Using Ultrasensitive Hydrocarbon Detection to Elucidate Nascent Pipeline Leaks

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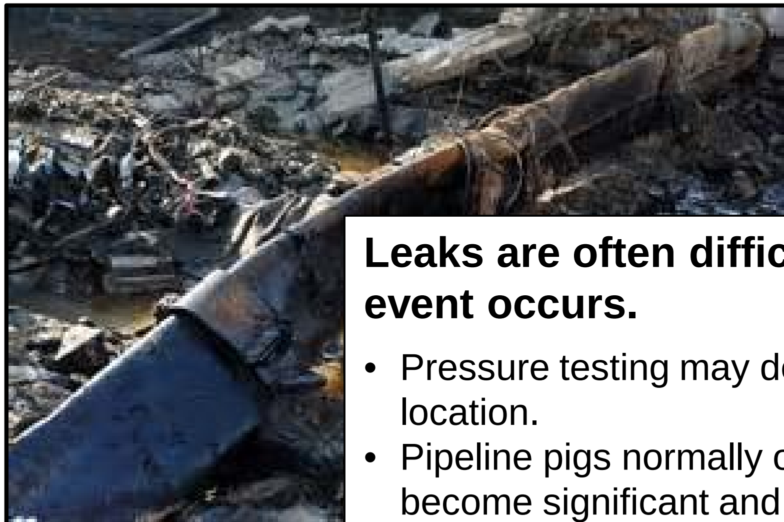
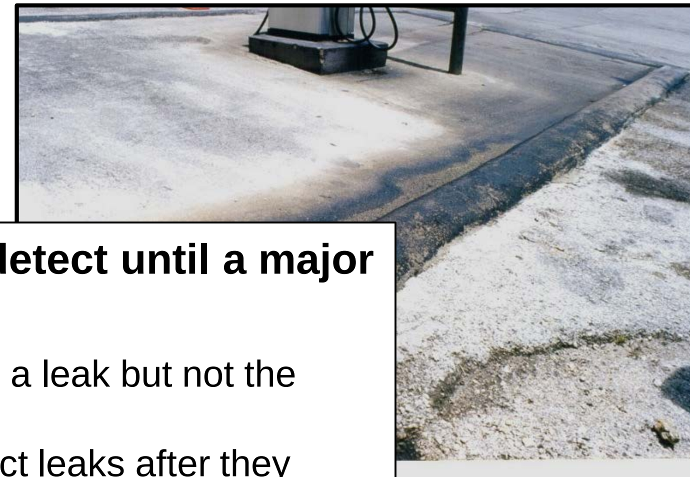
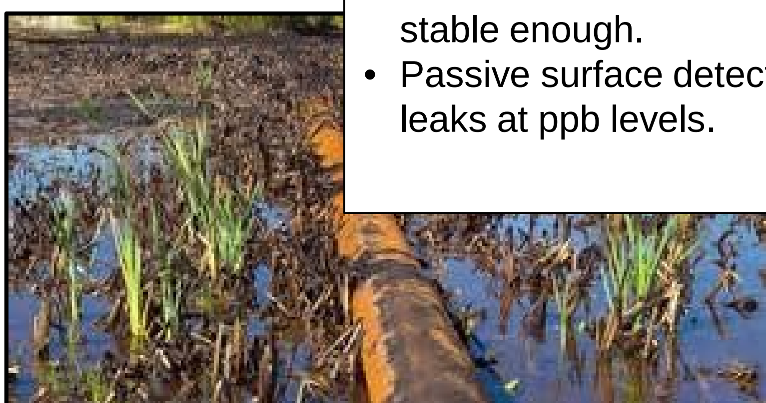
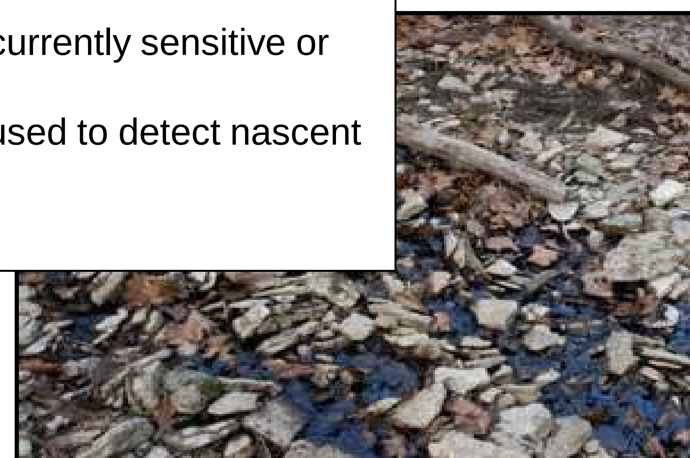




Leaks are often difficult to detect until a major event occurs.

- Pressure testing may determine a leak but not the location.
- Pipeline pigs normally only detect leaks after they become significant and costly.
- Drones – the detectors are not currently sensitive or stable enough.
- Passive surface detection was used to detect nascent leaks at ppb levels.



