 %	iC_5 %	nC_5 %	C_6+ %
61776	959597	FOMW2-LE	3/11/25	IsoBag	nd	nd	0.947	1.82	11.59	78.52	nd	7.13	nd	nd	nd	nd	nd	nd	nd	nd	nd

Isotech Job No.	Isotech Lab No.	Sample Name	Sample Date	Container	He %	H_2 %	Ar %	O_2 %	CO_2 %	N_2 %	CO %	C_1 %	C_2 %	C_2H_4 %	C_3 %	C_3H_6 %	iC_4 %	nC_4 %	iC_5 %	nC_5 %	C_6+ %
63126	976298	Office Closet	7/16/25	Isotech LP Tank	nd	nd	0.717	1.35	19.99	60.01	nd	17.93	nd	nd	nd	nd	0.0001	nd	nd	nd	nd
63126	976299	LP-3	7/16/25	Isotech LP Tank	nd	nd	0.913	20.36	0.63	77.02	nd	1.08	nd	nd	nd	nd	nd	nd	nd	nd	nd

All gas com All gas component carbon isotope values are reported on a scale defined by a two point calibration of LSVEC and NBS 19.
nd = not detected, na = not analyzed

Table 2. Summary of isotopic results for the gas samples from the Henry County Sanitary Landfill near Mt. Pleasant, Iowa (Jobs 61776 and 63126).

Isotech Job No.	Isotech Lab No.	Sample Name	Sample Date	Container	$\delta^{13}CO_2$ ‰	$\delta^{13}C_1$ ‰	δDC_1 ‰	$^{14}C_1$ pMC	$^{14}C_1$ Std. Dev.	Tritium C_1 TU	Tritium C_1 Std. Dev.
61776	959597	FOMW2-LE	3/11/25	IsoBag	-33.84	-36.80	-193.7	121.53	0.47	na	

Isotech Job No.	Isotech Lab No.	Sample Name	Sample Date	Container	$\delta^{13}CO_2$ ‰	$\delta^{13}C_1$ ‰	δDC_1 ‰	$^{14}C_1$ pMC	$^{14}C_1$ Std. Dev.	Tritium C_1 TU	Tritium C_1 Std. Dev.
63126	976298	Office Closet	7/16/25	Isotech LP Tank	-30.31	-44.99	-251.9	122.66	0.48	56.6	5.9
63126	976299	LP-3	7/16/25	Isotech LP Tank	4.93	-50.14	-279.4	122.30	0.48	*	

