Letter Health Consultation

Review of the Pennsylvania Department of Environmental Protection's Open-Path Fourier Transform Infrared Sampling Data Collected between 2013 and 2015 from Locations near Natural Gas Compressor Stations in Susquehanna County, Pennsylvania

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Prepared by

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Health Consultation: A Disclaimer

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The conclusions and recommendations presented in this health consultation document are based on an analysis of the environmental sampling data and information made available to the Pennsylvania Department of Health within a limited time frame. The availability of additional sampling data, new information and/or changes in site conditions could affect the conclusions and recommendations presented in this document. The Pennsylvania Department of Health will consider reviewing additional future data related to the site, if made available and deemed appropriate.

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On September 2016, the Pennsylvania Department of Environmental Protection (PADEP) requested the Pennsylvania Department of Health (PADOH) and the Agency for Toxic Substances and Disease Registry (ATSDR) to review the OPFTIR air data for any potential health impact near natural gas compressor stations in Susquehanna County, Pennsylvania. ATSDR recommended that PADOH perform the evaluation. Based on PADEP's request, this letter health consultation provides evaluation of the available data, conclusions and recommendations for future actions to protect the public health.

PADEP conducted ambient air sampling using the open-path fourier transform infrared (OPFTIR) method at three different locations adjacent to natural gas compressor stations. Monitoring was conducted to study air quality near the development and operation of natural gas compressor stations that were near community locations. Air data from the OPFTIR method can be helpful to rapidly identify the presence of chemicals in the air at the potential source location, and can only be used to screen for potential acute health effects and odor-related events. This method has limited utility for public health exposure assessment because of its high detection limits and because the instantaneous readings cannot be converted into appropriate exposure values for the evaluation of chronic health effects. In addition, this instrument's detection limits vary markedly from place to place due to factors such as instrument calibration, distance/angle that the electromagnetic beam traverses (beam path), deployment of beam transmission and reception, ambient air temperature, and relative humidity of air.

As a preliminary health evaluation, PADOH screened the contaminants detected by OPFTIR method against appropriate acute health-based comparison values (CVs) to select contaminants for further evaluation for any potential acute health risk. ATSDR CVs, like minimum risk levels, are conservative estimates of contaminant levels below which no health effects would be expected. Concentrations above a CV will not necessarily be harmful. Contaminants that exceed a CV were further evaluated using other standards and/or scientific studies, where appropriate, to determine whether adverse health effects are likely. When an ATSDR acute CV is not available, acute screening values are acquired from other environmental and health agencies.

Upon review of data, six contaminants detected (benzene, methyl mercaptan, methylamine, nitric acid, nitrogen dioxide, and n-octane) were selected for further evaluation, since the detected concentrations exceeded the acute health-based CVs. Of these six contaminants, three contaminants (methyl mercaptan, methylamine, and nitrogen dioxide) exceeded their odor threshold levels (OTLs) as well. Three other contaminants (1, 2, 4-trimethylbenzene; acetaldehyde; and dimethyl sulfide) exceeded the OTLs, but not health-based CVs (Table 1).

Because of the instantaneous one-time screening nature of the OPFTIR method, it is difficult to determine whether adverse chronic health effects are possible from exposure to the contaminants. Also, for many contaminants the minimum detection levels are set higher than the CVs. For instance, the minimum detection limit for benzene was 28 ppb; however, the acute CV for benzene is 9 ppb. With the method used, it was not possible to know whether benzene was present at a level above the CV of 9 ppb, but below 28 ppb. Therefore, we do not know if additional chemicals were present but at concentrations lower than what can be detected by this monitoring method. Based on the limited environmental data available, PADOH cannot conclude whether airborne chemicals near the natural gas compressor stations could harm people's health. Although we were unable to make a conclusive statement based on OPFTIR data, there may be a potential acute health risk based on contaminants detected (benzene, methylamine, methyl mercaptan, nitrogen dioxide, nitric acid, and n-octane) that exceeded acute health-based CVs. Also, there may be potential odor risk as some of the contaminants detected (1, 2, 4-trimethylbenzene; acetaldehyde; dimethyl sulfide; methyl mercaptan; methylamine; and nitrogen dioxide) exceeded the OTLs.

PADOH recommends that more rigorous environmental sampling and analytical methods be used to identify and quantify the specific chemical emissions in community's ambient air. PADOH also recommends conducting concurrent SUMMA Canister TO-15 analysis for each OPFTIR sampling period at the source location and the monitoring locations. This would better characterize the presence of harmful airborne contaminants and provide sufficient data for the thorough evaluation of potential health effects.

Background

In 2013, PADEP's Northeast Regional Office Air Quality program requested PADEP's Bureau of Laboratories Mobile Analytical Unit (MAU) to conduct 8-hour ambient air monitoring over multiple days using the OPFTIR method to measure ambient air pollutants near natural gas compressor stations in Susquehanna County, PA. Monitoring was conducted at three different locations to screen and study the potential adverse health effects from ambient air near natural gas compressor stations. The three monitoring sites were Carson/White Pad Site (C/WPS), Post Pad Site (PPS), and Elk Lake Elementary School Site (ELESS) (Figure 1). PADEP also collected data from another site to test the background levels. However, the data from the background location was not provided for PADOH's evaluation. Monitoring was conducted on three occasions at each site: May 2013, June 2014, and August 2015. Of the three monitoring sites, C/WPS and PPS were immediately adjacent to completed unconventional natural gas wells or a natural gas well pad with a dewatering facility. The third monitoring site, ELESS, was on the property of a regional elementary school complex that is also adjacent to completed unconventional natural gas wells.