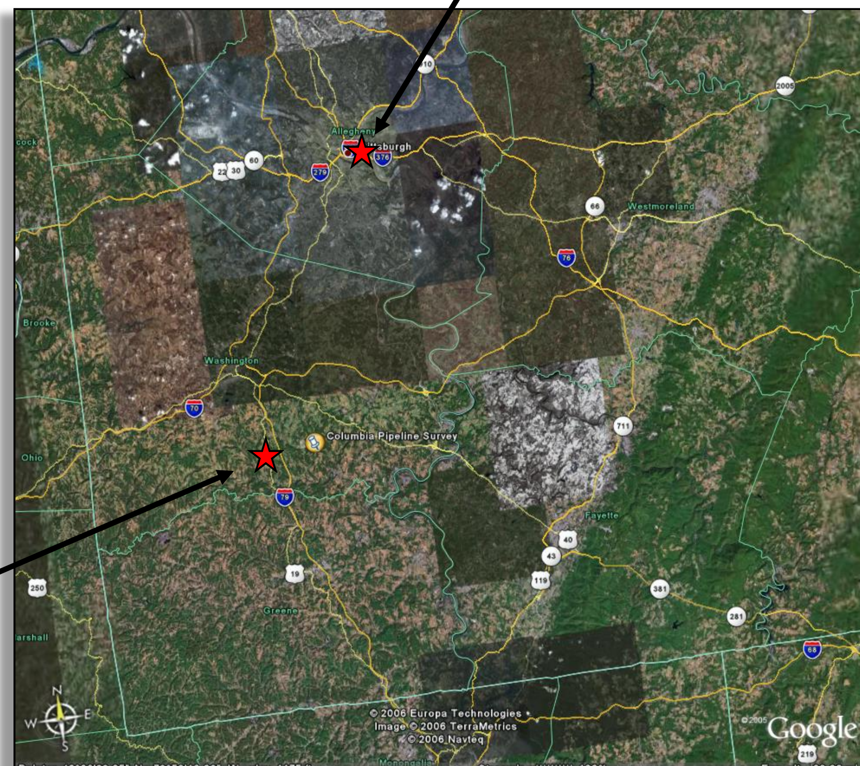


Leaking Gas Pipeline Case Study

The Columbia pipeline leak detection case study in Washington County, PA.

Survey location, south of Pittsburgh, in Washington County, PA.

Pittsburgh



Survey location

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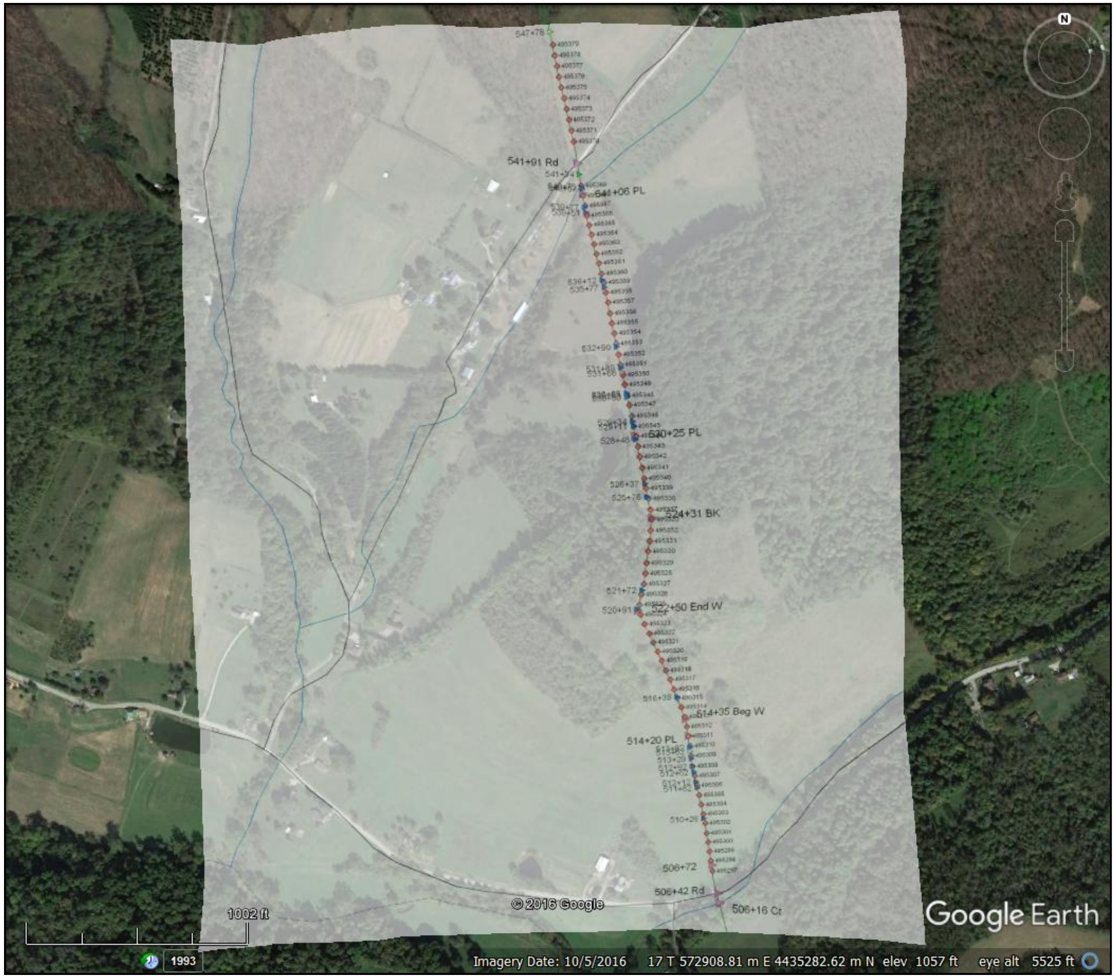
Expanded View of the Survey Location

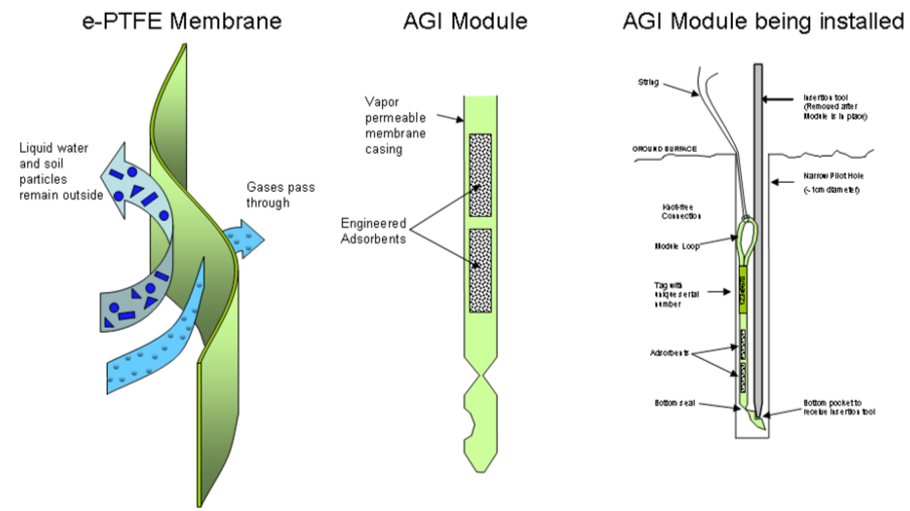


Area of pipeline survey, north of Lone Pine Road.

