SMITH ANALYTICAL

WELLHEAD EMISSIONS MANAGEMENT SYSTEMS

A CASE STUDY OF FUGITIVE EMISSIONS AT PRODUCING GAS WELLS

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OVERVIEW

While presenting a paper at IPEC 23 Conference in New Orleans in 2016, we were approached about a potential issue with fugitive hydrocarbon emissions at various individual gas well sites in East Texas.

Residents in the area of the gas wells complained about various health effects, and the local government had been seeking an explanation for skin irritation, nausea, dizziness, headaches, ataxia, confusion, nose bleeds, and tiredness reported by those in the immediate area of the well sites.

OVERVIEW

Upon arrival at the first gas well site it was obvious operations being performed at this upstream location were quite different than what was expected. It was obvious that hydrocarbon emissions were present, as gases were clearly being vented from process equipment at the site. Additionally, the thief hatches on the storage tankage were either not properly secured or wide open allowing for head space vapors to escape into the surrounding environment.

INITIAL AIR TESTING

After several meetings with the client environmental liaison, it was determined that air samples would be collected in accordance with EPA Summa Canister Sampling SOP#: 1704 Rev. 01.

The air samples collected at each well site would then be submitted to a Texas certified lab in order to conduct an EPA Method 15 - Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air Second Edition.

INITIAL AIR TESTING

WELL #	SAMPLE ID	BENZENE (PPBW)	TOLUENE (PPBW)	ETHYLENZENE (PPBW)	XYLENES (PPBW)
H3499	18021366.01	<MDL	<MDL	<MDL	<MDL
H3487	18021366.02	172.5	381.4	<MDL	694.6
C1178	18021366.03	53.4	214.1	<MDL	127.3
C1194	18021366.04	98.8	331.6	<MDL	180.6
S1693	18021366.05	35	199	<MDL	52.1
SH3504	18021366.06	<MDL	<MDL	<MDL	<MDL
1076	18021366.07	7.2	18.7	<MDL	<MDL
1080	18021366.08	876.6	3361	515.9	2676.1

*<MDL = Result Less Than Minimum Detection Limit

INITIAL AIR TESTING

Per the EPA Refinery Fence Line Monitoring & Method 325A/B regulatory program which manages fugitives by requiring perimeter monitoring and corrective action upon exceeding a trigger of 9 ug/m3 (2.8 ppb), it was clear that seven of the eight gas wells in service exceed the EPA fence line limit and additional site measurements would be required.