nd = not detected, na = not analyzed   *Insufficient concentration of methane for 3H of C1 analysis.
Counting TU values are calculated for date of sample collection, as provided by the submitter.
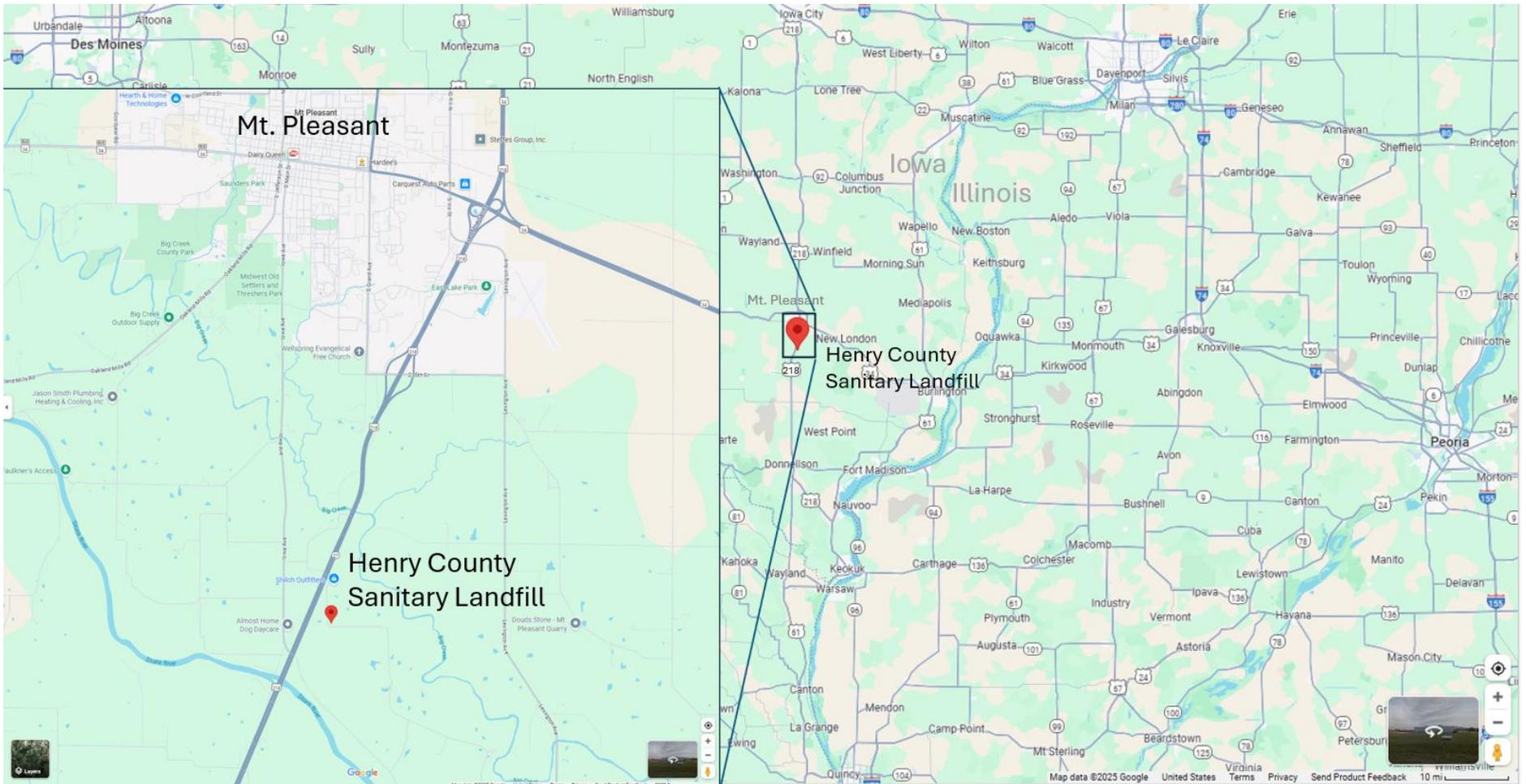
Figure 1. Google map showing location of the Henry County Sanitary Landfill a few miles south of Mount Pleasant, in eastern Iowa.
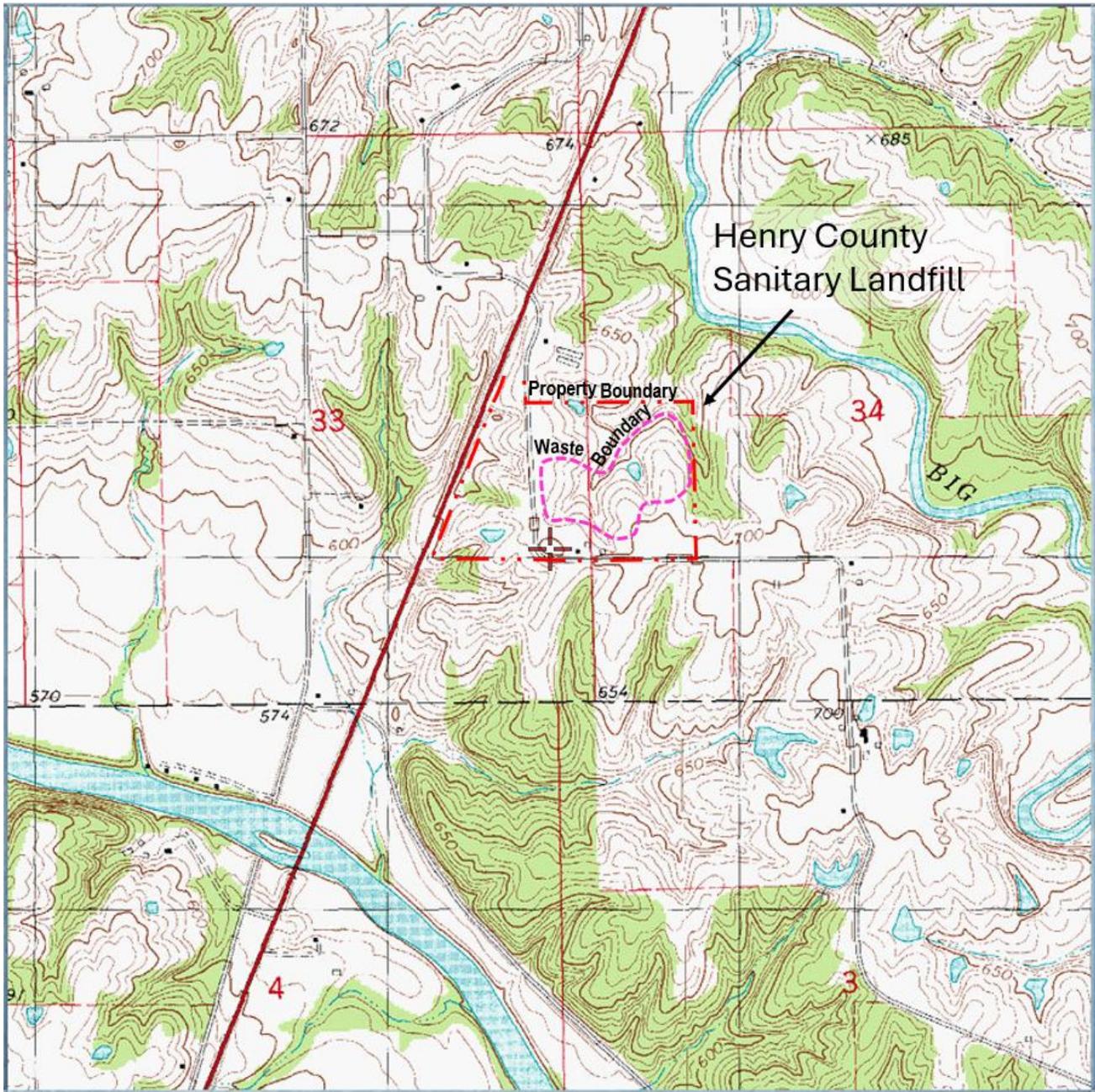
Figure 2. Topographic map showing the location of the Henry County Landfill, including the approximate property boundary (red dashed-dotted line) and waste repository boundary (pink dashed line). (Map