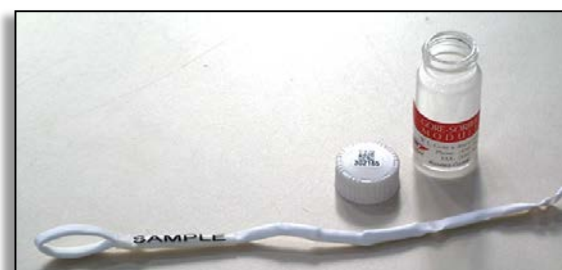
Sample spacing was every 50 ft along a one mile section of pipeline.

Passive Sorbers

- **Patented, passive, sorbent-based**
  - Chemically-inert, waterproof, vapor permeable
  - Direct detection of organic compounds
  - Sample integrity protected
- **Engineered sorbents**
  - Consistent sampling medium
  - Minimal water vapor uptake
- **Time-integrated sampling**
  - Minimize near-surface variability
  - Maximize sensitivity (up to C20)
  - Avoids variables inherent in instantaneous sampling
- **Duplicate samples**
- **Effective in air, soil and water**
- **Collects VOCs/SVOCs**
- **Lower total sampling costs**
- **No refrigeration for shipping**
- **Time integrated sampling gives ppt sensitivity**
- **US EPA ETV Verification of the method for soil gas and groundwater**



AGI Module and Installation Schematic (onshore)



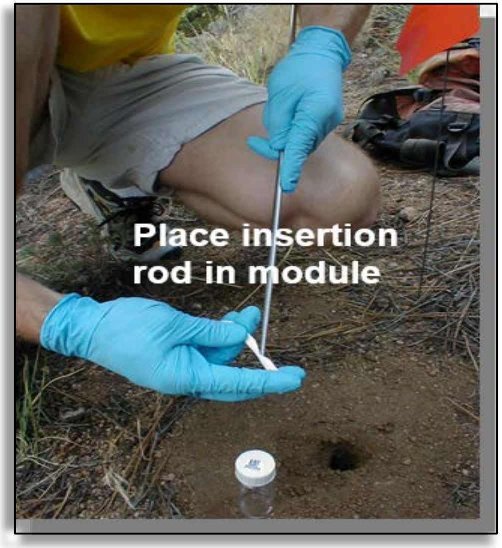
AGI Passive Module Installation

Field personnel drill a 1” diameter hole ~3 ft deep using a battery operated hand drill.

The AGI module is lowered into the hole and remains in place for 1 week or less for pipeline integrity & remediation projects.

By remaining in the ground for 1 week, the hydrocarbons concentrate on the absorbers within the module to provide a 1,000-fold increase in concentration.

This provides detection limits in the low parts per billion (ppb) range **which is unique and critical for nascent leak detection capabilities**.



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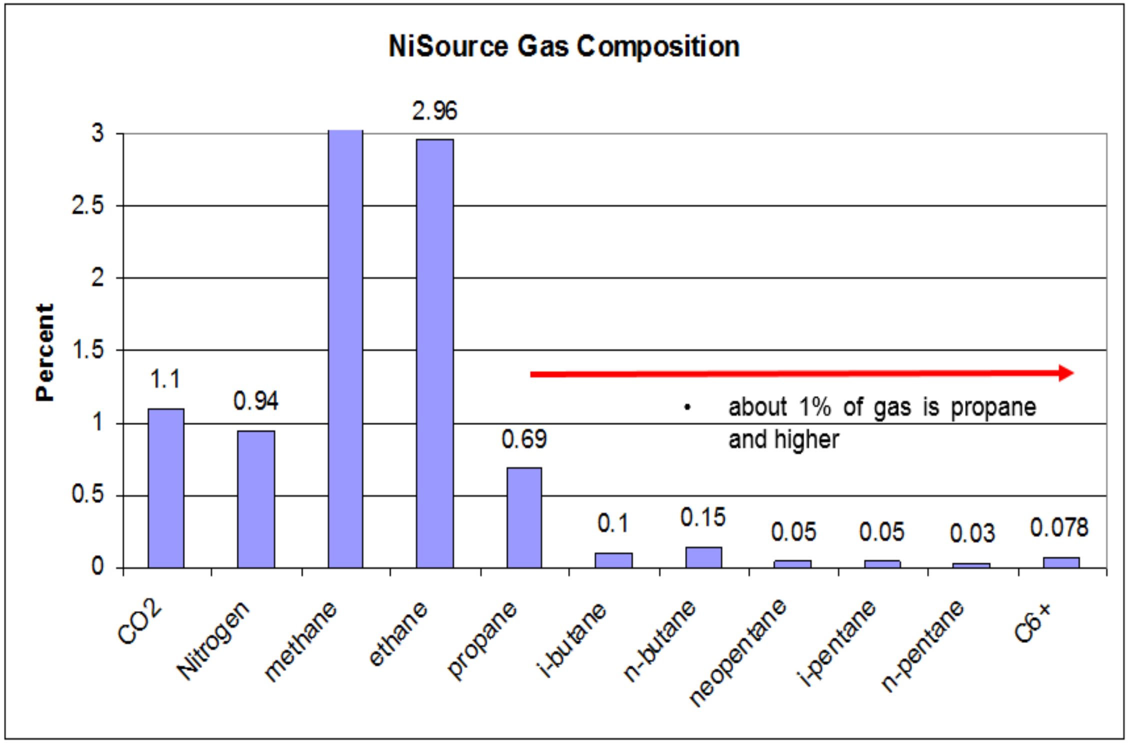
Columbia Pipeline Project Objectives

Objectives:

- Examine the variation of compound patterns along the pipeline for evidence of natural gas leakage
- Examine potential detection of nascent leaks
- Compare results with pipeline maintenance history
- Make recommendations for future advancement of the methodology

Composition of the Pipeline Gas



Only 1% of Pipeline Gas was >C_2

With the gas composition being 99% methane, soil gas methods are severely limited – can't detect anything but methane.

