Reducing Consequences of Gas Pipeline Damage

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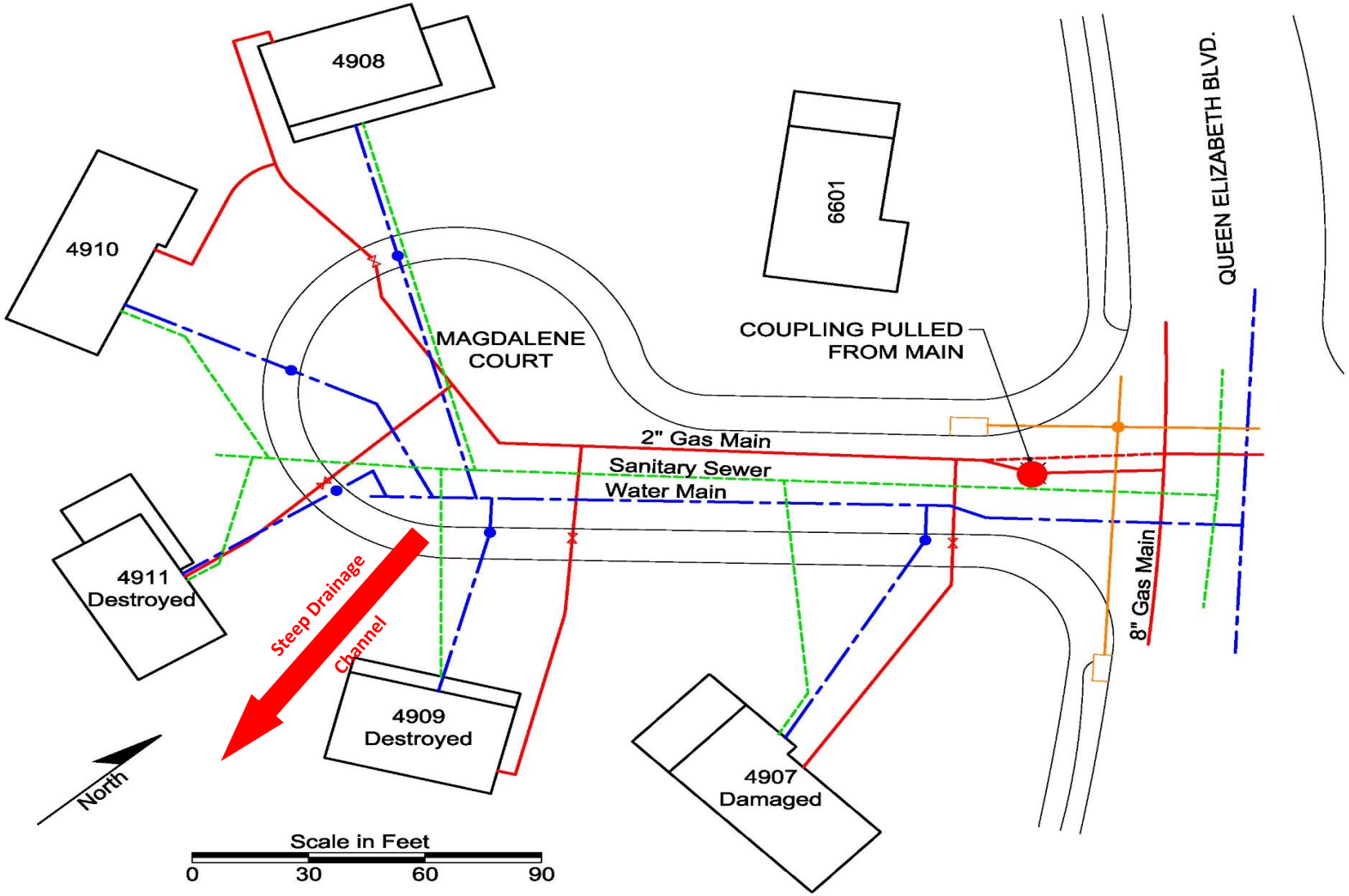
Pipeline Damage and Soil Gas Migration

- Review gas pipeline incidents that have led to a fire or explosion
- Compare similarities and differences
- Test theories of soil gas migration
- Review emergency response procedures