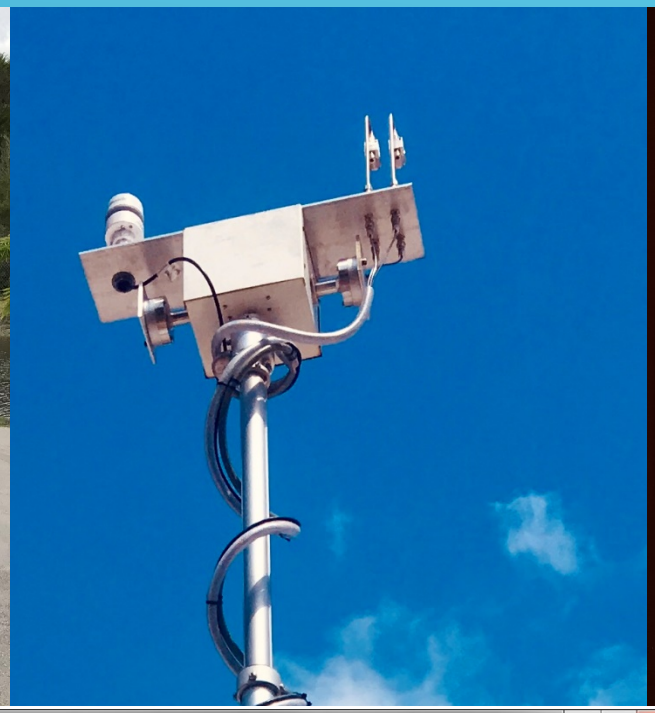
MOBILE TESTING VAN

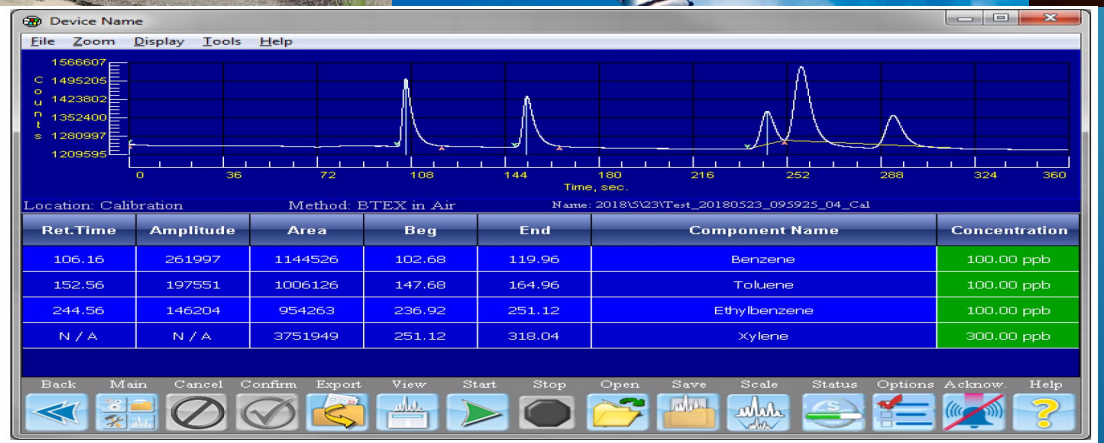
After review of the lab air analysis results, funding for a thirty-six (36) month test using a mobile lab were obtained.

The equipment had to operate off generator power, withstand the potential for high dust loads, be easy for the operator to use, allow for remote diagnostics, remote data collection, and be easily repaired in the field.

The analyzer ultimately selected was the Ametek Mocon Model 9100, which was specifically designed to measure for benzene, toluene, ethylbenzene, and total xylenes (BTEX) in an ambient air matrix.