PADEP prepared a draft report on August 2016 based on OPFTIR monitoring results entitled "Technical Review of Multiple Open-Path Fourier Transform Infrared Method TO-16 Monitoring Results from Locations in Susquehanna County, PA."

Air Sampling Locations

Elk Lake Elementary School Site

The ELESS is part of a larger school complex located at 2380 Elk Lake School Road, Springville, Dimock Township, Pennsylvania. Based on U.S. Census 2010 data, Dimock Township had a population of 1,449. The school complex consists of the Elk Lake School District Administration Office, the Elementary School, and the Susquehanna County Career and Technology Center. All the buildings are located approximately three miles west-southwest of the village of Dimock. The school district serves the Townships of Auburn, Middletown, Rush, Dimock, and Springville in Susquehanna County (Figure 2), and Meshoppen Township in Wyoming County. The complex employs about 180 teachers, support staff and administrators for approximately 1,400 student attendees, based on 2008 data [PADEP 2016]. The sampling site was located southeast on school property opposite to the compressor station, which was northeast of the school property. There are eleven active unconventional natural gas producing wells within a one-mile radius of this sampling location (Figure 3). During the three sampling periods at this location, the average wind speed was 6 to 8 mph moving upwind from either the west, southwest or south-southwest of the Church compressor station. Hence, the wind direction and the location were not favorable enough to collect reliable data from the source location. School was not in session for the June 18, 2014 or August 4, 2015 sampling events per school calendar. School was likely in session for the May 14, 2013 sampling event although this was not confirmed in the OPFTIR reports. The absence or presence of traffic related to school activity could have an impact on observed results.

Post Pad Site

PPS is located at 2512 Van Auken Road, Kingsley, Brooklyn Township, Pennsylvania. Based on U.S. Census 2010 data, Brooklyn Township had a population of 928. This site is located at or near two unconventional wells. Also, seven other wells are located within a one-mile radius of this location (Figure 4). Recorded wind data for the three sampling events were variable in direction (south, east-southeast, and west) with average speeds of 6 to 11 mph. Weather was variable ranging from light rain to partly cloudy and sunny. Given the variability in wind direction and unknown path orientation at each sampling event, directionality of any detected emissions from the wells and tanks cannot be determined.

Carson / White Pad Site

C/WPS is located at Springville Township, Pennsylvania. Based on U.S. Census 2010 data, Springville Township had a population of 1,560. Monitoring was conducted at White pad site in 2013 and at Carson pad site in 2014 and 2015, to avoid interferences from a nearby compressor station (White Station) at the White pad site. Carson pad site has two active wells and five additional well pads within a one-mile radius (Figure 5). Winds on all three sampling days were from the south, southwest, or west at 3 to 4 mph. Like the two other sites, weather was variable ranging from light rain to partly cloudy to sunny and clear.

Results and Discussions

Based on the limited environmental data available using the OPFTIR method, certain chemicals were identified in the air at all the three monitoring locations. However, these levels could vary greatly, since these samples represent exposure levels for a snapshot in time. Actual average and

peak levels could be considerably higher or lower than those found in the single sampling events. For preliminary health evaluation, PADOH screened the available environmental sampling data against appropriate ATSDR's acute health-based CVs to identify contaminants of potential public health risk. ATSDR CVs like the Minimum Risk Levels (MRLs), are conservative estimates of contaminant levels below which no health effects would be expected. Concentrations above a CV will not necessarily be harmful. CVs are considered screening values. Contaminants that exceed a CV require further evaluation using other standards/scientific methods to determine whether adverse health effects are likely. When an ATSDR acute CV is not available, acute screening values are acquired from other environmental and health agencies such as the Texas Commission on Environmental Quality short-term Effects Screening Levels (TCEQsESL), TCEQ Air Monitoring Comparison Values (TCEQ AMCV) [TCEQ 2010], California Air Resources Board acute Reference Exposure Levels (CARBaREL), American Conference of Governmental Industrial Hygienists-Threshold Limit Values (ACGIH-TLV), National Institute for Occupational Safety and Health Reference Exposure Levels (NIOSH-REL), National Ambient Air Quality Standards (NAAQS), and the Air Quality Index (AQI) by the Environmental Protection Agency.

Table 1 summarizes all the contaminants detected (two-minute maximum concentrations) at all three monitoring locations, quantities detected, lower detection limits, acute health-based CVs/ OTLs and the source for health-based CVs. Contaminants that exceeded the acute CVs are in bold, and contaminants that exceeded OTLs are in italics. Contaminants that exceeded both acute CVs and OTLs are in bold italic fonts. Six contaminants that exceeded the health based acute CVs were benzene, methyl mercaptan, methylamine, nitric acid, nitrogen dioxide, and n-octane. Six contaminants that exceeded the OTLs were 1, 2, 4-trimethylbenzene; acetaldehyde; dimethyl sulfide; methyl mercaptan; methylamine; and nitrogen dioxide.

Benzene detected at all three monitoring locations exceeded ATSDR's acute MRL of 9 ppb. N-Octane, nitrogen dioxide and nitric acid detected only at ELESS exceeded each of their respective acute CVs. Methylamine detected only at C/WPS exceeded TCEQsESL of 44 ppb. Methyl mercaptan detected at C/WPS and PPS exceeded NIOSH REL of 500 ppb.