Annandale, VA
March 19, 1972

- A backhoe fractured a gas line.
- One hour later, two houses exploded 240 feet away.
- Gas was smelled inside a home within 30 minutes.
- Theoretical “path of least resistance” from a backhoe strike is into the open air near the gas line. **How can it cause an explosion 240 feet away?**

Annandale, VA



Annandale, VA
March 19, 1972

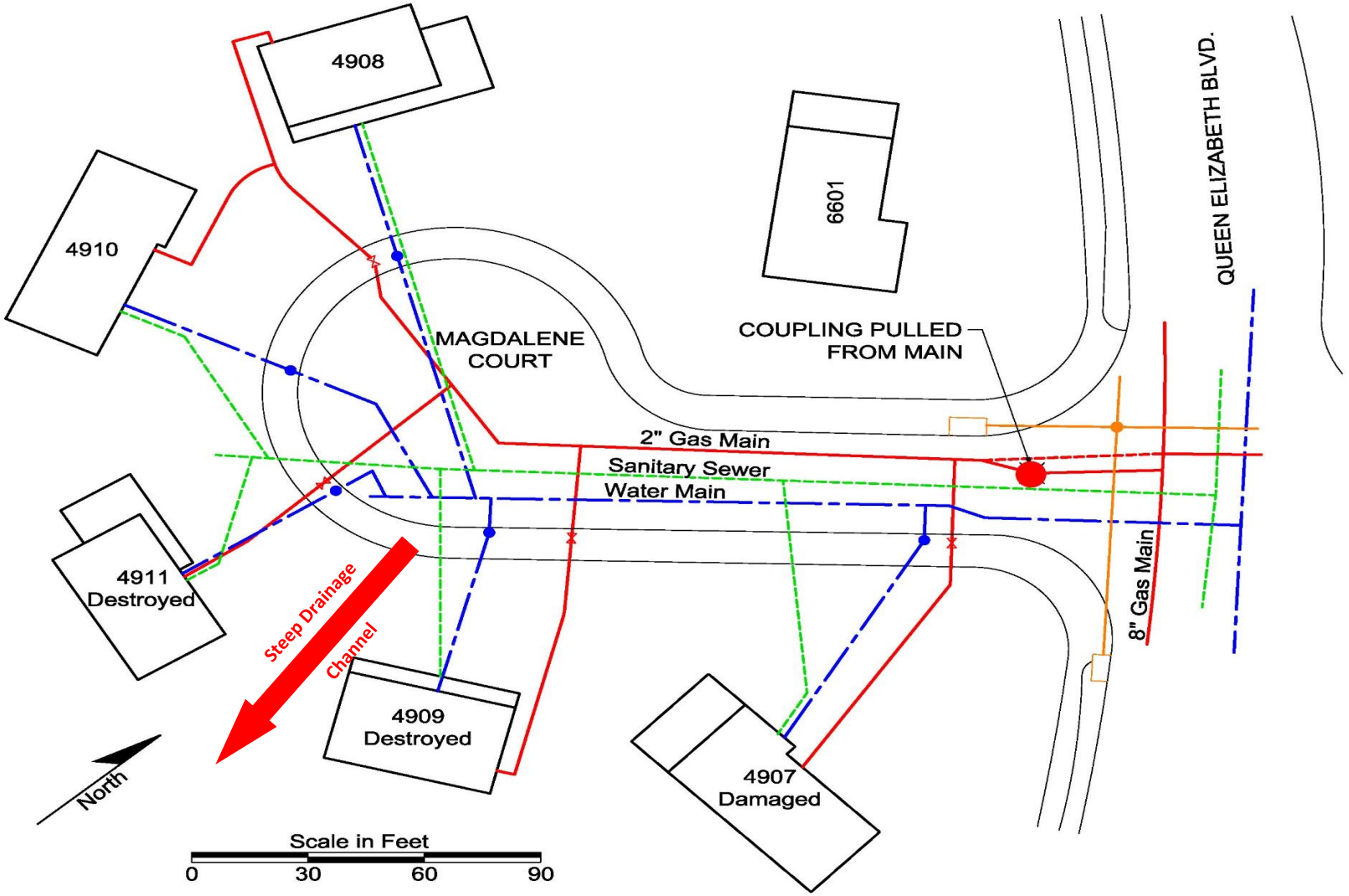
Annandale, VA
1972

- Saw a **distinct drainage pattern between the two houses**.
- Cul-de-sac is the lowest point of the surrounding area and **natural drainage is between the two houses**.
- **Path of least resistance** was directly to the surface, but the explosions were 240’ away.