MOBILE TESTING VAN





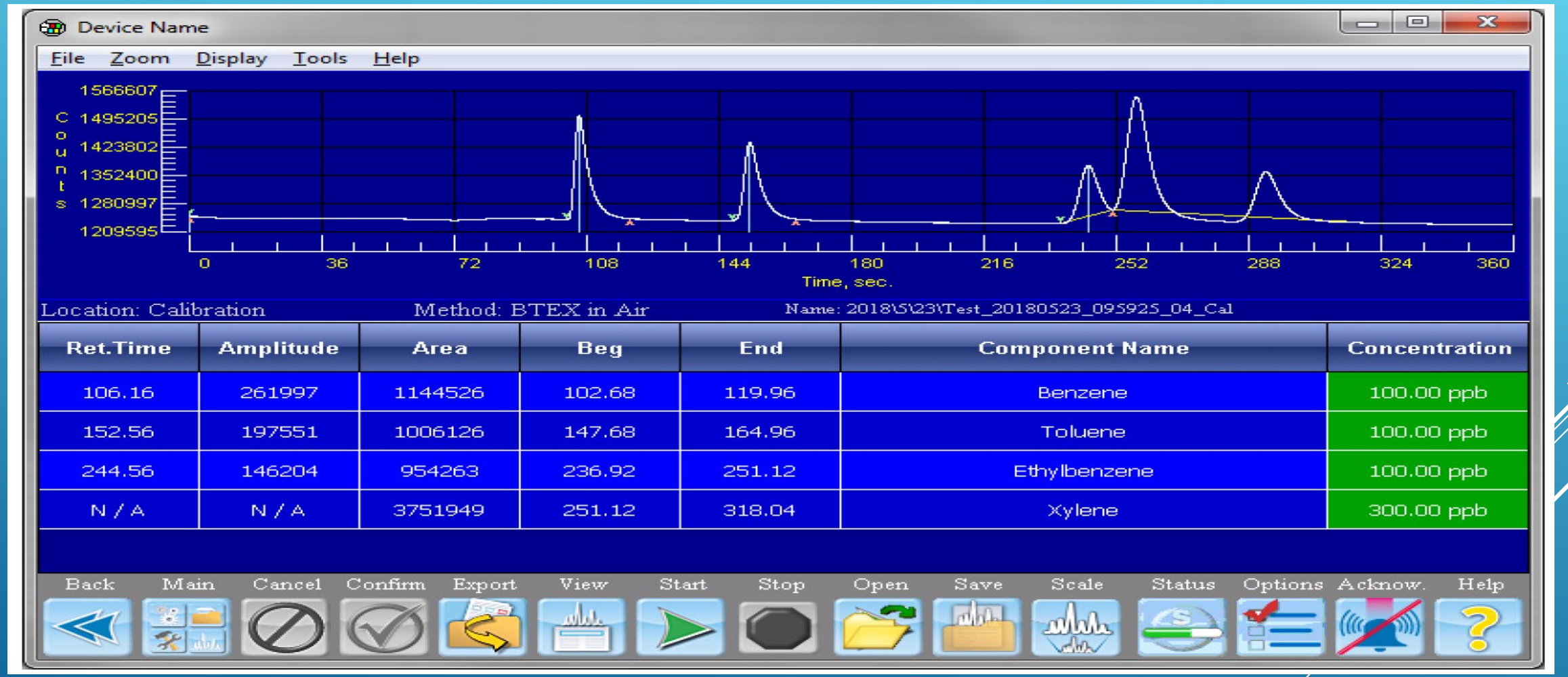
MOBILE TESTING VAN

The selected gas chromatograph uses nitrogen carrier, a Valco inject valve, capillary columns, a high sensitivity photo ionization detector and isothermal oven.

The minimum detection limit (MDL) of the selected analyzer is 100 parts per trillion (ppt).

Cycle time to complete the analysis is six minutes. The analyzer software package allowed for remote access to the equipment for maintenance or data collection activities.

MOBILE TESTING VAN



Ret.Time	Amplitude	Area	Beg	End	Component Name	Concentration
106.16	261997	1144526	102.68	119.96	Benzene	100.00 ppb
152.56	197551	1006126	147.68	164.96	Toluene	100.00 ppb
244.56	146204	954263	236.92	251.12	Ethylbenzene	100.00 ppb
N / A	N / A	3751949	251.12	318.04	Xylene	300.00 ppb

Air Chromatogram Generated by GC-PFD

MOBILE TESTING VAN

Per the EPA approved QAPP, calibration and quality assurance of the analytical measurements was central to a successful testing project. All Stake Holders wanted to ensure the highest degree of confidence in the measurements taken at the various well sites.

To allow for the greatest flexibility of calibration equipment, an Environics Model S6100 electronic gas divider certified to comply with EPA Method 205 was installed in the mobile lab.

MOBILE TESTING VAN

The gas divider would allow for the calibration of the equipment using a single bottle of calibration gas at the initial testing concentration of approximately 100 ppb for each of the target analytes and allow for the EPA Performance Specification 9 (EPA PS-9) testing to be conducted.

The EPA PS-9 testing is done using the NIST Calibration Bottle and a bottle of ultra high purity nitrogen . This arrangement allowed for the equipment to be checked at 40-60%, 90-110% and 140-160% of range as mandated in EPA PS-9.

MOBILE TESTING VAN

To collect the air samples, a Larson Model VMPLM-13.5 electro-pneumatic mast was installed on the roof of the van to provide samples at the various heights around the gas well sites.

The mast is remotely operated from the cab of the testing van and offers a nested testing height of twelve feet (4 meters) and can be extended out to twenty five (8 meters) feet above grade.

MOBILE TESTING VAN

The van is equipped with identical redundant gas chromatographs, delivery of the sample to the sample system for each analyzer is done via redundant probes and sample lines up to the analyzers.