from *https://topoquest.com/map.php?lat=40.90503&Opm=-91.54601&datum=nad83&zoom=4&map=auto&coord=d&mode=pan&size=m&cross=on*)
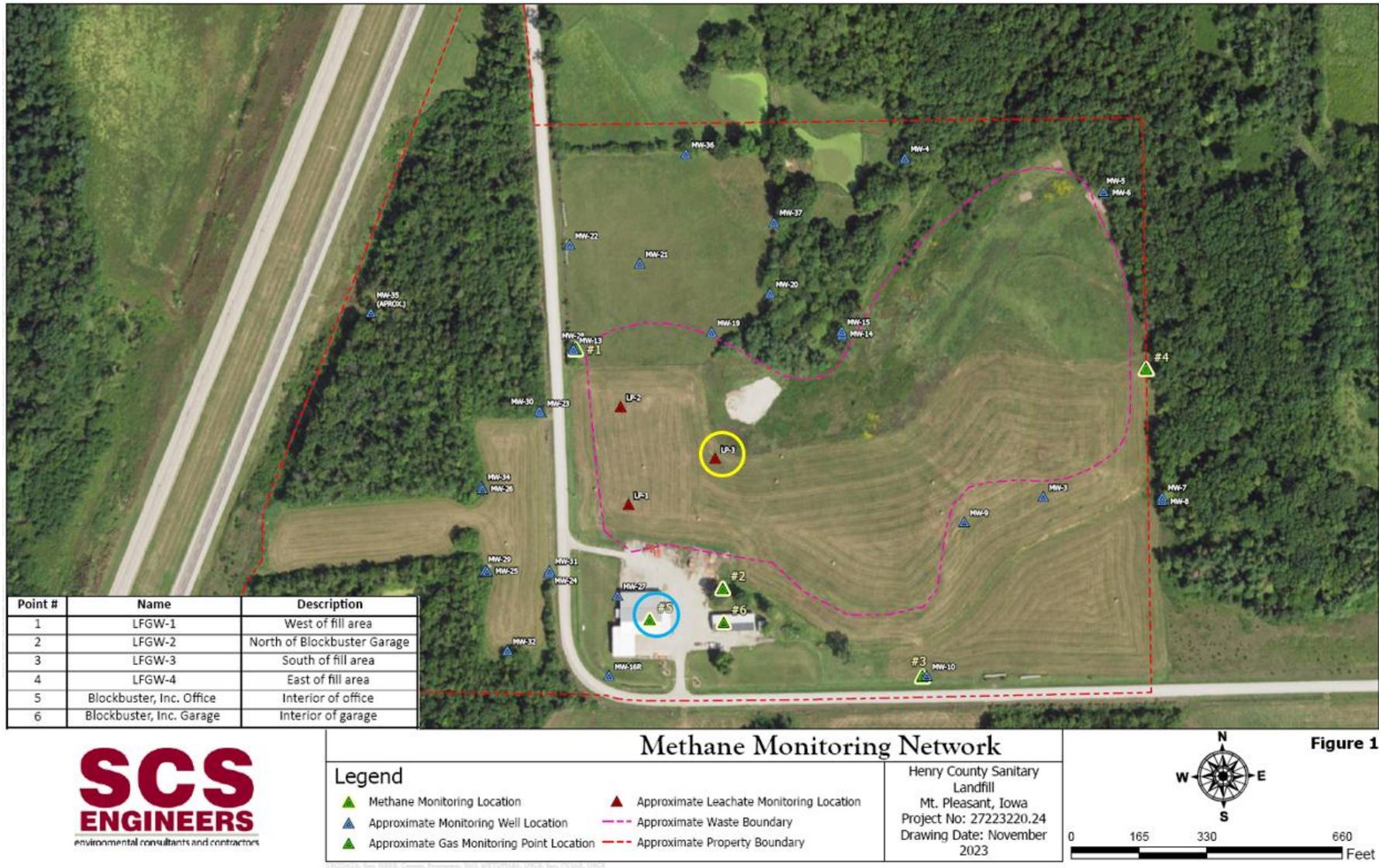
Figure 3. Site map of Henry County Sanitary Landfill showing where the leachate monitoring probe (LP-3) is located (yellow circle) and where the FOMW2-LE and Office Closet gas samples were collected (gas monitoring location #5, blue circle). Also included are the landfill waste boundry (pink dashed line) and landfill property boundary (red dashed line). (*Map provided by SCS Engineers.*)
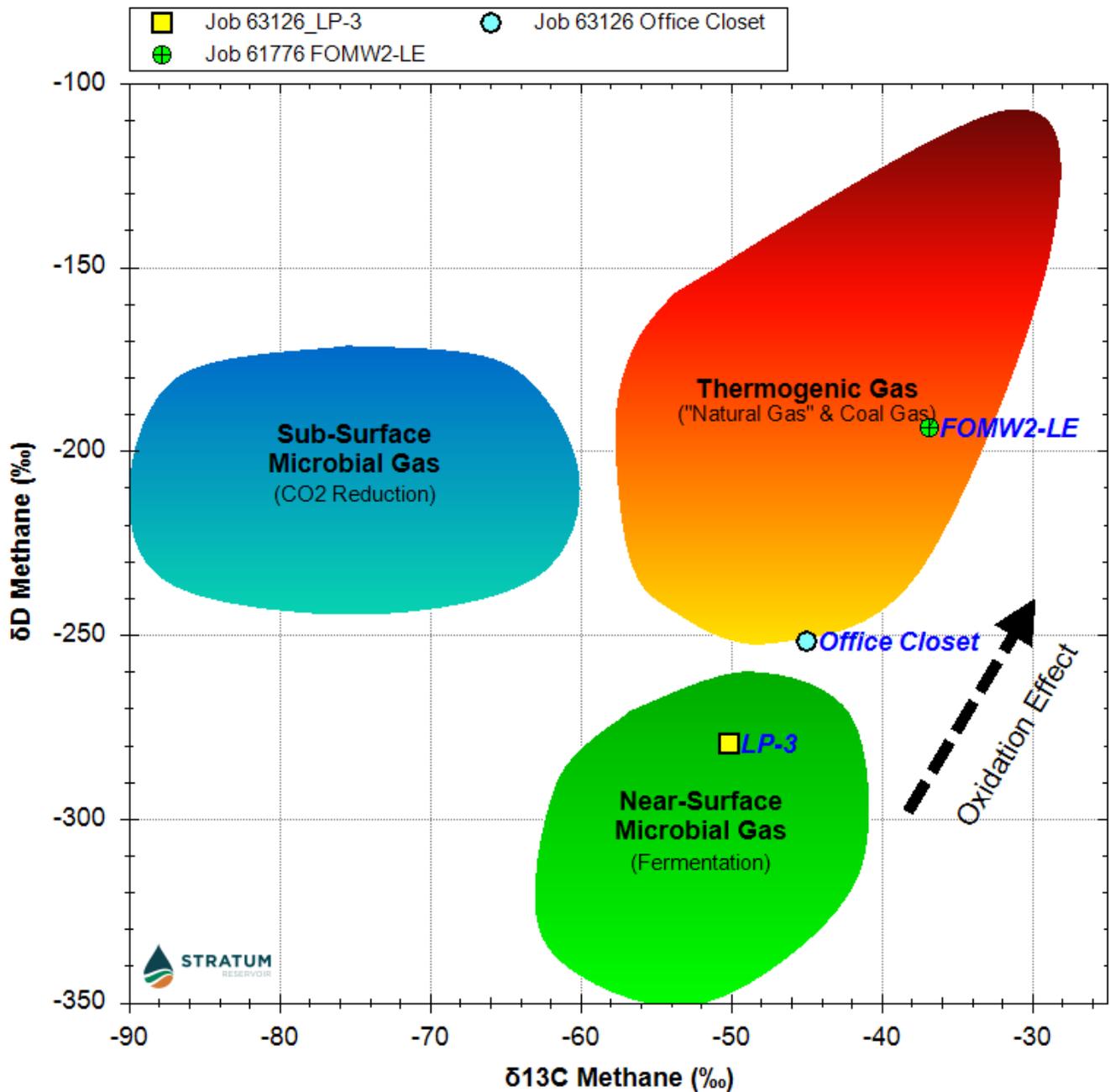
14