Annandale, VA
1972

- Terrain was all a rocky material, including the trenches
- **Explosions occurred within 60 minutes** of the fracture
- Gas did not get into the sanitary sewer line
- Gas did not follow the surface of the gas line
- NTSB tested and eliminated both possibilities
- NTSB concluded the gas followed the rocky backfill in the ditch lines. All the terrain was rocky, however.

Annandale, VA



Annandale, VA
1972

- All of the gas did not go “up and out”
- Gas did not “follow the pipeline”
- Gas did not “get into the sewer line”
- New ideas needed to explain how gas leaks cause explosions.
- Enough gas traveled 240’, in 60 minutes, to cause explosion.

Saratoga Springs, Utah
2007

- HDD crew damaged a gas line 40’ from a home
- A first responder arrived an hour later.
- First responder and homeowner were checking for gas in the basement with CGI when home exploded
- Two fatalities

Saratoga Springs, Utah
2007

- Gas leak was not isolated prior to entering building.
- After the incident, a simulated a gas leak was created.
- Immediately upon startup of the air compressor, dust blew out from the expansion joint all along the bottom of the basement wall.

Saratoga Springs, Utah
2007

- Gas entered the structure **instantly** upon initiation of gas pressure.
- Gas was forced at least 7’ below ground, while pipeline was only 3’ deep.
- Gas did not go “up and out”
- Gas did not “follow the pipeline” or the HDD bore
- Under these conditions… (1) damage was less than 50’ from structure and (2) it was a significant leak

Saratoga Springs, Utah
2007

- In my opinion, first responder should *not* have entered structure under these conditions.
- Gas leak should have been isolated and the home evacuated prior to entering the structure
- Pressure forced enough gas 40’ through the ground to cause the explosion.

Dallas, Texas
2018

- Sanitary sewer line was installed on top of a gas line
- The steel gas line was gouged and damaged, and failed many years later.
- Sanitary sewer line was embedded in coarse gravel and the gas was injected directly into this medium.

Dallas, Texas
2018

- Three homes over three days were damaged by gas explosions; resulted in several injuries and one fatality
- Two homes were 150’ and 250’ away; third home, which was possibly involved from the gas leak, was 375’ from the leak.
- Leak was difficult to pinpoint because of the very porous nature of sanitary sewer line’s gravel embedment material
- Gas did not get into the sewer line
- Gas leak was not isolated prior to the explosions