To ensure no bias of the analytical data, the EPA approved QAPP requires for a line loss test as mandated in EPA Method 15. Prior to every six hours of field testing, a direct and remote validation test of the analyzers is performed.

MOBILE TESTING VAN

The results from the direct validation check and the remote check are then entered into the approved quality assurance form and the resulting bias must be < 20% as mandated by EPA Method 15.

Of note, all quality assurance testing is done pre and post field test per the QAPP.

MOBILE TESTING VAN

To track the location of the testing van, an Airmar weather station was installed on the air sampling mast. The weather station reports the:

1. Time
2. Date
3. GPS coordinates of the van
4. Altitude of the sample probes
5. Wind direction and wind speed
6. Temperature
7. Barometric pressure
8. Relative humidity, dew-point, and wind chill

MOBILE TESTING VAN

The analytical and the weather data are synced to allow for the accurate reporting of each sample location the testing van performs a measurement at.

All data is stored on the testing van data acquisition system and the remote server which offers both on-site and off-site back-up.

MOBILE TESTING VAN

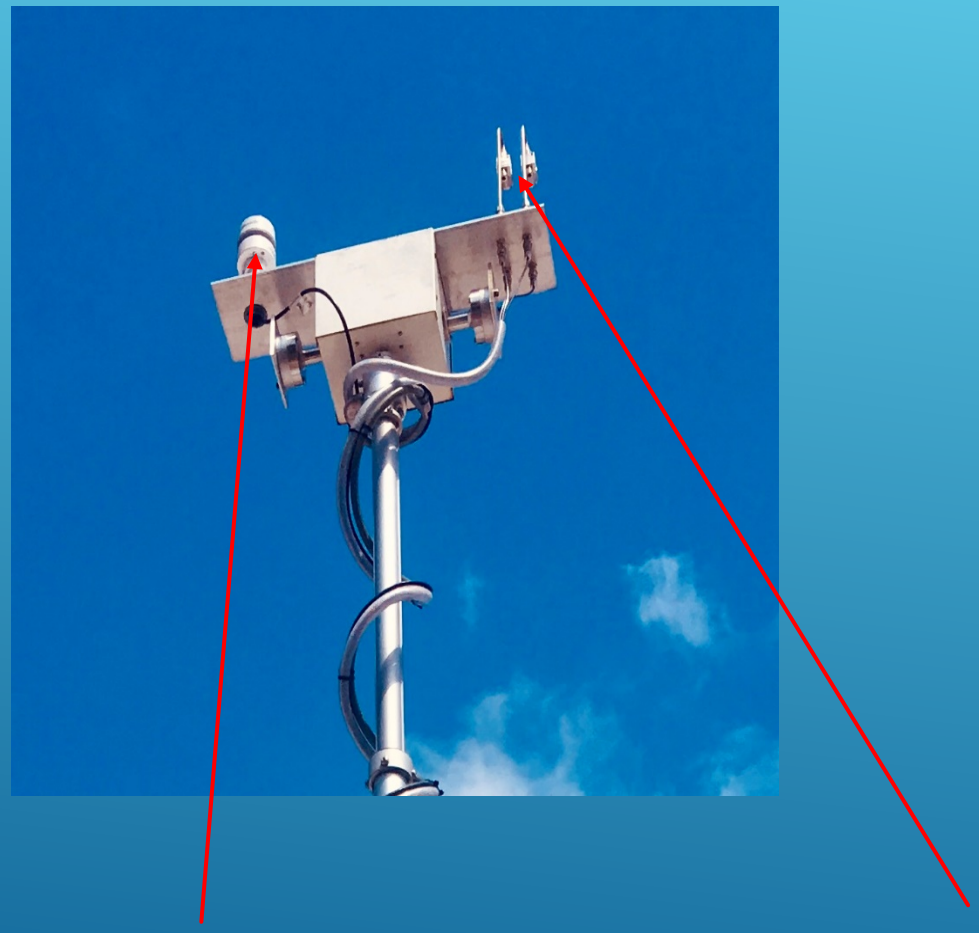
Data is remotely accessed in order that the required emissions, quality assurance, and visualization reports can be completed by the home office.