Potential acute health effect evaluation for contaminants that exceeded CVs

Benzene

Benzene is a highly flammable, colorless liquid with a sweet odor, which can be present in outdoor air because of emissions from many sources, including the burning of coal and oil, benzene waste and storage operations, motor vehicle exhaust, and evaporation from gas stations. The concentration of benzene in urban areas is generally between 0.3 and 19 ppb, and in rural areas between 0.02 and 1 ppb [EPA 1987; Roberts 1985; ATSDR 2007].

Automobile exhausts and industrial emissions account for about 20% of the total national exposure to benzene. About half of the benzene exposure in the United States comes from smoking tobacco or from exposure to tobacco smoke. The average smoker (32 cigarettes per day) takes in about 1.8 milligrams (mg) of benzene per day. This amount is about 10 times the average daily intake of benzene by nonsmokers. People may be exposed to higher levels of benzene in air by living near hazardous waste sites, petroleum refining operations, petrochemical manufacturing sites, or gas stations [ATSDR 2007]. A study by Macey et al 2014 on air quality near oil and gas production

sites nationwide found benzene, formaldehyde, and hydrogen sulfide were the most commonly detected contaminants above the CVs.

Out of three monitoring periods, benzene was detected twice at ELESS (202 ppb, 192 ppb) and C/WPS (182 ppb, 177 ppb), and once at PPS (84 ppb). However, these levels are several times lower than the exposure level (2,550 ppb - adjusted for 24 hrs.) at which health effects (immune associated processes) were observed in animals. However, these levels exceed ATSDR's acute MRL of 9 ppb for benzene.

Humans breathing benzene at a concentration (1-2 days, 2.5-8 hrs./day) of 60,000 ppb have been shown to experience dizziness, nausea, headache, peculiar or strong odor, chemical taste, and fatigue. In most cases, these symptoms are reversible with the cessation of exposure [ATSDR 2007]. The maximum concentration identified during those three monitoring periods (202 ppb - ELESS) is much lower and not expected to result in acute health effects.

Many volatile organic compounds (VOCs) including benzene are released to the air at all stages of oil and gas operations, from exploration and drilling to processing, including venting, dehydration, gas processing, compression, leaks from equipment, evaporation of produced water from pond, and evaporation of wastes from open pits [Brown, 2007]. During the three monitoring periods at each location, the minimum detection limits for benzene ranged from 28-230 ppb which is above the chronic, acute, and cancer risk CV of 3 ppb, 9 ppb, and 0.040 ppb respectively. Hence, sophisticated air monitoring (SUMMA Canister TO-15) is needed to further characterize the source of detected benzene concentration and to determine the chronic non-cancer health effects, and the lifetime cancer risks related to benzene near compressor stations. It is not possible to characterize lifetime cancer risks or chronic risks based on OPFTIR method, sampling of larger duration to get an average concentration is needed.

Methyl Mercaptan

Methyl mercaptan is a natural substance found in the blood, brain, and other tissues of people and animals. It occurs naturally in certain foods, such as some nuts and cheese. Methyl mercaptan is also present in the natural gas of certain regions in the United States, in coal tar, in some crude oils, and is released as a decay product of wood in pulp mills. Methyl mercaptan is a colorless gas that smells like rotten cabbage with a low odor detection level of 2 ppb. It is also released to the atmosphere through several industrial processes and produced naturally from the decomposition of organic matter. It can also be present in oil and natural gas deposits [ATSDR 1999].

Acute inhalation exposure to methyl mercaptan can irritate the mucous membranes of the respiratory tract. Also, restlessness, headache, staggering, and dizziness may develop, which might harm quality of life. Children may be more vulnerable to gas exposure because of relatively higher minute ventilation per body weight and failure to evacuate an area promptly when exposed. Exposure to high concentrations of methyl mercaptan can cause eye irritation. Nausea and vomiting may occur with inhalation exposure to the gas [ATSDR 2017].

Methyl mercaptan detected at C/WPS (517 ppb, 625 ppb) and PPS (561 ppb) exceeded NIOSH-REL of 500 ppb, not to be exceeded during any 15-minute work period. The Occupational Safety and Health Administration (OSHA) has set a permissible exposure limit (PEL) of 10,000 ppb as

the ceiling exposure concentration for workers. NIOSH and OSHA determine their permissible and recommended exposure limits for healthy, working age individuals. The detection limits for methyl mercaptan ranged from 26-488 ppb, which is above the odor threshold level of 2 ppb (Table 1). As mentioned above, methyl mercaptan was detected on three occasions above NIOSH REL of 500 ppb, which can have adverse health effects on the general population, if they are exposed for a longer period. However, without additional assessment information, including longer duration sampling events to determine average air concentrations, PADOH cannot conclude on the potential chronic health effects from exposure to methyl mercaptan.

Methylamine

Methylamine is a colorless gas with a fish- or ammonia-like odor. Methylamine is used in the production of insecticides, herbicides, fungicides, surfactants, rocket fuels, explosives, pharmaceuticals, photographic chemicals, dyes, textiles, dye assists, rubber, and anticorrosive chemicals.

Transient irritation of the eyes, nose, and throat has resulted from brief exposures to methylamine at concentrations of 20,000 to 100,000 ppb; the odor is considered intolerable at 100 to 500,000 ppb [Clayton and Clayton 1981]. Inhalation of methylamine vapors at concentrations greater than 100,000 ppb can cause irritation of the nose and throat. It can also cause violent sneezing, burning sensation of the throat, coughing, constriction of the larynx and difficulty in breathing, pulmonary congestion, and edema of the lungs [Deichmann and Gerarde 1969].