Figure 4. Graph of the $\delta^{13}C$ and δD data for the methane associated with the closet void gas samples (FOMW2-LE and Office Closet) and the landfill gas sample (LP-3) from the Henry County Landfill plotted along with typical domains for various sources of methane. The data for closet void gas samples (blue and green circles) plot along a trajectory expected for partial oxidation of the landfill gas sample LP-3 (yellow square). The effects of partial oxidation are shown by the large, dashed arrow in the lower right corner of the diagram. (Diagram template is based on *Coleman et al., 1995.*)
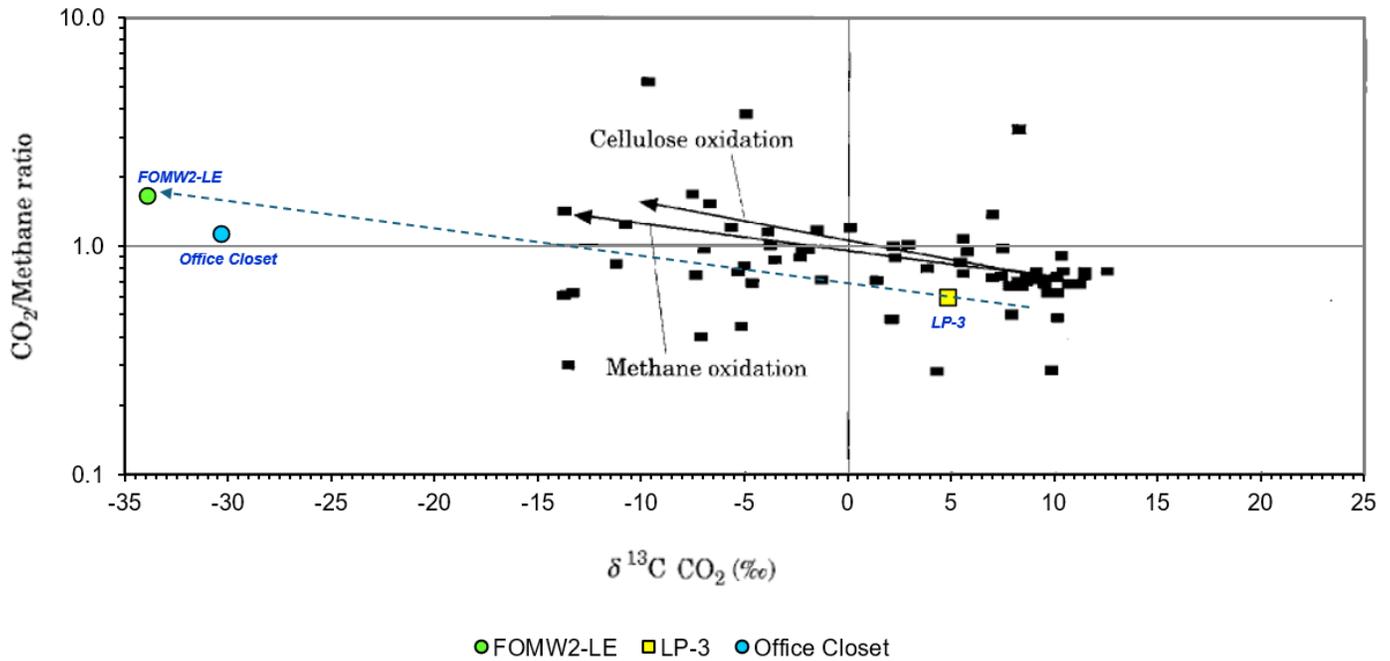
Figure 5. The CO_2/CH_4 ratio versus the $\delta^{13}C$ of CO_2 results of the closet void gas samples (FOMW2-LE and Office Closet) and the landfill gas sample (LP-3) from the Henry County Landfill plotted on a published diagram showing data from a study that included roughly 130 gas samples from landfills thoughout the