The testing data is available for real time access to all Stake Holders.

MOBILE TESTING VAN

BTEX TESTING VAN

MOBILE TESTING VAN



LARSON MAST WITH WEATHER STATION (LEFT) & SAMPLE POINTS (RIGHT)

MOBILE TESTING VAN

TOP AND CENTER ARE THE AMETEK MOCON GAS CHROMATOGRAPHS
BOTTOM IS THE AIRMAR WEATHER STATION INTERFACE

MOBILE TESTING VAN

As there is no shore power available for the testing van when it is in the field, an externally mounted dual fuel generator is used to operate all the testing and auxiliary equipment required to perform testing operations. All test equipment is protected from the generator or a power loss by a UPS.

The primary fuel source is propane with gasoline as the secondary fuel source. Propane was selected for ease of transport and to prevent false high benzene readings from the gasoline.

FIELD TESTING RESULTS

The van was deployed in September 2018 with testing being conducted at various well sites at the client's location.

While fence line requirements have not been established for toluene, ethylbenzene or total xylenes, the OSHA 8-hour personal exposure limit (PEL) and fifteen-minute short term exposure limit (STEL) are documented. The EPA fence line limit for benzene is set at 2.85 ppb.

FIELD TESTING RESULTS

1. Benzene limit - EPA Refinery Fence Line Monitoring & Method 325A/B = 2.85 PPB
2. Toluene limited - OSHA 8 Hour PEL = 100 PPM and 15-minute STEL = 150 PPM
3. Ethylbenzene limit - OSHA 8 Hour PEL = 100 PPM and 15-minute STEL = 125 PPM
4. Total Xylenes limit - OSHA 8 Hour PEL = 100 PPM and 15-minute STEL = 150 PPM

FIELD TESTING RESULTS – MAX READING

MONTH	COMP	MAX CONC (PPB)	COP	MAX CONC (PPB)	COMP	MAX CONC (PPB)	COMP	MAX CONC (PPB)	°F
Sept 18	Benzene	8,192	Toluene	8,800	Ethylbenzene	59	Xylene	612	91°
Nov 18	Benzene	524	Toluene	178	Ethylbenzene	0	Xylene	4	47°
Dec 18	Benzene	107	Toluene	65	Ethylbenzene	0	Xylene	4	63°
Jan 19	Benzene	43	Toluene	40	Ethylbenzene	0	Xylene	0	48°
Feb 19	Benzene	121	Toluene	48	Ethylbenzene	4	Xylene	0	43°
Mar 19	Benzene	7.19	Toluene	6.83	Ethylbenzene	0	Xylene	0	74°
Apr 19	Benzene	23.24	Toluene	33	Ethylbenzene	0	Xylene	4	84°
June 19	Benzene	165.65	Toluene	248	Ethylbenzene	0	Xylene	43	94°
July 19	Benzene	3335	Toluene	6724	Ethylbenzene	199	Xylene	2748	98°
Aug 19	Benzene	141	Toluene	293	Ethylbenzene	6	Xylene	83	94°
Sept 19	Benzene	411	Toluene	48	Ethylbenzene	0	Xylene	5	90°