Although ATSDR does not have a CV value for methylamine, TCEQ developed their methylamine Effect Screening Level (ESL) by adding a safety factor to the American Conference of Government Industrial Hygienists (ACGIH) threshold limit value of 5,000 ppb for an 8-hour work day (per email communication from TCEQ to ATSDR R3 on January 12, 2010). This short-term ESL is for comparison to approximate 1-hour exposure data. Methylamine detected at C/WPS (153 ppb, 163 ppb) exceeded TCEQsESL of 44 ppb and the odor level of 35 ppb [Nagata 2003], which can have adverse health effects on the general population. However, without additional assessment information, including longer duration sampling events to determine average air concentrations, PADOH cannot conclude on the potential chronic health effects from exposure to methylamine.

Nitrogen Dioxide

Nitrogen oxides are a mixture of gases that are composed of nitrogen and oxygen that create a pungent, acrid odor. Near-roadway (within about 50 meters) concentrations of nitrogen dioxide (NO_2) have been measured to be approximately 30 to 100% higher than concentrations away from roadways [ATSDR 2002]. The observed concentration (322 ppb) exceeded the NO_2 OTL of 120 ppb [Nagata 2003]. Current scientific evidence links short-term NO_2 exposures, ranging from 30 minutes to 24 hours, with adverse respiratory effects, including airway inflammation in healthy people and increased respiratory symptoms in people with asthma. Studies have also shown a connection between breathing elevated short-term NO_2 concentrations, and increased visits to emergency departments and hospital admissions for respiratory issues, especially asthma [ATSDR 2002].

NO_2 was detected only once at the ELESS (322 ppb) which exceeded NAAQS 1-hour daily maximum concentration of 100 ppb [EPA 2010], which is a regulatory value determined by

averaging concentrations over a 3-year period. The one-hour average AQI for the observed maximum concentration (322 ppb) is 143 [EPA 2016]. This AQI value is considered "unhealthy for sensitive groups," where sensitive populations (such as people with asthma or other respiratory diseases, the elderly, and children) may begin to experience adverse health effects. NO_2 has the potential to cause acute health effects as well as odor related symptoms. The level of NO_2 detected is high enough to cause acute health effects and odor related symptoms if people are exposed to it for longer periods. The one-time only detection at the ELSS site did not give enough data for PADOH to make any conclusion on the long-term health effects of NO_2 at this site.

Nitric Acid

Nitric acid may exist as liquid, gas, or vapor with a characteristic, irritating odor. It is a highly corrosive acid. It is used to make fertilizer, as solvents for dissolving, etching and cleaning metals, and in making nitrogen compounds and explosives. The NIOSH-REL recommended airborne exposure limit for nitric acid is 4,000 ppb, not to be exceeded during any 15-minute work period. Acute inhalation exposure to nitric acid can irritate nose and throat causing coughing and/or shortness of breath. Inhalation exposure to nitric acid involves exposure to nitric acid as well as nitrogen oxides such as NO_2 and nitric oxide.

Nitric acid detected at the ELESS (35 ppb) exceeded the CARBaREL of 30 ppb. In a study, [Sackner and Ford 1981] five healthy volunteers were exposed to nitric acid vapor at a concentration of 1,600 ppb for 10 minutes. At this exposure concentration, no observed adverse effects were observed. This concentration was considered as the No Observed Adverse Effect Level (NOAEL) and is the highest NOAEL available in humans. An experimental self-exposure to nitric acid at 62,000 ppb for one hour resulted in irritation of the larynx, thirst, and an objectionable odor [Lehmann and Hasegawa 1913]. The detected level (35 ppb) was approximately 46 times lower than the NOAEL. Therefore, based on the available data on nitric acid, no acute health effects can be expected at the concentrations detected at this site. Also, PADOH cannot comment on the long term or chronic health effects from nitric acid based on this data.

n-Octane

n-Octane is a colorless liquid with a gasoline odor. It is used as a solvent, blowing agent, and to make other chemicals. Acute inhalation exposure can irritate the nose, throat, and lungs causing coughing, wheezing, and/or shortness of breath.

n-Octane detected once at the ELESS (1,495 ppb) slightly exceeded TCEQ AMCV of 1,400 ppb. The NIOSH-REL recommended airborne exposure limit for n-octane is 385,000 ppb, not to be exceeded during any 15-minute work period. The maximum n-octane concentration (1,495 ppb) is 257 times below the NIOSH-REL concentration (385,000 ppb). Therefore, acute health effects from the maximum exposure to n-octane are unlikely. Also, PADOH cannot comment on the chronic or long term health effects from n-octane at this site based on the limited data available by the OPFTIR method.

Odors

Compressor stations emit gases comprised of a wide range of chemicals. Some of these chemicals are strong odorants. Some of the VOCs detected in those three monitoring locations were above

their respective OTLs, including 1, 2, 4-trimethyl benzene; acetaldehyde; dimethyl sulfide; methyl mercaptan; methylamine; and nitrogen dioxide (Table 1). However, there were insufficient data to determine whether there were other chemicals present (e.g. hydrogen sulfide) in the community's ambient air at levels of public health concern because of the high analytical detection limits for these chemicals. Exposure to odorous chemicals can cause transient effects such as headaches and nausea [ATSDR 2001].

Uncertainties and Data Limitations

The OPFTIR method is used to identify the presence of chemicals from a known library of chemicals along the entire path of the infrared beam, but the data have limitations. Air data from the OPFTIR method can be helpful to rapidly identify the presence of chemicals in the air at the potential source location.