United States (*Bogner et al., 1996*). The data for the FOMW2-LE and Office Closet gas samples follow the expected trajectory for partial oxidation of the LP-3 sample.
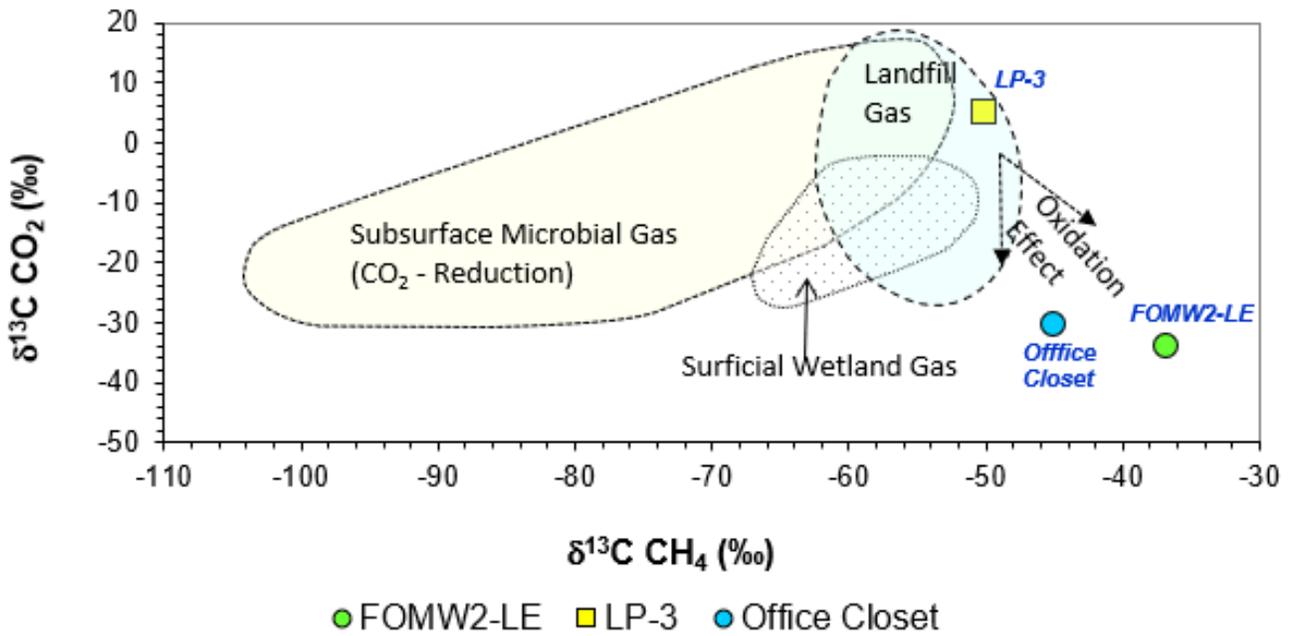
Figure 6. Plot of $\delta^{13}C$ of CO_2 and CH_4 for the gas samples from Jobs 61776 and 63126 along with domains of typical values for different sources of gas (*modified from Hackley et al., 1996*).
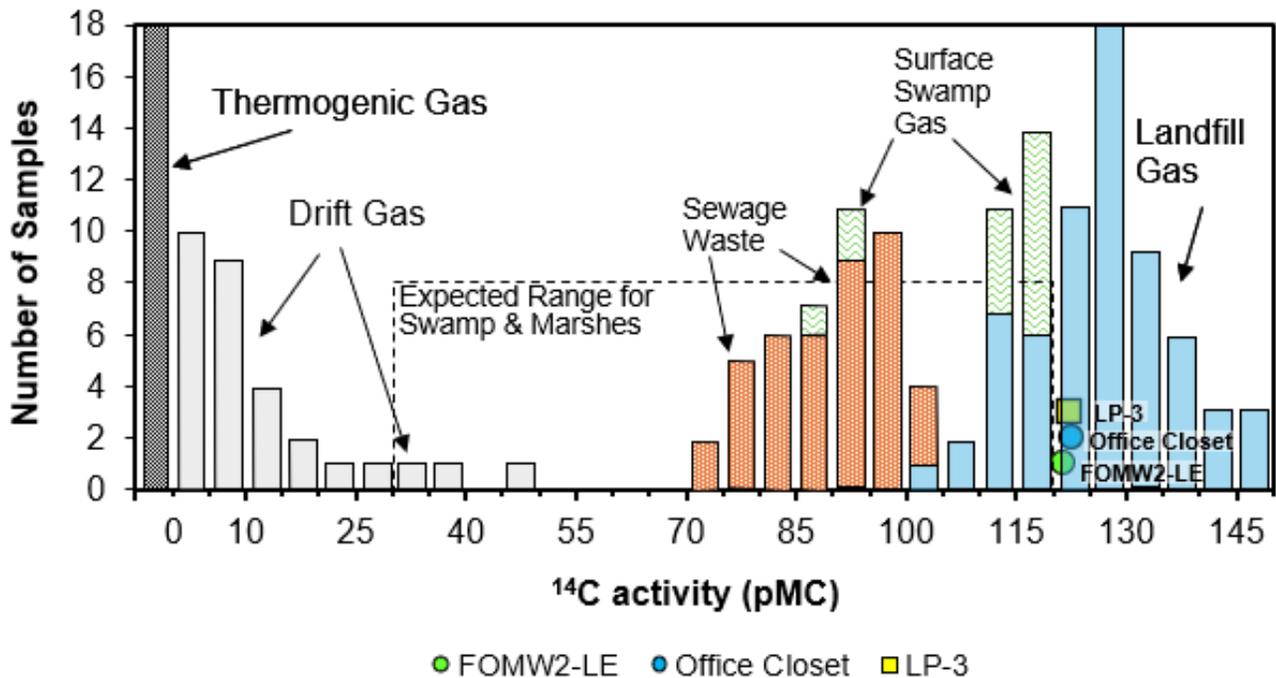
Figure 7. Results of ^{14}C of CH_4 in percent modern carbon (pMC) for the gas samples from the Henry County Landfill site (Job 63126 and 61776) compared to ^{14}C activities observed for various different sources of CH_4. The bar diagram includes examples of ^{14}C activity of CH_4 from municipal landfills, near-surface swamp gas (fermentation), sub-surface microbial methane produced primarily via CO_2-reduction (Drift Gas), and thermogenic gas (*based on Hackley et al., 1999; Coleman et al., 1995*), plus samples from various sewage waste and septic systems (*Law et al., 2013; Nara et al., 2010 and Griffith et al., 2009*).