FIELD TESTING RESULTS – AVG READINGS

MONTH	# OF SAMPLES	COMP	AVG CONC (PPB)	COMP	AVG CONC (PPB)	COMP	AVG CONC (PPB)	COMP	AVG CONC (PPB)	°F
Sept 18	28	Benzene	348.67	Toluene	9,725	Ethylbenzene	2.57	Xylene	28.62	91°
Nov 18	27	Benzene	29.94	Toluene	12.25	Ethylbenzene	0	Xylene	0.31	47°
Dec 18	82	Benzene	9.13	Toluene	6.26	Ethylbenzene	0	Xylene	0.30	63°
Jan 19	15	Benzene	5.58	Toluene	5.47	Ethylbenzene	0	Xylene	0	48°
Feb 19	20	Benzene	5.77	Toluene	2.34	Ethylbenzene	0.19	Xylene	0	43°
Mar 19	63	Benzene	0.45	Toluene	0.73	Ethylbenzene	0	Xylene	0	74°
Apr 19	17	Benzene	3.56	Toluene	4.40	Ethylbenzene	0	Xylene	0.27	84°
June 19	52	Benzene	10.35	Toluene	15.76	Ethylbenzene	0	Xylene	3.01	94°
July 19	53	Benzene	217.50	Toluene	438.25	Ethylbenzene	12.60	Xylene	168.66	98°
Aug 19	70	Benzene	26.50	Toluene	60.56	Ethylbenzene	1.56	Xylene	21.91	94°
Sept 19	51	Benzene	9.65	Toluene	11.01	Ethylbenzene	.07	Xylene	1.4	90°

FIELD TESTING - OBSERVATION

The average benzene concentration is 122 times the allowable EPA fence line limit.

The concentrations measured during the first year of testing suggest the offending well sites may prove to be an issue for those living in proximity to these well sites.

FIELD TESTING - OBSERVATION

CHANCE OF DEVELOPING CANCER	CONC (PPB)	HOUSTON URBAN AREA RANGE (PPB)	HOUSTON SEMI-RURAL RANGE (PPB)	TESTING SITE AVG (PPB)
1/1,000,000	0.14106	1.2-8.7	0.55-6.3	155.5
1/100,000	1.4106	1.2-8.7	0.55-6.3	348.67
1/10,000	14.106	1.2-8.7	0.55-6.3	29.94
1/1,000	141.06	1.2-8.7	0.55-6.3	9.13
1/100	1410.6	1.2-8.7	0.55-6.3	5.58

WORLD HEALTH ORGANIZATION CANCER PROBABILTY DUE TO LONG TERM BENZENE EXPOSURE

FIELD TESTING - OBSERVATION

The suggested benzene average for the Houston urban area is 4.95 ppb. For semi-rural areas outside of Houston this value decreases to 3.42 ppb.

The average benzene concentration for the well sites under surveillance is 109.76 ppb.

FIELD TESTING - OBSERVATION

WELLSITE PROXIMTY TO RESIDENCE

FIELD TESTING - OBSERVATION

WELLSITE PROXIMTY TO RESIDENCE 0 – 3,000 FEET

VISUAL DATA SUMMARY

One of the project deliverables was for a concise way to visualize the measurements taken by the testing van so this information could be disclosed in a meaningful way to a non-technical audience.