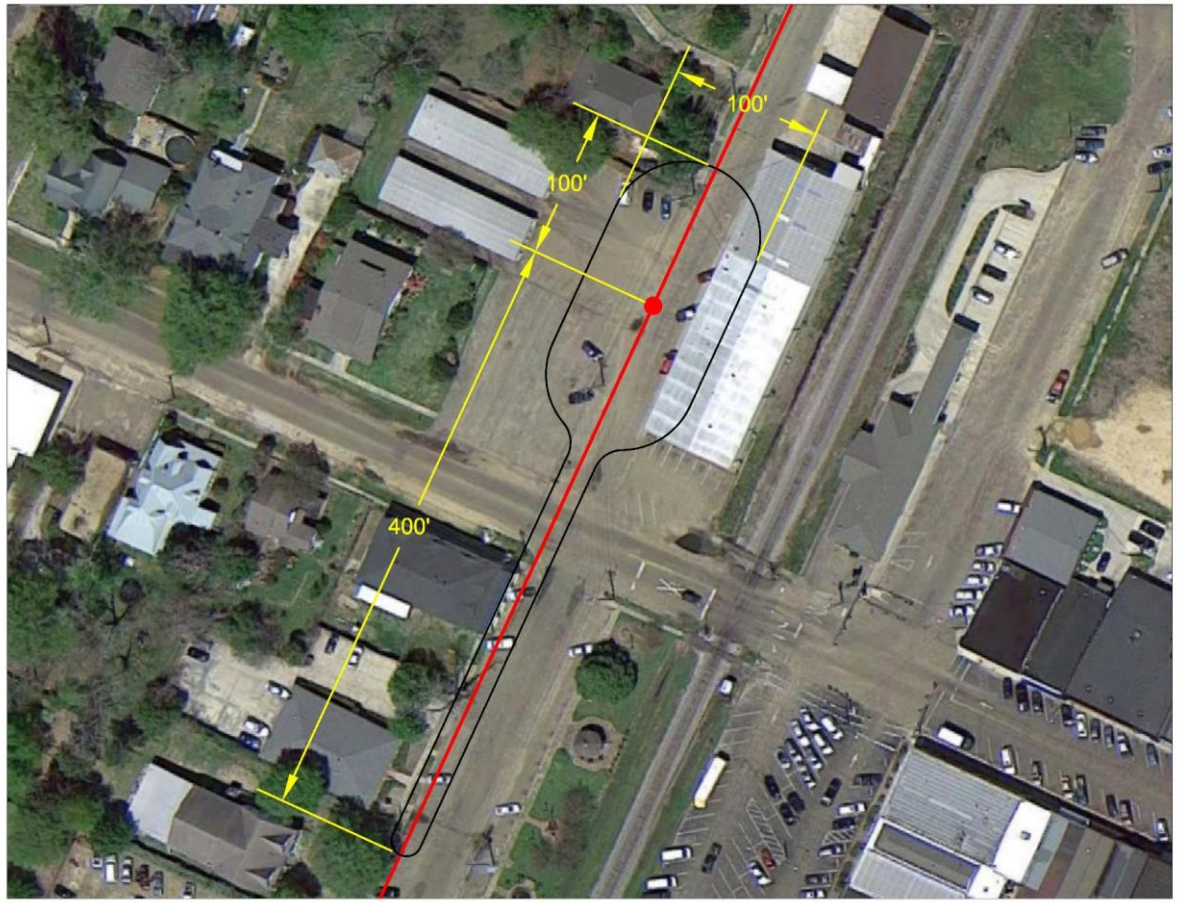
Crystal Springs, MS
February 1986

- A PE gas line was severed with a backhoe and repaired with a PVC coupling
- Gas line pulled out of the coupling, caused an explosion resulting in 8 fatalities
- Water line was installed in select sandy fill and the gas was injected directly into it; adjacent soil was clay

Crystal Springs, MS
February 1986

- I found elevated gas concentrations from bar hole readings along the waterline for a distance of 400’ **downhill** and 100’ **uphill** from the leak, **but the explosion occurred in the building 50’ perpendicular to the water line trench**