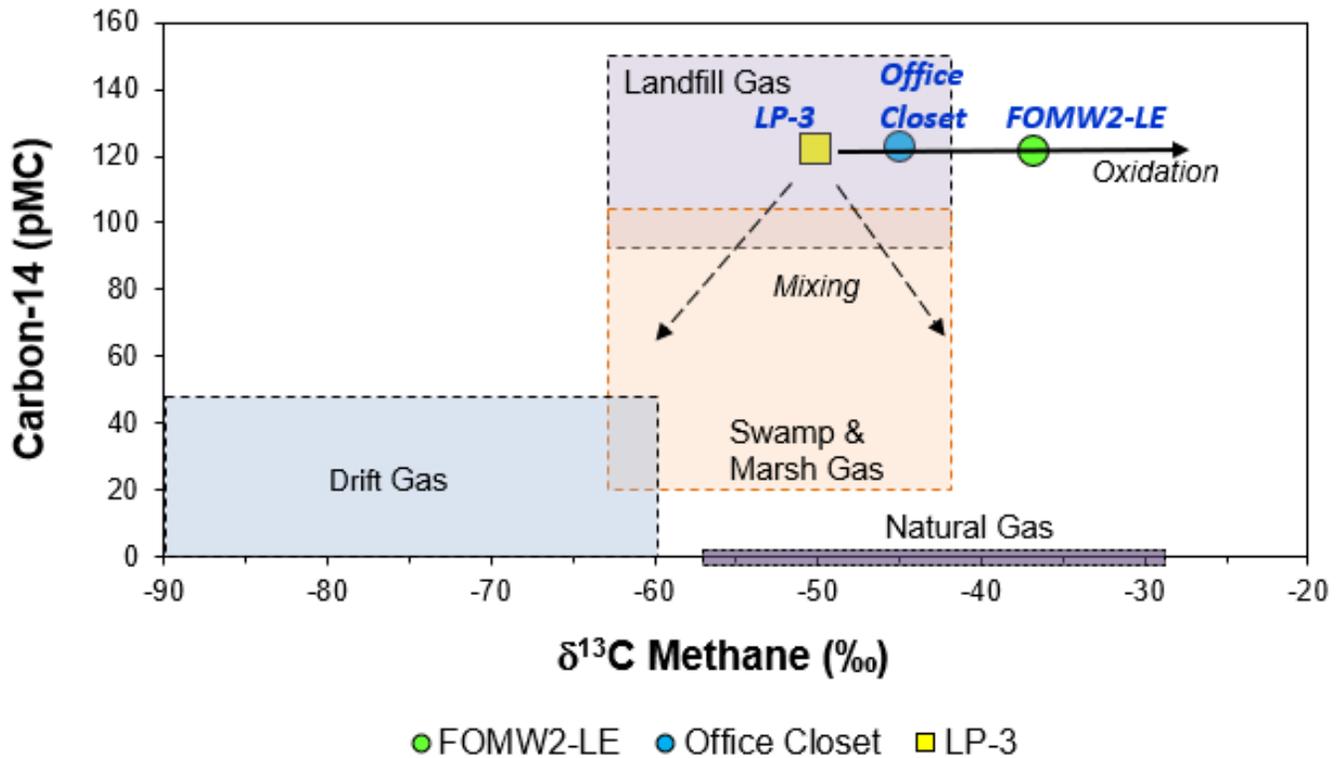
Figure 8. A plot of the ^{14}C versus $\delta^{13}C$ of the methane for samples from the Henry Sanitary Landfill site (Job 63126 and 61776) as well as expected ranges of values for different sources of methane. Hypothetical oxidation and mixing lines are also shown. During oxidation the ^{14}C of the residual methane would remain constant whereas the $\delta^{13}C$ would shift to more positive values (black-solid horizontal arrow).
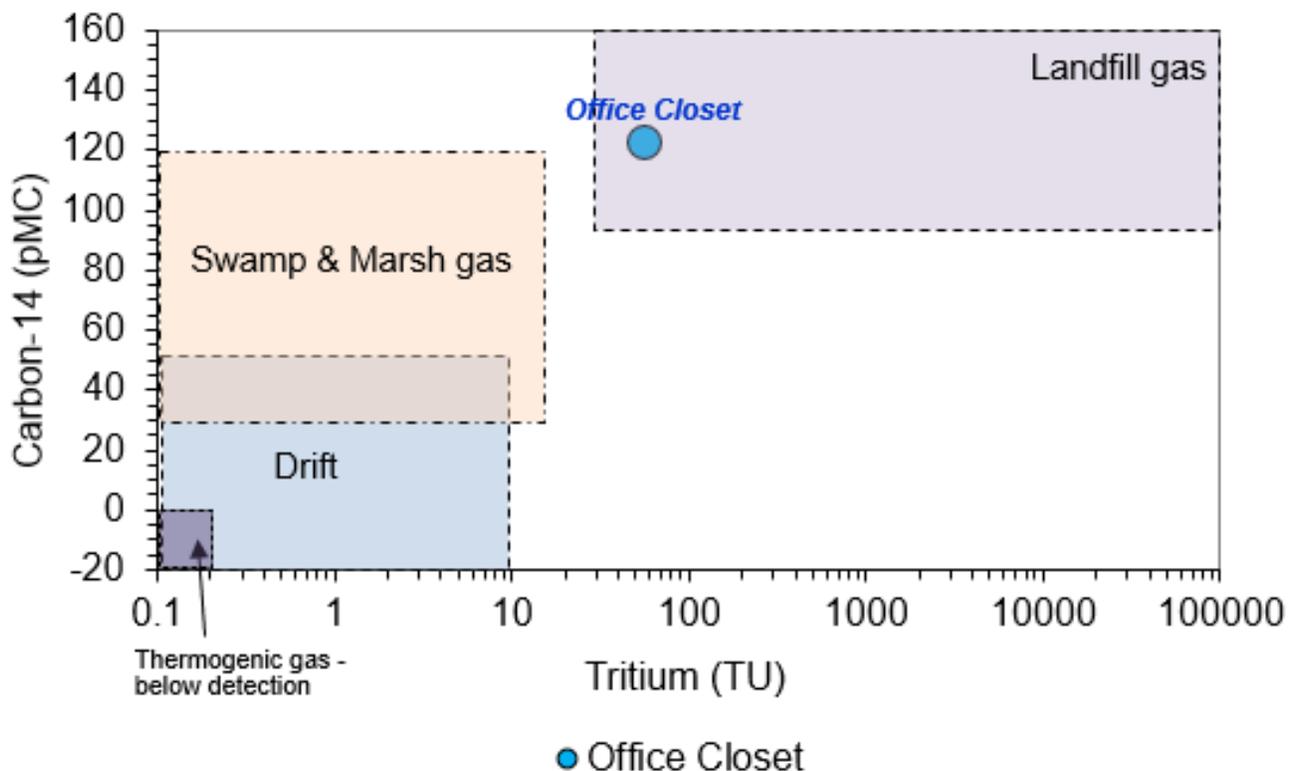
Figure 9. Graph of ^{14}C versus ^{3}H showing how the CH$_4$ from the gas sample Office Closet from the void space beneath the closet floor in one of the buildings at the Henry County Sanitary Landfill compares with the typical ranges of values expected for various sources of CH$_4$ (*diagram modified from Hackley et al., 1996*).