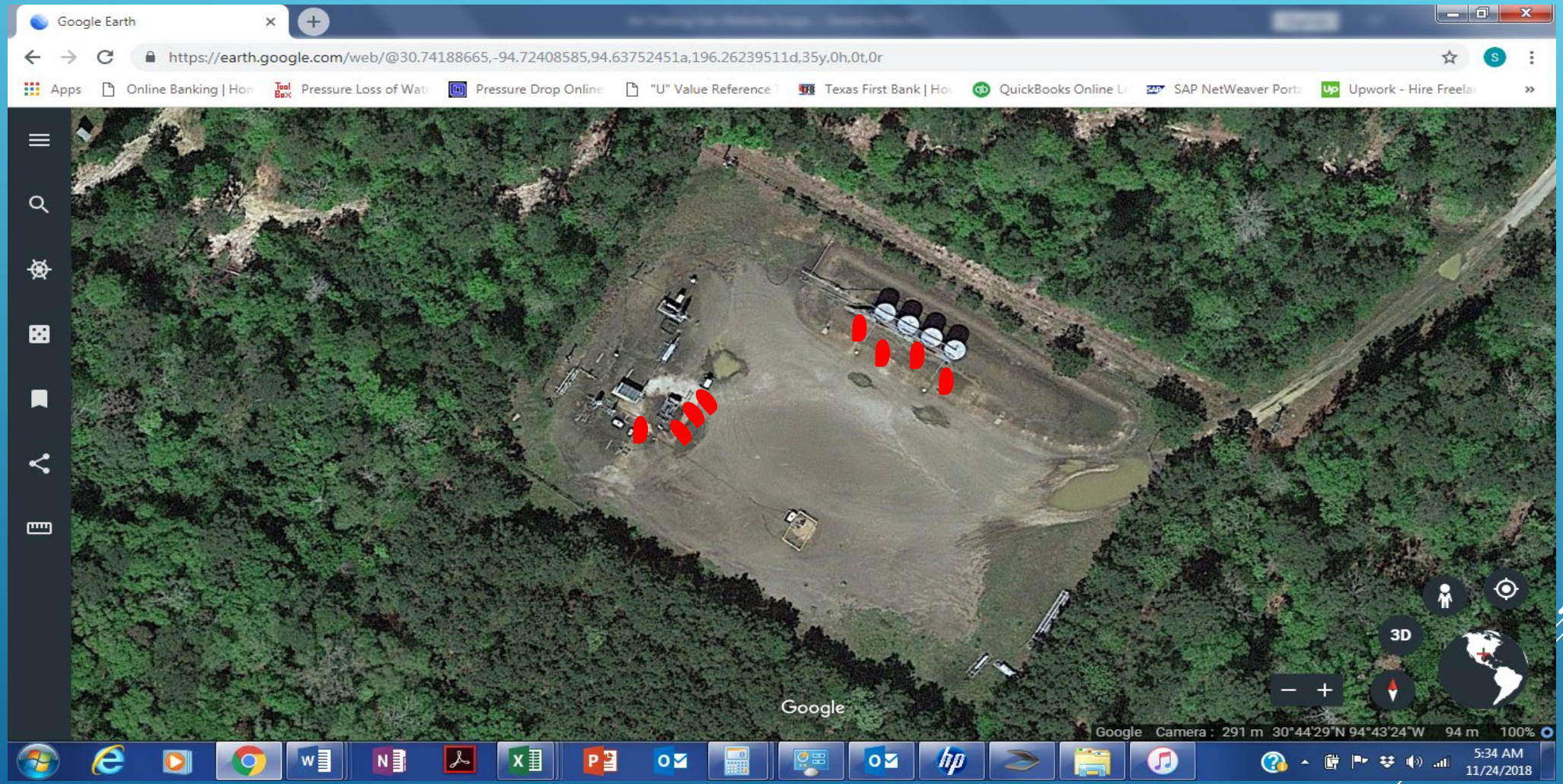
Additionally, all stake holders, including the EPA, wanted real time access to the data. Due to the need for remote diagnostics, visualization, and data acquisition, the testing van was outfitted with a cell hot spot. Once the van is placed "online" by the Operator, all weather, GPS and analytical data is stored on the rack mounted PC located in the van. From this location, the data is copied to the remote server once every 30 minutes.

VISUAL DATA SUMMARY

The data on the remote server is maintained in a SQL database. With this information, all the required reports and maps visualizing the measurements taken by the van can be produced.