Crystal Springs, MS
February 1986

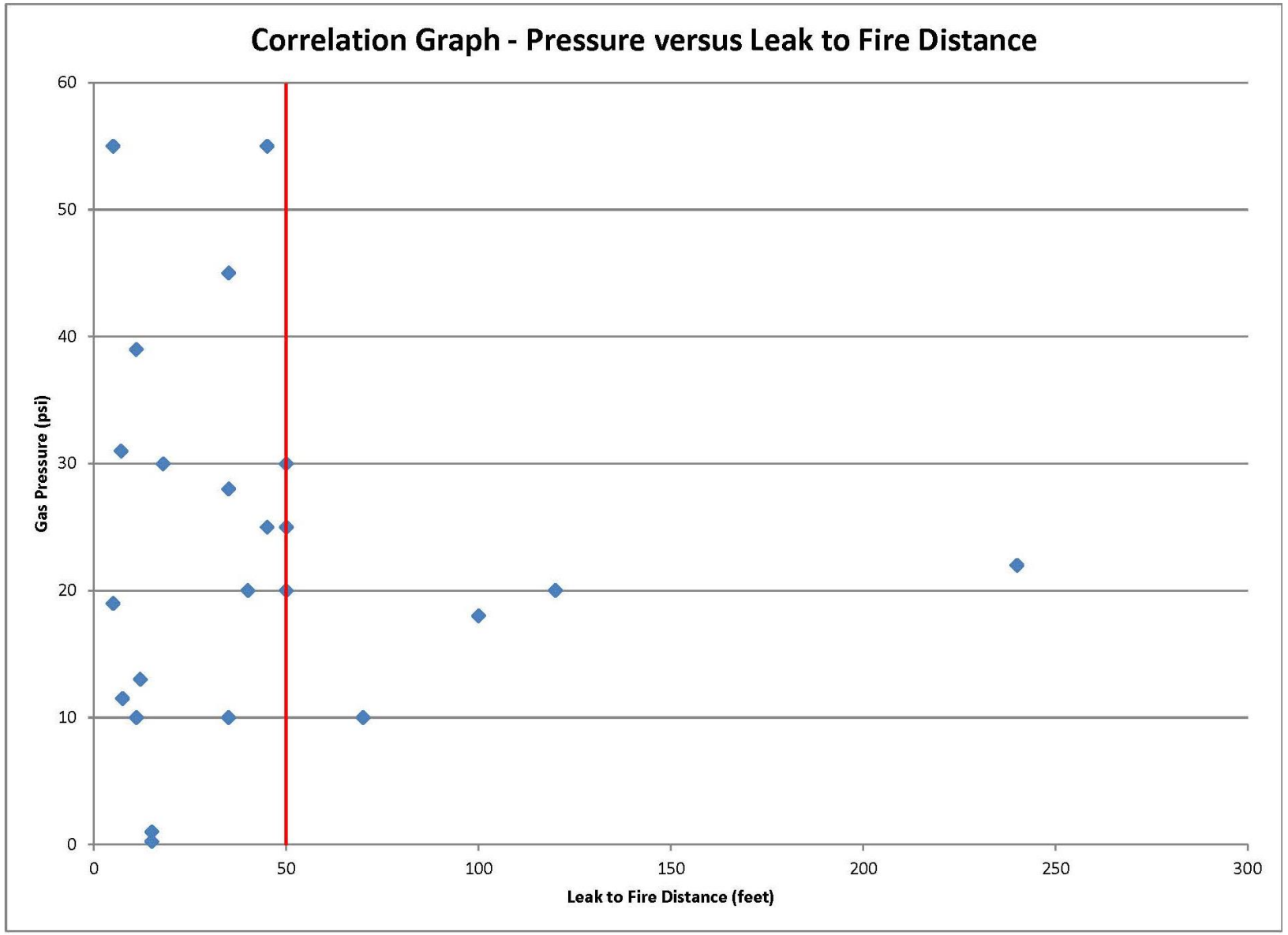


Crystal Springs, MS
February, 1986

- "Path of least resistance" was along the sandy backfill of the water line, but the explosion was 50 feet perpendicular to it
- Gas went uphill, downhill and laterally through clay
- Theory of the "path of least resistance" implies a singular path

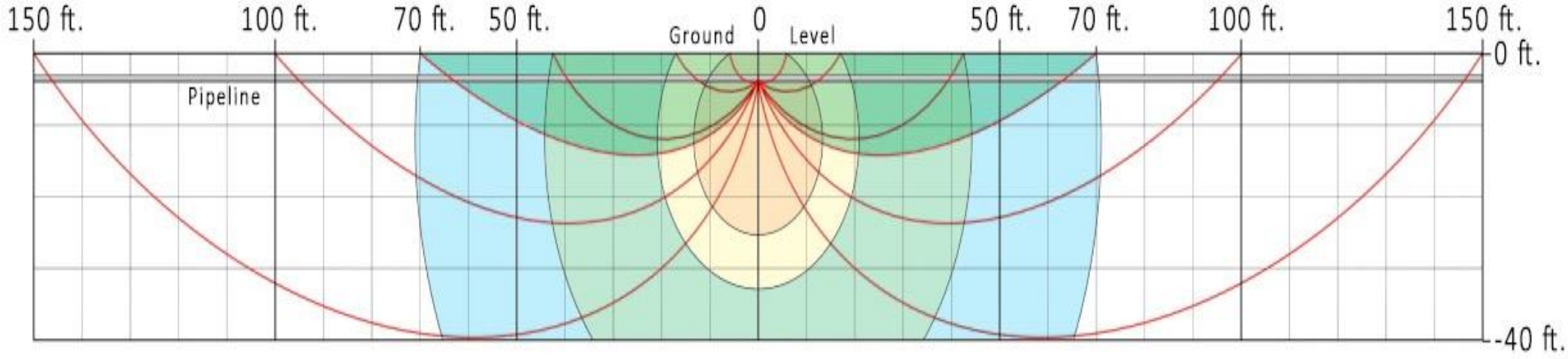
Crystal Springs, MS
February, 1986

- Gas radiates in all directions from the source.
- A large flow rate is necessary to cause a fire.
- **A small residual pressure over a broad surface area forces gas into structures to cause an explosion.**