Methane and sulfur sniffers lack the sensitivity to detect nascent leaks and only detect strong or serious leaks.

Methane sniffers cannot determine if the methane is petroleum related or biogenic.

AGI Compound List

Typical Petroleum Constituents
Carbon number in ( )

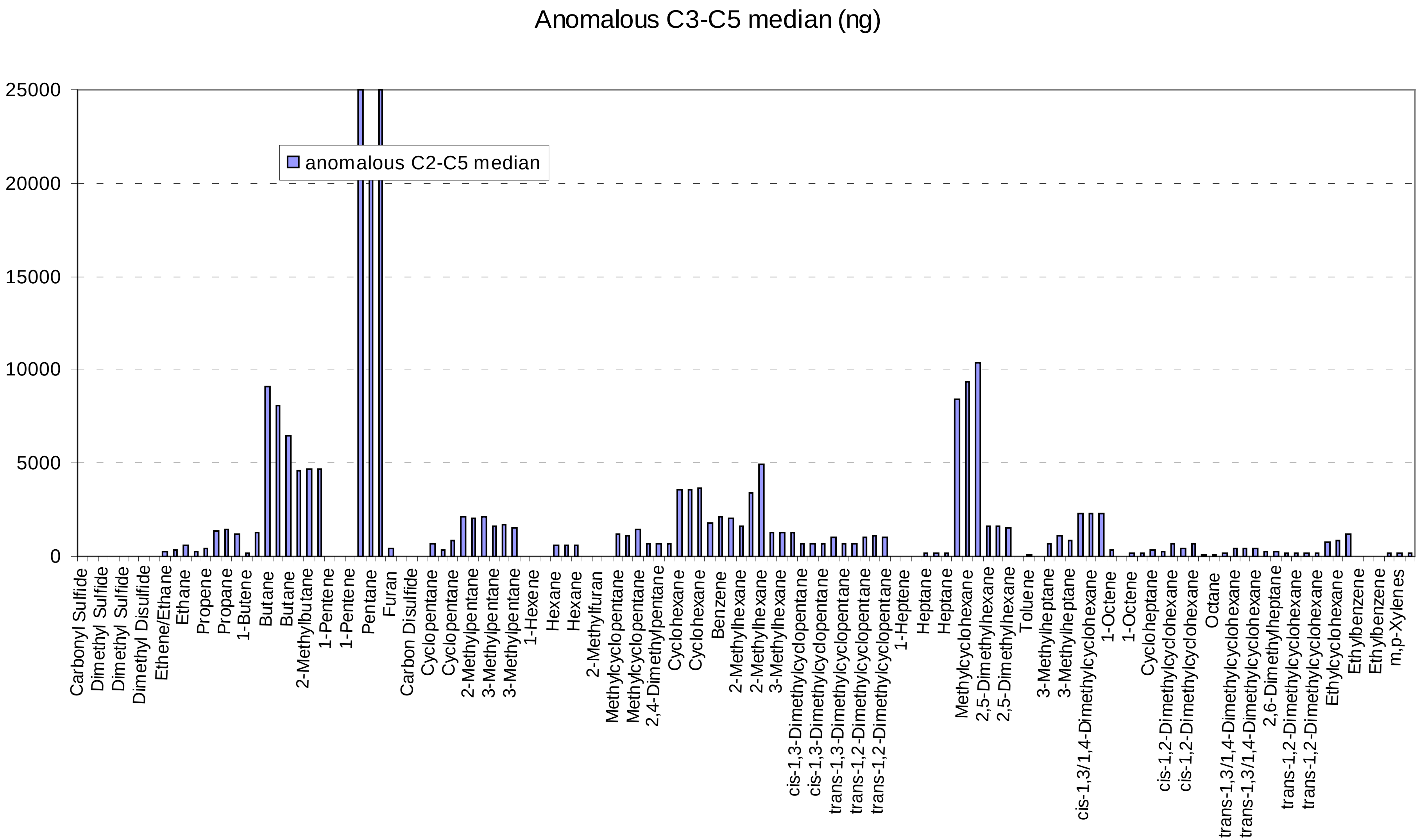
Normal Alkane: 17 compounds	Iso-alkane: 11	Cyclic Alkane: 15	Aromatic and PAH: 17
Ethane (2)	2-Methylbutane (5)	Cyclopentane (5)	Benzene (6)
Propane (3)	2-Methylpentane (6)	Methylcyclopentane (6)	Toluene (7)
Butane (4)	3-Methylpentane (6)	Cyclohexane (6)	Ethylbenzene (8)
Pentane (5)	2,4-Dimethylpentane (7)	cis-1,3-Dimethylcyclopentane (7)	m,p-Xylenes (8)
Hexane (6)	2-Methylhexane (7)	trans-1,3-Dimethylcyclopentane (7)	o-Xylene (8)
Heptane (7)	3-Methylhexane (7)	trans-1,2-Dimethylcyclopentane (7)	Propylbenzene (9)
Octane (8)	2,5-Dimethylhexane (8)	Methylcyclohexane (7)	1-Ethyl-2/3-methylbenzene (9)
Nonane (9)	3-Methylheptane (8)	Cycloheptane (7)	1,3,5-Trimethylbenzene (9)
Decane (10)	2,6-Dimethylheptane (9)	cis-1,3/1,4-Dimethylcyclohexane (8)	1-Ethyl-4-methylbenzene (9)
Undecane (11)	Pristane (19)	cis-1,2-Dimethylcyclohexane (8)	1,2,4-Trimethylbenzene (9)
Dodecane (12)	Phytane (20)	trans-1,3/1,4-Dimethylcyclohexane (8)	Indane (9)
Tridecane (13)		trans-1,2-Dimethylcyclohexane (8)	Indene (9)
Tetradecane (14)		Ethylcyclohexane (8)	Butylbenzene (10)
Pentadecane (15)		Cyclooctane (8)	1,2,4,5-Tetramethylbenzene (10)
Hexadecane (16)		Propylcyclohexane (9)	Naphthalene (10)
Heptadecane (17)			2-Methylnaphthalene (11)
Octadecane (18)			Acenaphthylene (12)