Since the results were obtained from instantaneous readings, they were only compared to acute exposure comparison values. Actual average and peak levels could be considerably higher or lower than those found in these single sampling events.

One other limitation was that wind directions and traffic patterns were not taken into account when collecting data from the sites, which could have an effect on observed results.

The instrument's lower detection limits are set very high for several airborne contaminants and these limits vary markedly from place to place due to many factors, including the following: instrument calibration, the distance/angle that the electromagnetic beam traverses (beam path), the deployment of beam transmission and reception, ambient air temperature, and relative humidity of air.

The data also has limited quality control and quality assurance, and can only be used as screening level data for acute health effect evaluation. Therefore, this method has limited utility for public health exposure assessment and its instantaneous readings cannot be converted into appropriate exposure values for the evaluation of chronic health effects.

Conclusions and Recommendations

Based on the limited environmental data available, PADOH cannot currently conclude whether airborne chemicals near the compressor stations could harm people's health. There were insufficient data to determine whether chemicals were present in the community's ambient air at levels of public health concern because analytical detection limits for some of these chemicals were above health-based CVs. Although we were unable to make a conclusive statement based on OPFTIR data, there may be a potential acute health risk based on contaminants detected (benzene, methylamine, methyl mercaptan, NO_2, nitric acid, and n-octane) that exceeded acute health-based CVs. Also, there may be potential odor risk as some of the contaminants detected (1, 2, 4-trimethylbenzene; acetaldehyde; dimethyl sulfide; methyl mercaptan; methylamine; and nitrogen dioxide) exceeded the OTLs.

PADOH recommends more rigorous environmental sampling and analytical methods be used to identify and quantify specific chemical emissions in the surrounding community's ambient air. PADOH recommends conducting concurrent SUMMA Canister TO-15 analysis for each OPFTIR sampling period at the source locations to detect VOCs at or below the health CVs when possible.

If you have any questions regarding this letter health consultation or its contents, please contact:

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Tables

Table 1: All contaminants detected using the OPFTIR near compressor stations, Susquehanna County, Pennsylvania (ppb)

Contaminants	Lower Detection Limit	Observed Maximum 2-minute Concentration									Acute Health-based CV/OTL	Source for Health-based CV
		Elk Lake Elementary School Site (ELESS)			Carson/White Pad Site (C/WPS)			Post Pad Site (PPS)				
					White Site	Carson Site						
		5/14/13	6/18/14	8/04/15	5/16/13	6/19/14	8/6/15	5/15/13	6/17/14	8/05/15		
1,2,4-Trimethyl benzene	*37 – 343*	ND	ND	*272*	ND	*248*	ND	ND	ND	ND	900/120	TCEQsESL
2-Methyl butane	4 – 163	ND	ND	ND	ND	ND	ND	ND	14	ND	20,000/NA	TCEQsESL
3-Methyl pentane	5 – 144	ND	*36*	ND	ND	ND	ND	ND	19	ND	1,000/NA	TCEQsESL
Acetaldehyde	*18 – 303*	ND	ND	ND	*147*	ND	ND	ND	ND	ND	256/1.5	CARBaREL
Ammonia	1 – 13	ND	ND	7	ND	9	ND	ND	ND	ND	1,700/1,500	aMRL
BENZENE	**28 – 230**	ND	**202**	**192**	ND	**182**	**177**	ND	ND	**84**	9/2,700	aMRL
Carbon disulfide	14 – 588	ND	128	ND	ND	144	ND	ND	ND	ND	2,400/210	TCEQsESL
Carbon monoxide	16 – 46	49	120	84	ND	116	62	ND	31	16	35,000/NA	NAAQS 1hr
Chloroform	1 – 42	ND	ND	12	11	ND	ND	13	5	ND	100/3,800	aMRL
Dimethyl sulfide	*13 – 204*	*225*	ND	ND	*131*	ND	*80*	ND	*53*	ND	500/3	ACGIH TLV
Ethane	14 – 288	ND	81	ND	ND	243	ND	ND	78	ND	NA/NA	NA
Ethanol	4 – 82	ND	112	74	23	35	88	37	50	ND	10,000/NA	TCEQsESL
Ethyl benzene	13 – 556	ND	196	295	ND	ND	111	ND	131	48	5,000/NA	aMRL
Formaldehyde	3 – 26	ND	ND	ND	ND	ND	ND	ND	11	ND	40/500	aMRL
Iso-butane	4 – 104	169	ND	ND	82	ND	ND	76	ND	ND	10,000	TCEQsESL
Methane	13 – 228	ND	ND	1,157	11,591	5,208	3,847	ND	186	58	NA/NA	NA
Methanol	2 – 18	ND	ND	14	ND	15	29	ND	ND	ND	200/33,000	TCEQsESL
METHYL MERCAPTAN	***22 – 488***	ND	ND	ND	***517***	***625***	*323*	***561***	*116*	*37*	500/2	NIOSH-REL
Methyl tert-butyl ether	2 – 19	ND	15	25	ND	ND	ND	8	ND	2	2,000/170	aMRL
METHYLAMINE	**22 – 198**	ND	ND	ND	***153***	***163***	ND	ND	ND	ND	44/35	TCEQsESL
Naphthalene	4 – 50	ND	ND	ND	ND	ND	ND	ND	ND	4	85/38	TCEQsESL
n-butane	5 – 113	154	ND	68	86	ND	44	ND	ND	ND	28,000/NA	TCEQsESL