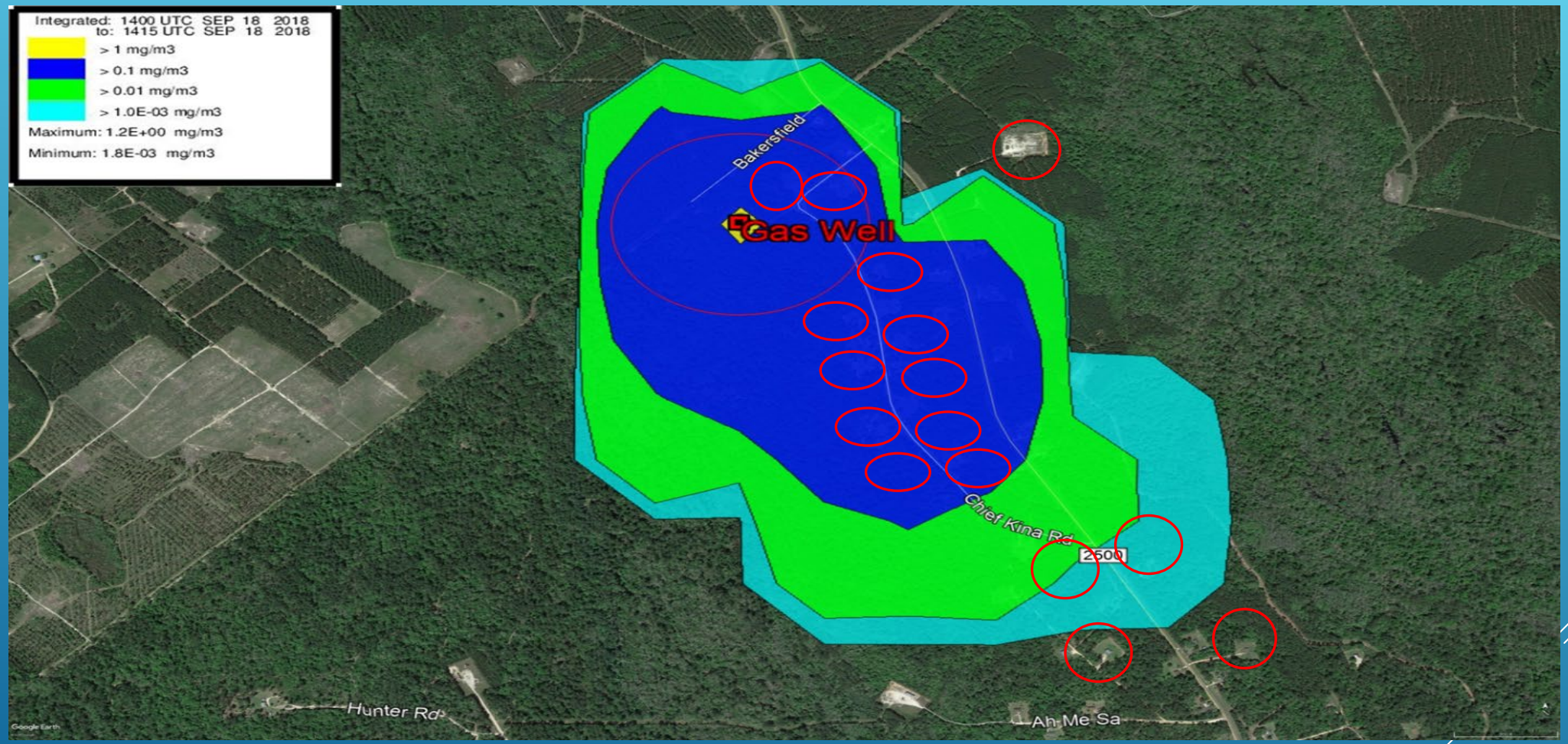
The figure below shows one of the well site locations and every point where the benzene concentration exceeded 2.85 ppb.

VISUAL DATA SUMMARY



- LOCATION WHERE BENZENE VALUES EXCEEDED FENCE LINE LIMIT

VISUAL DATA SUMMARY



AIR DISPERSION MODEL Concentration Overview – 14:00h to 14:15h

Residence in Plume

SUMMARY

While fugitive emissions along with BTEX fence line emissions are tightly regulated for downstream production facilities, the concern about these emissions at some production well sites seem to be of less concern. The well sites currently under surveillance are not operated by a large multinational company or even a mid-level producer.

SUMMARY

These are relatively low production well sites under the control of smaller firms which seem to operate with an emphasis on very low overhead cost with no little to no oversight by the company health, safety and environmental staff.

Those living in proximity of these well sites may well be placing their health at risk without ever knowing what they have been exposed to.

SUMMARY

As none of the individuals living in proximity to the well sites work in an industrial setting or work with chemicals of any type, a health care professional may never think to test someone who is ill for benzene exposure. Testing at these well sites over the coming years will provide our client with additional exposure information.

The goal is for our client to be able to get the well operator to commence mitigation procedures in order to reduce fugitive emissions.