Byproduct and Alteration Compounds
Included in this method to provide a comprehensive inventory of the geochemical system in the surface soil zone

Alkene: 10	Alteration/Byproduct: 3	Biogenic: 4	Nitrogen/Sulfur/Oxygen Compounds: 5
Ethene (2)	Octanal (8)	alpha-Pinene	Furan
Propene (3)	Nonanal (9)	beta-Pinene	2-Methylfuran
1-Butene (4)	Decanal (10)	Camphor	Carbon Disulfide
1-Pentene (5)		Caryophyllene	Benzofuran
1-Hexene (6)			Benzothiazole
1-Heptene (7)			
1-Octene (8)			
1-Nonene (9)			
1-Decene (10)			
1-Undecene (11)			

Subsets of this list can be devised for particular programs for increased specificity and reduced costs.

Example Natural Gas Signature



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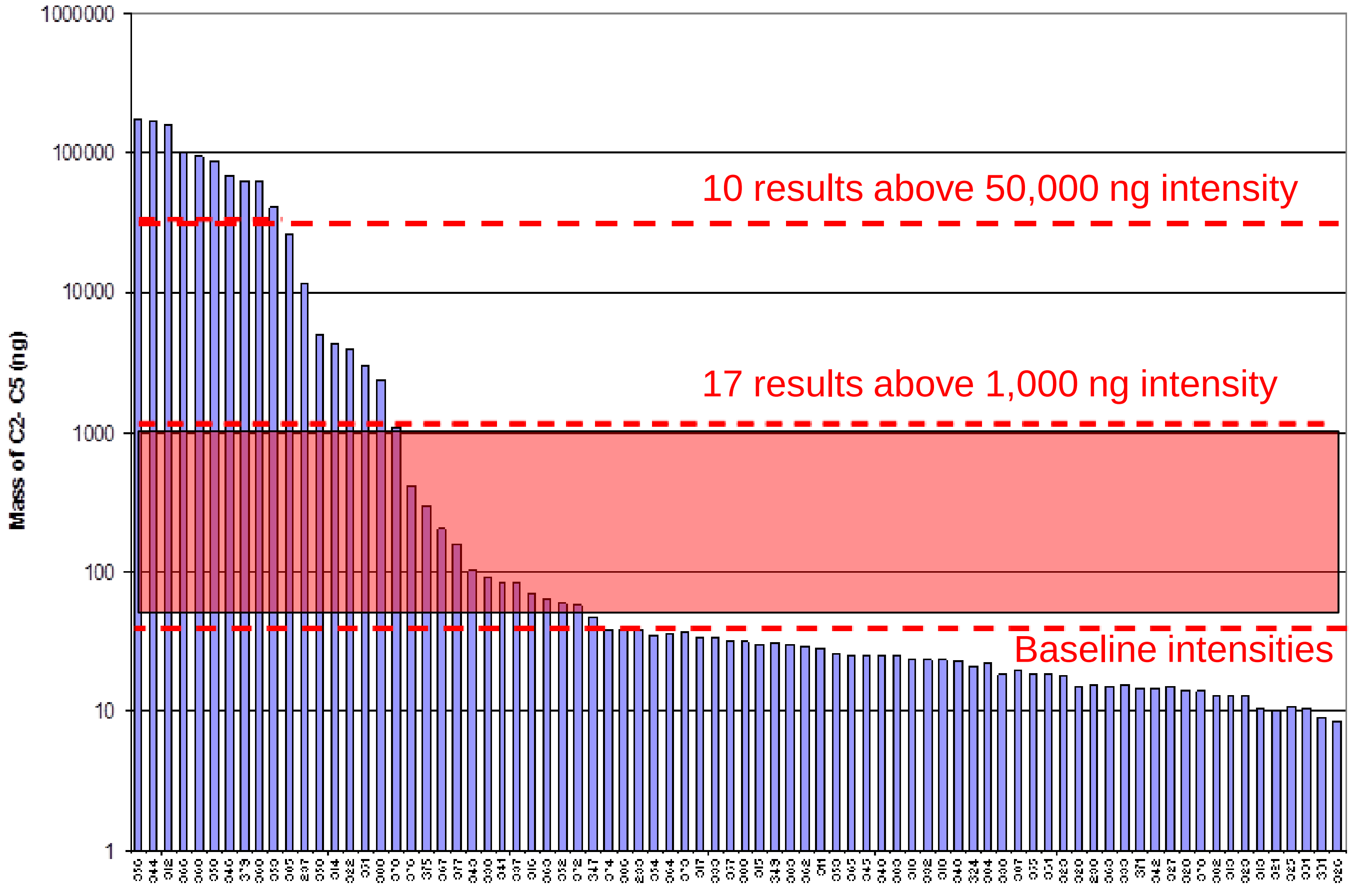
C_3 – C_5 Mass Distribution for all Samples

- The data clearly indicates 11 samples above the 10,000 ng level, **quickly identifying 11 potential significant leak points along the pipeline**.
- The data also indicates 5 samples between 1,000 – 10,000 ng which may be moderate leaks or areas of previous leaks.
- Due to the sensitivity of the method, the histogram clearly establishes a baseline mass level for the pipeline.
- The samples between 80 – 1,000 ng **may be indicative of nascent leak points along the pipeline, that would be undetectable by other methods.**