APPENDIX I

Background Isotope Information

The following is a short review of some background information for using isotope analyses for determining sources of methane. The use of environmental isotopes, including carbon-13 ($\delta^{13}C$), deuterium (δD), carbon-14 (^{14}C) and tritium (^{3}H) have been shown to be very effective in determining the source of methane (*Schoell, 1980; Whiticar et al., 1986; Coleman et al., 1995; Hackley et al., 1996)*. The $\delta^{13}C$ and δD of landfill methane typically ranges from -45 to -60‰ and -250 to -350‰, respectively. This is different compared to CH_4 associated with the microbial CO_2-reduction process typically found in sub-surface low temperature reducing environments with abundant organic matter. The isotopic composition of CO_2-reduction microbial gas usually ranges from -60 to -90‰ for $\delta^{13}C$ and -170 to -240‰ for δD. Methane generated from near-surface wetland or sewage type environments has $\delta^{13}C$ and δD values that basically overlap landfill methane values. This overlap is because the CH_4 derived from landfills and wetland (or sewage) environments are produced via the same microbial metabolic pathway referred to as acetate fermentation. The other major source of CH_4 is thermogenic methane (CH_4 associated with petroleum or natural gas pipelines) which has $\delta^{13}C$ and δD values that typically range from -30 to -55 ‰ and -110 to -240 ‰ respectively. As CH_4 migrates from the very reducing environments from which it is generated, it is often oxidized, altering the stable isotopic composition due to the fractionation involved with the microbial oxidation process. The lighter isotopes are oxidized more rapidly, producing isotopically more negative CO_2 compared to the CO_2 associated with the original gas composition, which causes the residual CH_4 to become isotopically heavier (more positive $\delta^{13}C$ and δD values). Thus, CH_4 which has migrated from a specific source may have a different isotopic composition compared to the original values due to this isotopic fractionation effect. This oxidation effect along with mixing of two different sources of CH_4 can complicate the interpretation of the stable isotopic results in some cases when trying to distinguish different methane sources.

The ^{3}H and ^{14}C analyses often help to clarify ambiguity that may exist from the stable isotope results. Typically, the ^{14}C and ^{3}H for methane originating from landfills have relatively large values compared to methane from CO_2-reduction gas or thermogenic origin. The half-life of ^{14}C is 5730 years. For dating purposes, ^{14}C is useful for up to almost 50,000 years or about 9 half-lives. In many environmental studies, ^{14}C concentrations are usually reported as percent modern carbon (pMC). By convention, "modern carbon" (100 pMC) is defined as 0.95% of the ^{14}C activity of

the NBS oxalic acid standard (*Clark and Fritz, 1997*). This activity represents the "normal" ^{14}C content of CO_2 in the atmosphere without significant anthropogenic contributions of carbon. For ^{14}C dating, 1950 is considered to be the 'present' (i.e., 100 pMC) (*Stuiver and Polach, 1977*). Samples of carbon buried prior to 1950 and isolated from exchange with atmospheric carbon will have begun to decay and have concentrations of ^{14}C less than 100 pMC. Carbon sources from very old sediments, such as coal and oil deposits which are millions of years old, will no longer contain detectable ^{14}C activity. The ^{14}C activity in CH_4 derived from landfills comes from the organic material that ends up in a landfill which is primarily paper, cardboard, wood, and yard waste originating from plant material that grew in the previous few decades. Because of the substantial atmospheric testing of nuclear devices in the 1950's and 1960's the ^{14}C nearly doubled in the atmosphere of the northern hemisphere and in turn increased the ^{14}C concentration in plants and living organisms. Thus, organic debris buried in landfills since that time period also contains elevated ^{14}C concentrations (from approximately 100 to 150 pMC).