Contaminants	Lower Detection Limit	Observed Maximum 2-minute Concentration									Acute Health-based CV/OTL	Source for Health-based CV
		Elk Lake Elementary School Site (ELESS)			Carson/White Pad Site (C/WPS)			Post Pad Site (PPS)				
					White Site	Carson Site						
		5/14/13	6/18/14	8/04/15	5/16/13	6/19/14	8/6/15	5/15/13	6/17/14	8/05/15		
n-hexane	9 – 407	ND	ND	116	ND	ND	ND	ND	78	ND	1,500/1,500	TCEQsESL
n-heptane	35 – 1,267	ND	ND	ND	ND	750	276	ND	200	ND	850/750	TCEQsESL
NITRIC ACID	**3 – 25**	ND	ND	**35**	ND	ND	17	17	ND	ND	30/270	CARBaREL
NITROGEN DIOXIDE	***17 – 548***	ND	ND	***322***	ND	ND	ND	ND	ND	ND	100/120	NAAQS 1hr
Nitrous oxide	1 – 43	ND	ND	ND	ND	ND	ND	ND	6	ND	2,500	TCEQsESL
Nitrous acid	6 – 7	ND	ND	7	ND	6	ND	ND	ND	ND	NA	NA
n-OCTANE	**28 – 951**	**1,495**	ND	ND	762	ND	895	716	ND	ND	1,400/1,700	TCEQ AMCV
Ozone	4 – 33	ND	ND	30	ND	ND	ND	ND	19	16	70/100	NAAQS 8hr
Propane	5 – 220	ND	ND	86	ND	ND	ND	ND	29	8	NA	NA
Styrene	*5 – 32*	ND	ND	*45*	*32*	ND	22	23	21	ND	5,000/25	aMRL
Triethylamine	3 – 35	ND	ND	ND	20	ND	ND	18	19	9	676/22	CARBaREL
m-xylene	10 – 157	ND	62	103	ND	ND	ND	ND	44	32	2,000/1,000	aMRL
o-xylene	6 – 333	ND	40	ND	ND	87	ND	ND	33	29	2,000/380	aMRL
p-xylene	18 – 338	ND	ND	ND	ND	ND	ND	ND	89	ND	2,000/90	aMRL

OTL = Odor Threshold Level; Text in bold capital letters were detected above acute screening and text in italics were above OTL; CV = Comparison Value; ppb = parts per billion; NA = Not Available; aMRL = acute Minimum Risk Level; TCEQsESL = Texas Commission on Environmental Quality short-term Effects Screening Levels; AMCV = Air Monitoring Comparison Value; CARBaREL = California Air Resources Board acute Reference Exposure Levels; NIOSH-REL = National Institute for Occupational Safety and Health- Reference Exposure Levels (15 minutes); NAAQS = National Ambient Air Quality Standards; ACGIH TLV = American Conference of Governmental Industrial Hygienists threshold limit value; OPFTIR = Open Path Fourier Transform Infra-Red spectrometer; ppb = parts per billion;