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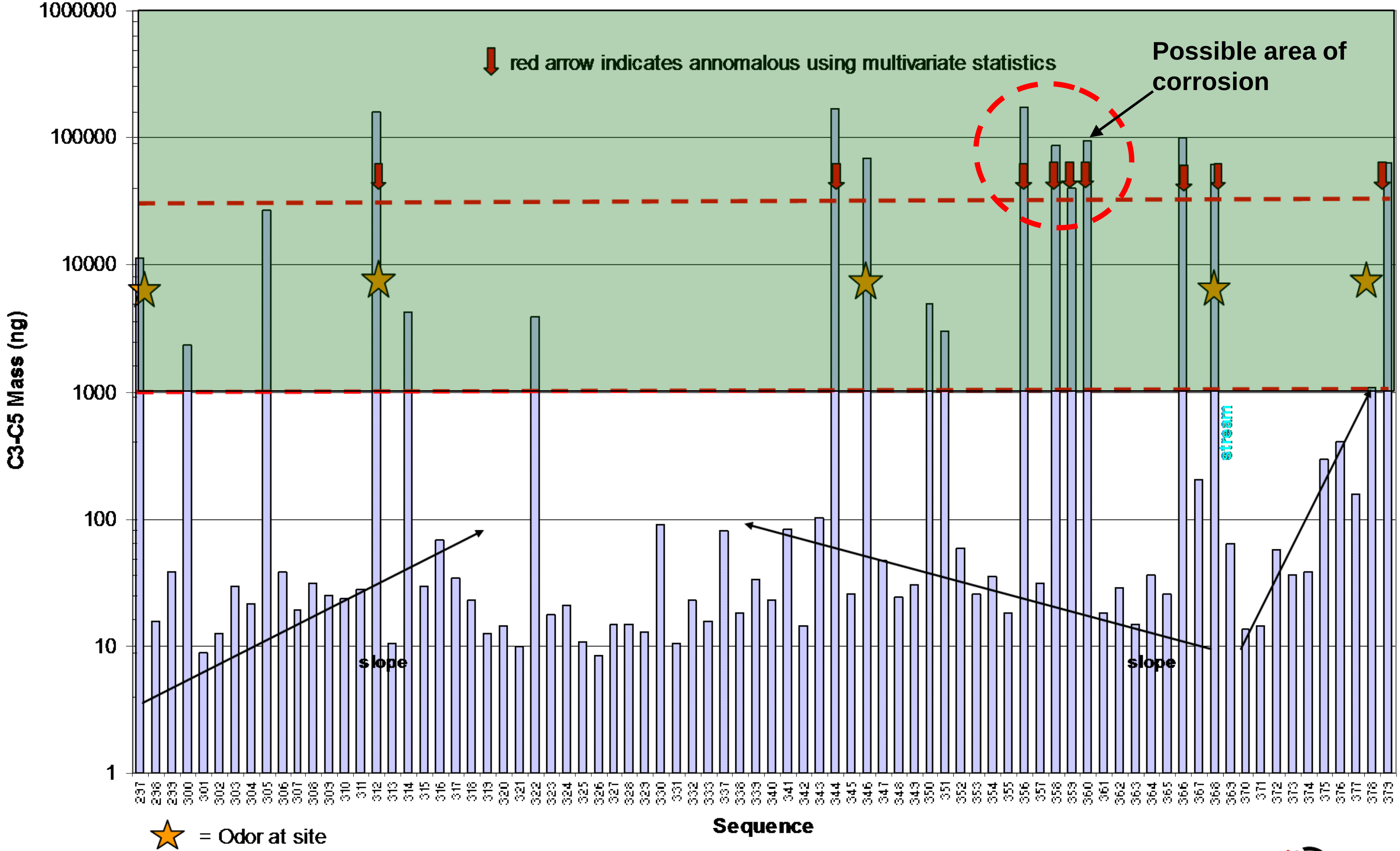
AGI Intensities for Each Sample

Gas Indication sequentially along Pipe

Note there are 17 points above the 1,000 ng threshold that separate from the other data points.