Methane produced from the shallow regions of swamps and marshy areas may also have a significant amount of recent plant/organic matter and can have ^{14}C concentrations that could overlap with landfill derived CH_4 (ranging from 30 to 120 pMC). However, the ^{3}H from swamps and marshes or shallowly buried plant debris would be similar to shallow groundwater or fairly recent precipitation (typically < 15 TU) while ^{3}H in landfills are typically quite large on the order of several 10's to 100's, 1000's, or even tens of 1000's of tritium units (TU). Although tritium in plant debris that grew during the 1950's through the 1970's might contribute some measurable concentrations to methane generation, the level of tritium in the methane produced from naturally buried organic debris in wetlands would still be low because of the relatively short tritium half-life (12.3 yrs) and the fact that there would normally be older organic debris (> 100 yrs) present in wetlands or flood deposits with no detectable tritium remaining. Isotopic characteristics of landfill gases are described in more detail by *Coleman et al. (1995)* and *Hackley et al. (1996)*.

APPENDIX II

Analytical Data Reports for Job 61776 and 63126

Lab #: 959597 **Job #:** 61776 **Co. Job#:** 27224515.25

Sample Name: FOMW2-LE

Company: SCS Engineers

Container: IsoBag

Location: Henry County

Date Sampled: 03/11/2025 11:51 **Date Received:** 03/13/2025 **Date Reported:** 05/19/2025

Component	Chemical mol%	δ¹³C ‰	δ¹⁸O ‰	δD ‰	¹⁴C conc. pMC	Tritium TU
Carbon Monoxide	nd					
Helium	nd					
Hydrogen	nd					
Argon	0.947					
Oxygen	1.82					
Nitrogen	78.52					
Carbon Dioxide	11.59	-33.84				
Methane	7.13	-36.80		-193.7	121.53 ± 0.47	
Ethane	nd					
Ethylene	nd					
Propane	nd					
Propylene	nd					
Iso-butane	nd					
N-butane	nd					
Iso-pentane	nd					
N-pentane	nd					
Hexanes +	nd					

Total BTU/cu.ft. dry @ 60deg F & 14.73 psia calculated: 72
Specific Gravity, calculated: 1.008
Remarks:

nd = not detected. na = not analyzed. Isotopic composition of hydrogen is relative to VSMOW. Isotopic composition of carbon is relative to VPDB. All gas component carbon isotope values are reported on a scale defined by a two point calibration of LSVEC and NBS 19. Isotopic composition of oxygen is relative to VSMOW, except for carbon dioxide which is relative to VPDB. Calculations for BTU and specific gravity per ASTM D3588. Chemical compositions are normalized to 100%. Mol % is approximately equal to vol. %.

Lab #: 976298   **Job #:** 63126   **Co. Job#:** Henry County Sanitary Landfill

Sample Name: Office Closet

Company: SCS Engineers

Container: Isotech LP Tank

Location: Henry County, Mt. Pleasant, IA

Date Sampled: 07/16/2025 12:25   **Date Received:** 07/17/2025 **Date Reported:** 08/20/2025

Component	Chemical mol%	$\delta^{13}C$ ‰	$\delta^{18}O$ ‰	δD ‰	^{14}C conc. pMC	Tritium TU
Carbon Monoxide	nd					
Helium	nd					
Hydrogen	nd					
Argon	0.717					
Oxygen	1.35					
Nitrogen	60.01					
Carbon Dioxide	19.99	-30.31				
Methane	17.93	-44.99		-251.9	122.66 ± 0.48	56.6 ± 5.90
Ethane	nd					
Ethylene	nd					
Propane	nd					
Propylene	nd					
Iso-butane	0.0001					
N-butane	nd					
Iso-pentane	nd					
N-pentane	nd					
Hexanes +	nd					

Total BTU/cu.ft. dry @ 60deg F & 14.73 psia calculated: 182
Specific Gravity, calculated: 1.008
Remarks:

nd = not detected. na = not analyzed. Isotopic composition of hydrogen is relative to VSMOW. Isotopic composition of carbon is relative to VPDB. All gas component carbon isotope values are reported on a scale defined by a two point calibration of LSVEC and NBS 19. Isotopic composition of oxygen is relative to VSMOW, except for carbon dioxide which is relative to VPDB. Calculations for BTU and specific gravity per ASTM D3588. Chemical compositions are normalized to 100%. Mol % is approximately equal to vol. %.

Lab #: 976299 **Job #:** 63126 **Co. Job#:** Henry County Sanitary Landfill

Sample Name: LP-3

Company: SCS Engineers

Container: Isotech LP Tank

Location: Henry County, Mt. Pleasant, IA

Date Sampled: 07/16/2025 13:00 **Date Received:** 07/17/2025 **Date Reported:** 08/20/2025

Component	Chemical mol%	$\delta^{13}C$ ‰	$\delta^{18}O$ ‰	δD ‰	^{14}C conc. pMC	Tritium TU
Carbon Monoxide	nd					
Helium	nd					
Hydrogen	nd					
Argon	0.913					
Oxygen	20.36					
Nitrogen	77.02					
Carbon Dioxide	0.63	4.93				
Methane	1.08	-50.14		-279.4	122.30 ± 0.48	
Ethane	nd					
Ethylene	nd					
Propane	nd					
Propylene	nd					
Iso-butane	nd					
N-butane	nd					
Iso-pentane	nd					
N-pentane	nd					
Hexanes +	nd					

Total BTU/cu.ft. dry @ 60deg F & 14.73 psia calculated: 11
Specific Gravity, calculated: 0.998
Remarks:
Insufficient concentration of methane for 3H of C1 analysis.

nd = not detected. na = not analyzed. Isotopic composition of hydrogen is relative to VSMOW. Isotopic composition of carbon is relative to VPDB. All gas component carbon isotope values are reported on a scale defined by a two point calibration of LSVEC and NBS 19. Isotopic composition of oxygen is relative to VSMOW, except for carbon dioxide which is relative to VPDB. Calculations for BTU and specific gravity per ASTM D3588. Chemical compositions are normalized to 100%. Mol % is approximately equal to vol. %.