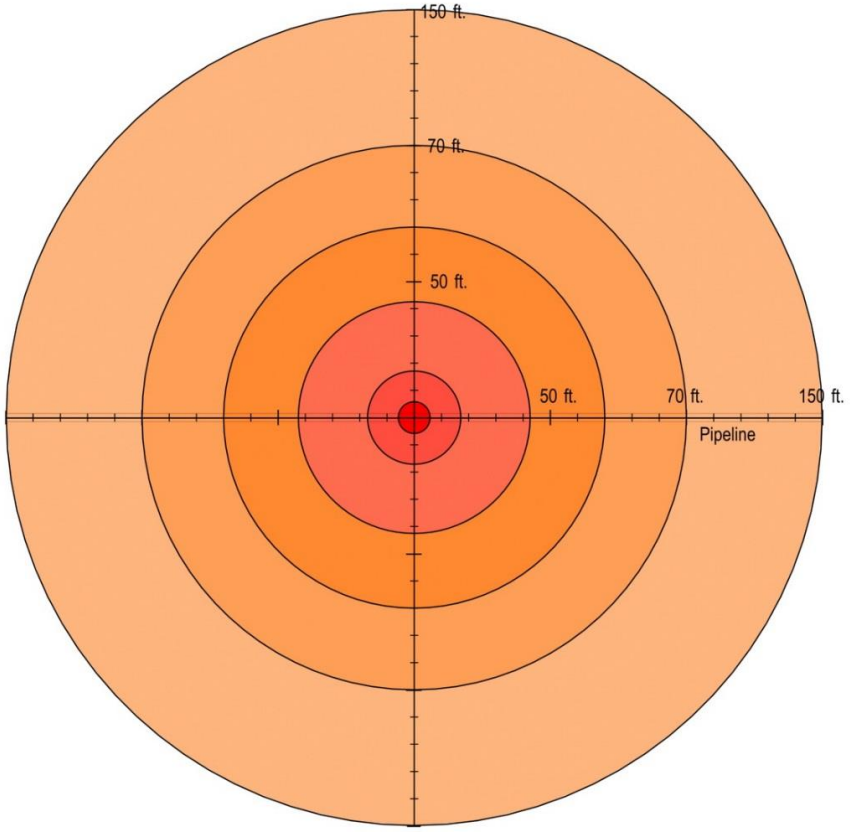

Correlation Graph - Pressure versus Leak to Fire Distance
Gas Pressure (psi)
60
50
40
30
20
10
0
0
50
100
150
200
250
300
Leak to Fire Distance (feet)

An Approximate Flow Net Diagram of the Radial Flow Pattern from a High Flow Rate Gas Leak

Stream lines : Red
Isobars perpendicular to stream lines



Top View of Flow Net Diagram



Ratio of Lateral Distance From the Leak to the Structure Compared to the Depth of Gas Line

• Sarasota Springs, UT	13
• Holly Springs, MS	17
• Jackson, MS	23
• Queen Creek, AZ	17
• Bowie, MD	40
• Annandale, VA	80
• Dallas, TX	100

- So, concluding that gas from an underground gas leak goes “up and out” is simply not accurate.

How Much **Time** Does it Take for a Gas Leak to Cause an Explosion?

Let's look at some cases where we know the time factor.

- Annandale, VA - **240** feet in **60** minutes at **22 psi**
- Philadelphia, PA - **30 feet** in **15 minutes** at **0.25 psi**
- Chicago Heights, IL - **40** feet in **30** minutes at **28 psi**
- New Iberia, LA - **10** feet in **15** minutes

How Does Soil Type Affect Soil Gas Migration?