Significant Odorants Found in 13 Samples

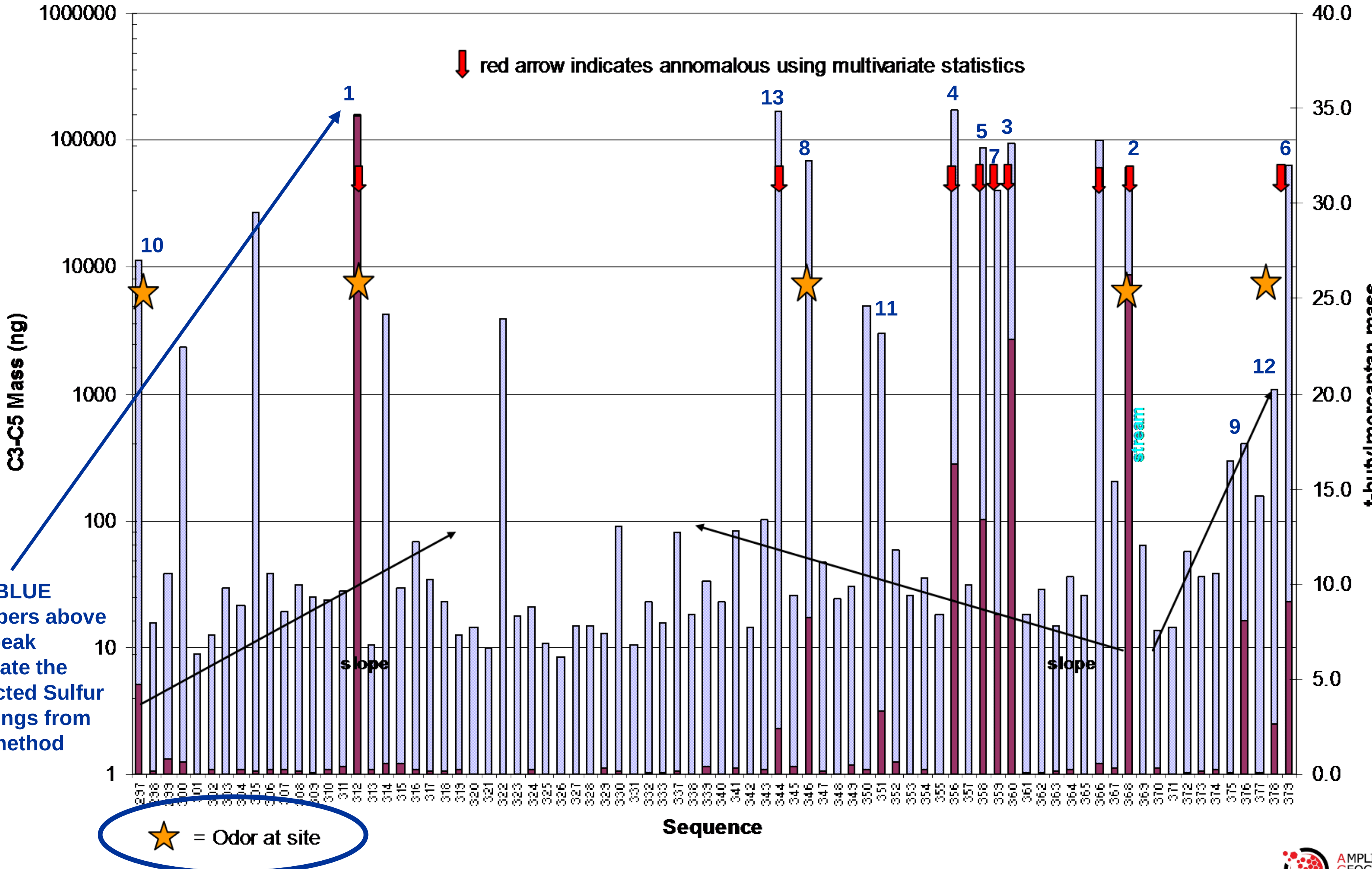
Module	t-butylmercaptan		Isopropylmercaptan	
495312.D	34.59	significant	10.8	significant
495368.D	26.30	significant	2.9	significant
495360.D	22.89	significant	3.2	significant
495356.D	16.28	significant	4.3	significant
495358.D	13.35	significant	0.8	
495379.D	9.05	significant	4.0	significant
495359.D	8.44	significant	3.7	significant
495346.D	8.23	significant	1.3	
495376.D	8.06	significant	2.5	significant
495297.D	4.76	significant	0.7	
495351.D	3.30	significant	1.7	
495378.D	2.64	significant	1.0	
495344.D	2.45	significant	1.4	
495299.D	0.79		0.9	

Baseline level

Alternate Methods Insufficient

Gas Indication sequentially along Pipe

The red bars indicated samples that tested positive with a hand-held Methane sniffer at the time of sampling.



The BLUE numbers above the peak indicate the detected Sulfur rankings from the method

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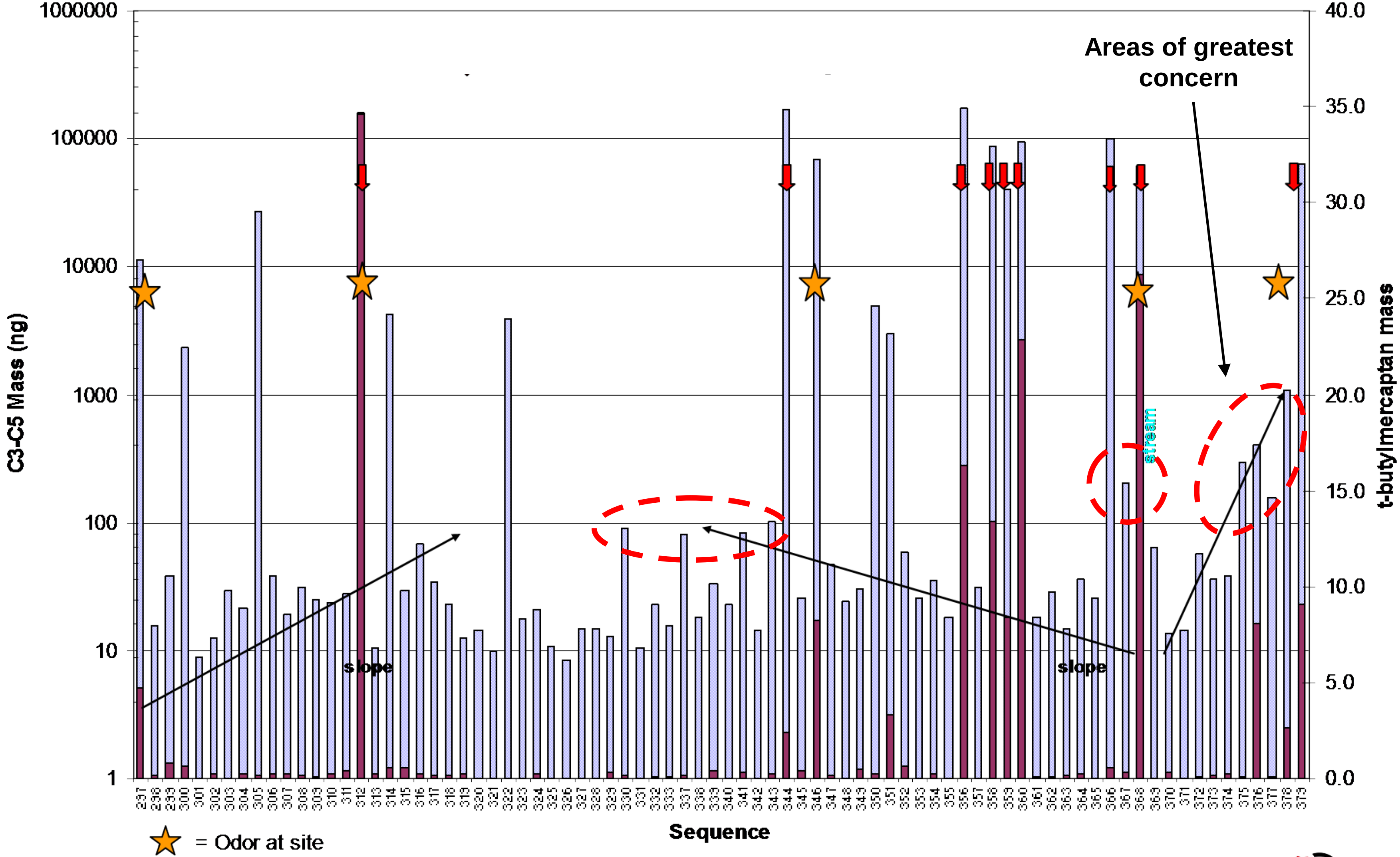
Detection of Possible Nascent Leaks