Figures

Figure 1: 2013 -- 2015 OPFTIR Monitoring Area Overview, Susquehanna County, PA

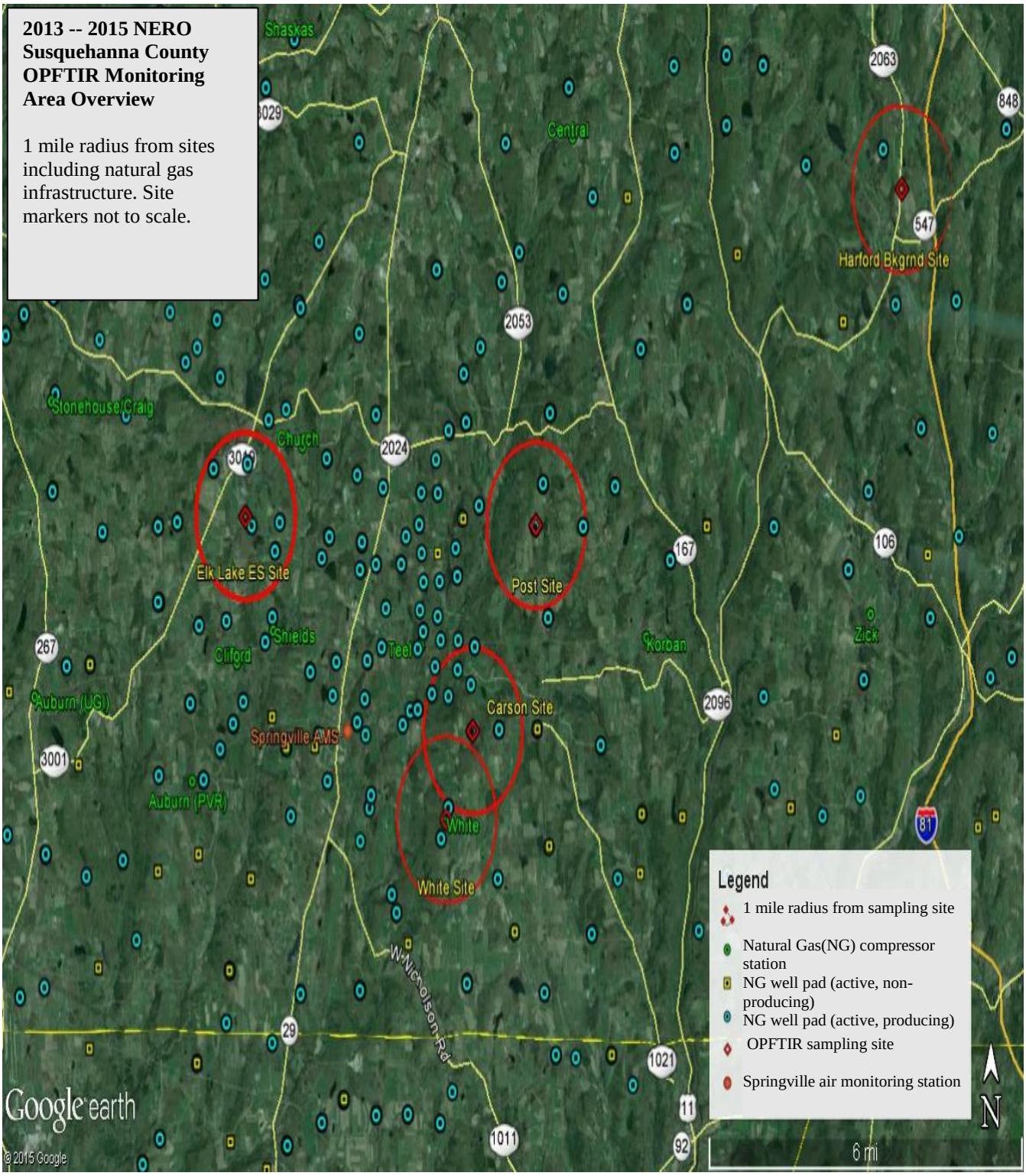

Figure 2: Susquehanna County's Townships

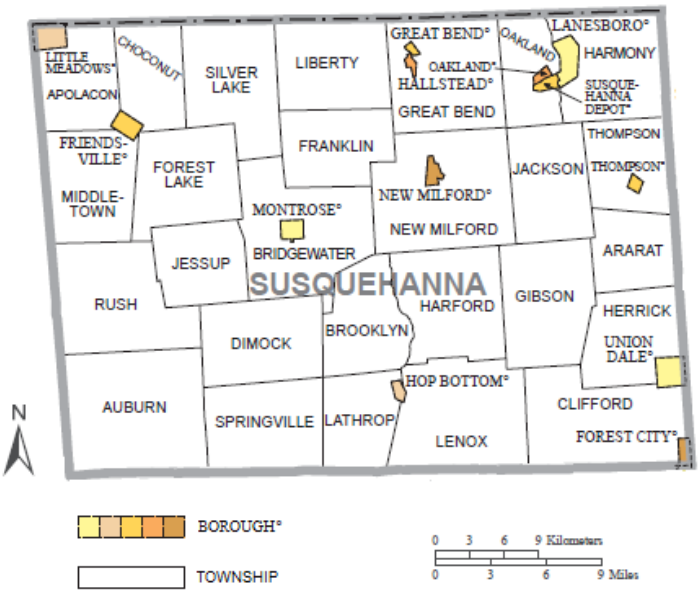