• Queen Creek, AZ	Clayey sand, sandy silt	50	feet
• Jackson, MS	Dense wet clay	70	feet
• Odessa, WA	Rock and volcanic ash	60	feet
• Saratoga, UT	Frozen silty clay	40	feet
• Ft. Worth, TX	Dense clay	40	feet
• Rancho C., CA	Silty clay loam	50	feet

How Does Pipeline Pressure Effect Natural Gas Migration Explosions?

• Philadelphia, PA	5/11/1979	0.25 psi, 30 ft.
• Williamsport, PA	1/25/1977	10 psi, 70 ft.
• Bowie, MD	6/23/1973	20 psi, 120 ft.
• Annandale, VA	3/24/1972	22 psi, 240 ft.
• Jackson, MS	12/24/2008	45 psi, 70 ft.
• Rancho C., CA	12/24/2008	55 psi, 45 ft.

Kansas City, KS
February 19, 2013

- HDD crew hit a gas line within a few feet of restaurant wall
- Gas company was onsite for two hours prior to explosion
- Customers were evacuated only minutes before explosion
- Gas leak was not isolated prior to the explosion

Kansas City, KS
February 19, 2013

- One restaurant employee died and others were injured
- The large leak was in **close proximity** to a building

Canton, Illinois
November 16, 2016

- Explosion caused 1 fatality and 11 injuries outside of the structure.
- **The large leak was in close proximity to a building**.
- **The leak was not isolated prior to the explosion**.

Durham, NC
April 10, 2019

- HDD crew hit a gas line 5’ from the structure
- Gas flowed for 1 hour prior to explosion
- 100% LEL in the structure almost immediately

Durham, NC
April 10, 2019

- A **large leak** in **close proximity** to the building
- 2 fatalities and 25 injuries
- **The leak was not isolated prior to the explosion**

Murrieta, CA
July 16, 2019

- Gas line struck outside of a residence
- First responders arrived 50 minutes prior to explosion
- 1 fatality and 15 injuries including 3 firefighters from flying debris outside the structure
- **The leak was not isolated prior to the explosion**

New Iberia, LA
2021

- Gas line damaged 10’ from the structure
- Gas-related fire within 15 minutes of pipeline damage
- Gas leak was not isolated prior to entering the building
- 4 injuries resulted from the explosion

Tyrone, PA
2021

- Gas line damaged by HDD crew
- Structure was 20’ from the damaged pipeline
- Explosion caused injuries and a fatality
- Leak was not isolated prior to the explosion

Summarizing Parameters

- Only two of these incidents were more than 50’ from the damaged gas line
- Pipeline damage from a backhoe caused an explosion 240’ away in 60 minutes; shows that the theory that all the gas takes “path of least resistance” needs re-evaluation

Summarizing Parameters

- Regarding pipeline damage caused by directional drilling, gas theoretically follows the annular space caused by the drilling itself, but incidents show assumption is incorrect
- Large leaks from pipeline damage create gas flow through the soil spherically, as far as 50-150’ in all directions
- **Most gas fires occur within a 50’ radius of the source**

Summarizing Parameters

- Soil type, other pipelines, and buoyancy of the natural gas, surface “caps” have little effect on overall flow path of gas from a leak
- “Path of least resistance” is not a valid, practical concept when pipeline damage occurs
- **Primary variable** in a gas explosion is the **ignition source,** not the time for gas to enter a structure

Summarizing Parameters

- Gas infiltrates structures primarily by differential pressure on large surface areas
- Gas is commonly forced as far as 50’ through voids, such as wall penetrations, expansion joints, cracks, etc., to cause incidents.
- Many times, large leaks that cause explosions have readily visible and/or audible indications

Pipeline Damage and Soil Gas Migration

If a gas line is damaged and a leak is created, a few instantaneous risk assessments can be made:

1. Is it a visible or audible leak?
2. Is the **distance** to occupied structures within **50'**? Risks increase the closer a leak is from a 50' radius, but decrease at farther than 50'
3. With these conditions, explosions can occur a short time after a gas pipeline is fractured; extreme caution is advised if entering structures prior to isolating the gas leak

Pipeline Damage and Soil Gas Migration

Questions? Comments?

Thank you for your interest in this subject.

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