Potential nascent leaks highlighted by the red dashed circles.



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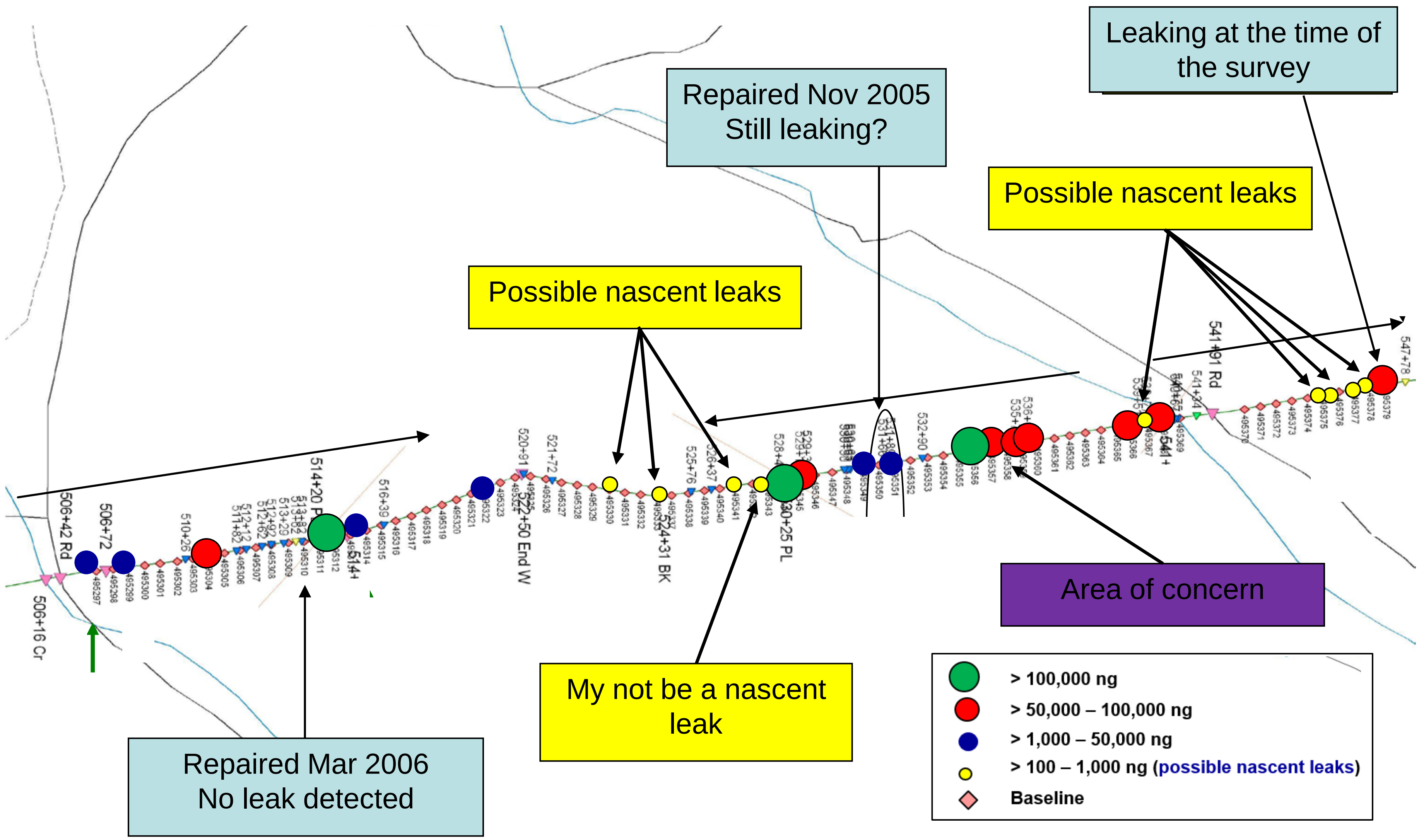
Map View of the Pipeline Sample Results

Survey conducted early 2007



Case Study Conclusions

- Several pipeline locations had strong potential as leakage points .
- **Hand-held sniffers** and olfactory receptors were **not adequate for detecting potential leakage** areas.
- The results were ground truthed with a known leak point at the time of the survey.
- The data **helped to monitor the efficiency of pipeline repair work** by showing one previous leak point to no longer have elevated amounts of hydrocarbons while another may still be leaking.
- Due to the sensitivity of the method baseline levels of hydrocarbons could be determined to define areas with no contamination.
- Due to the sensitivity of the method and the fact leakage areas were also identified, **the method could detect nascent leakage points that could not be identified by other methods**.
- Once leaks are identified a follow-up mini-survey could be implemented to map the extent of contamination (i.e. map the contaminant plume).

AGI's passive sorbers can be used for routine monitoring to identify nascent leaks to reduce leakage, repair costs, and environmental problems.

Thank You!

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