Figure 3: Elk Lake Monitoring Site Overview

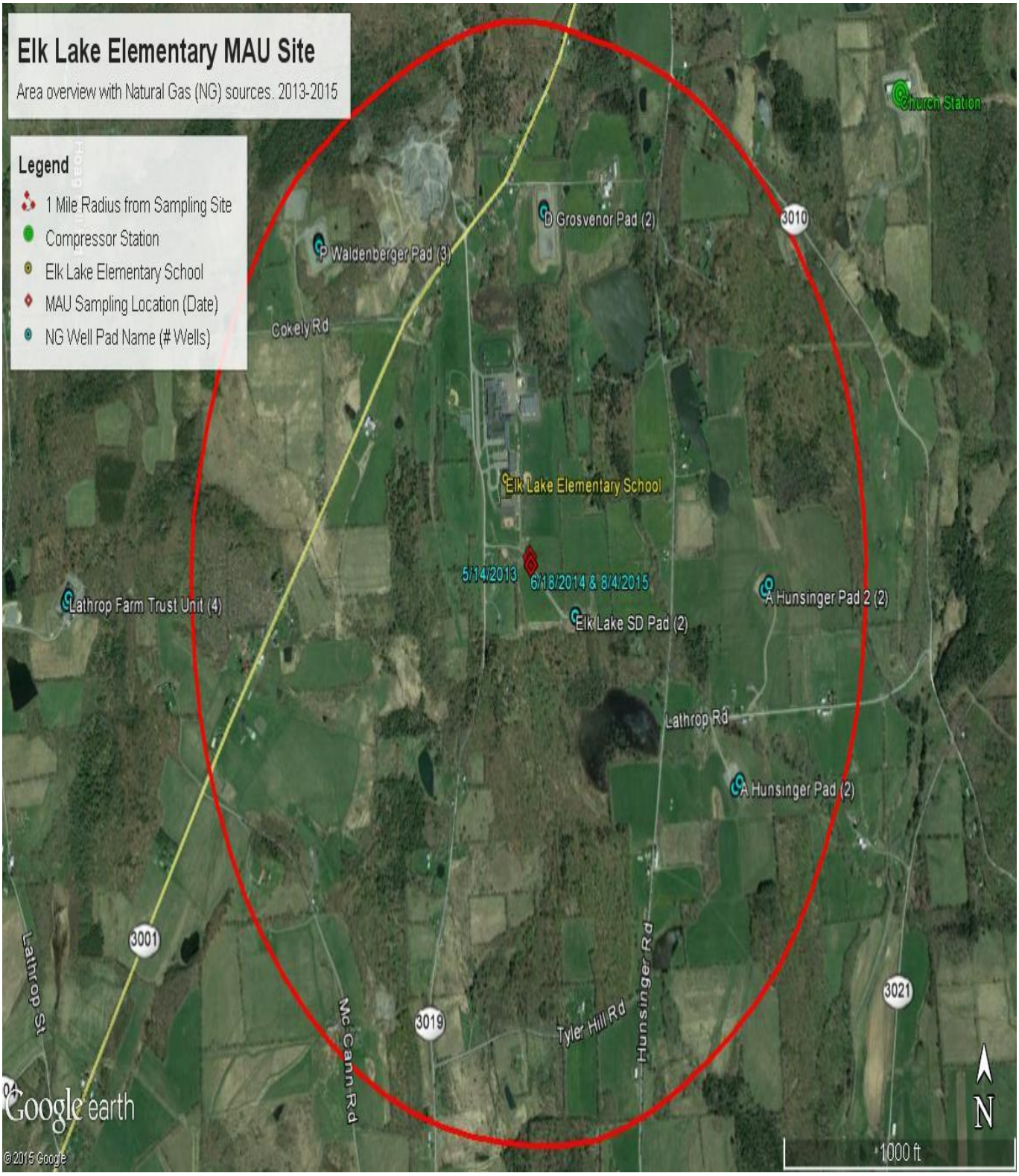

Figure 4 - Post Pad Monitoring Site Overview

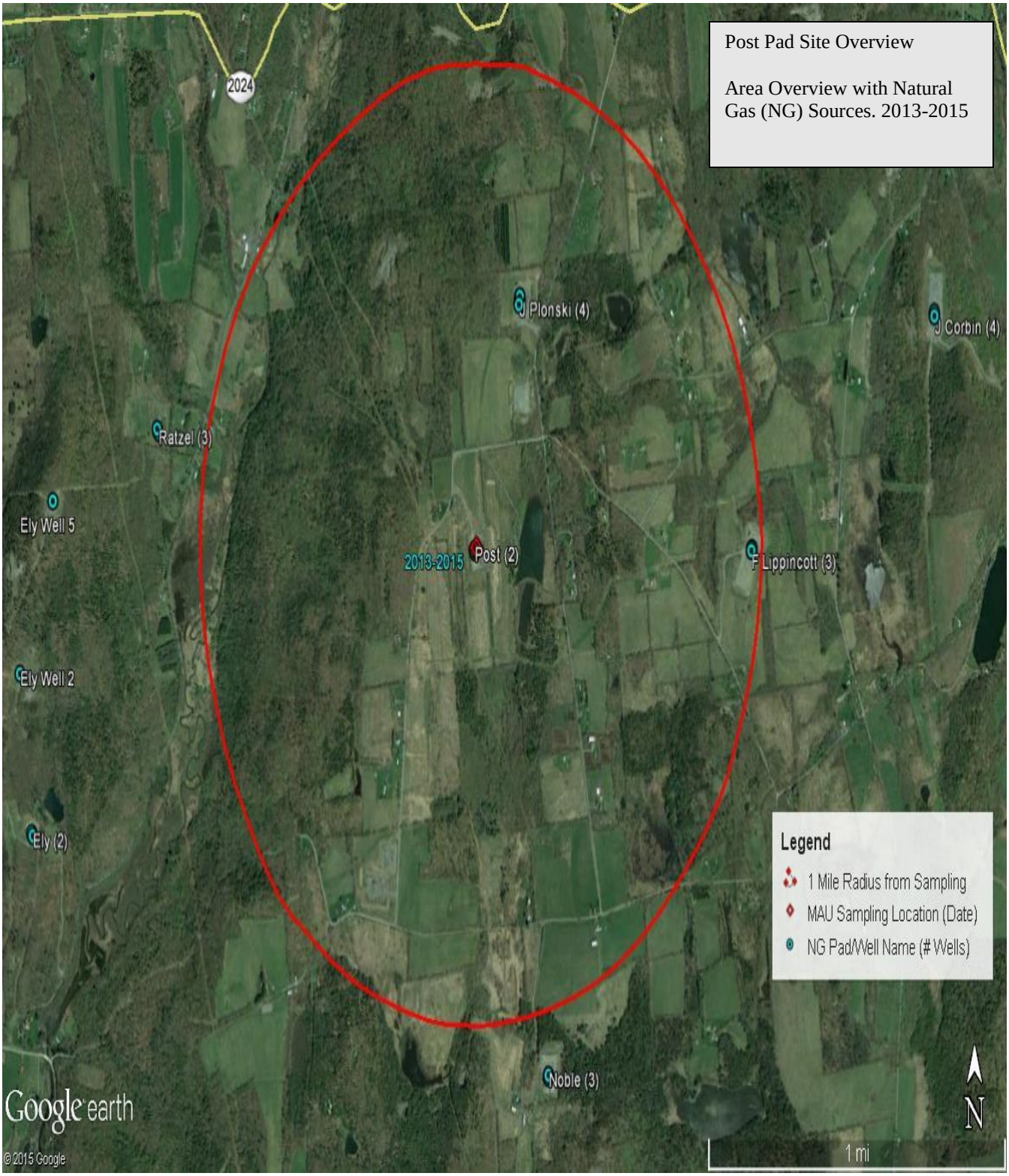

Figure 5 - Carson / White Monitoring Site Overview