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Elevated Subsurface Temperatures

Use of Technology to Identify and Mitigate Areas of Concern

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Introduction

Presenter:
Chris Peters
Operations Director

Author:
C. Lee Daigle, PE
Senior Project Manager

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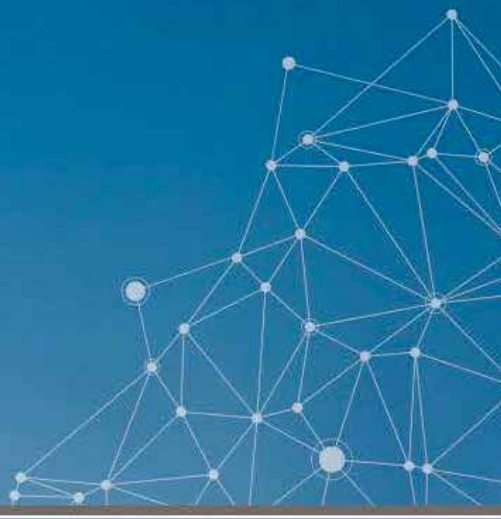
Senior Project Manager

- 15 Years of experience in the landfill gas industry
- Worked on landfills in over 20 states and 4 countries abroad
- Expertise in landfill gas collection system design, operation, maintenance and reporting
- Managed numerous responses to elevated subsurface temperatures / subsurface oxidation events

Presentation Outline

- Elevated Subsurface Temperature
  - The Basics
- Historical Approach
  - Typical Procedures
- Case Study
  - Thermal Imaging Basics
  - Identify Additional Areas
  - Confirm the Extent
  - Mitigate the Issue
  - Confirm Effectiveness
- Closing
- Questions



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Elevated Subsurface Temperatures

The Basics

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Elevated Subsurface Temperatures

The Basics

- Degradation of MSW occurs through metabolic activity of microorganisms
- All the reactions are exothermic, heat is generated naturally by an MSW landfill

Elevated Subsurface Temperatures

The Basics

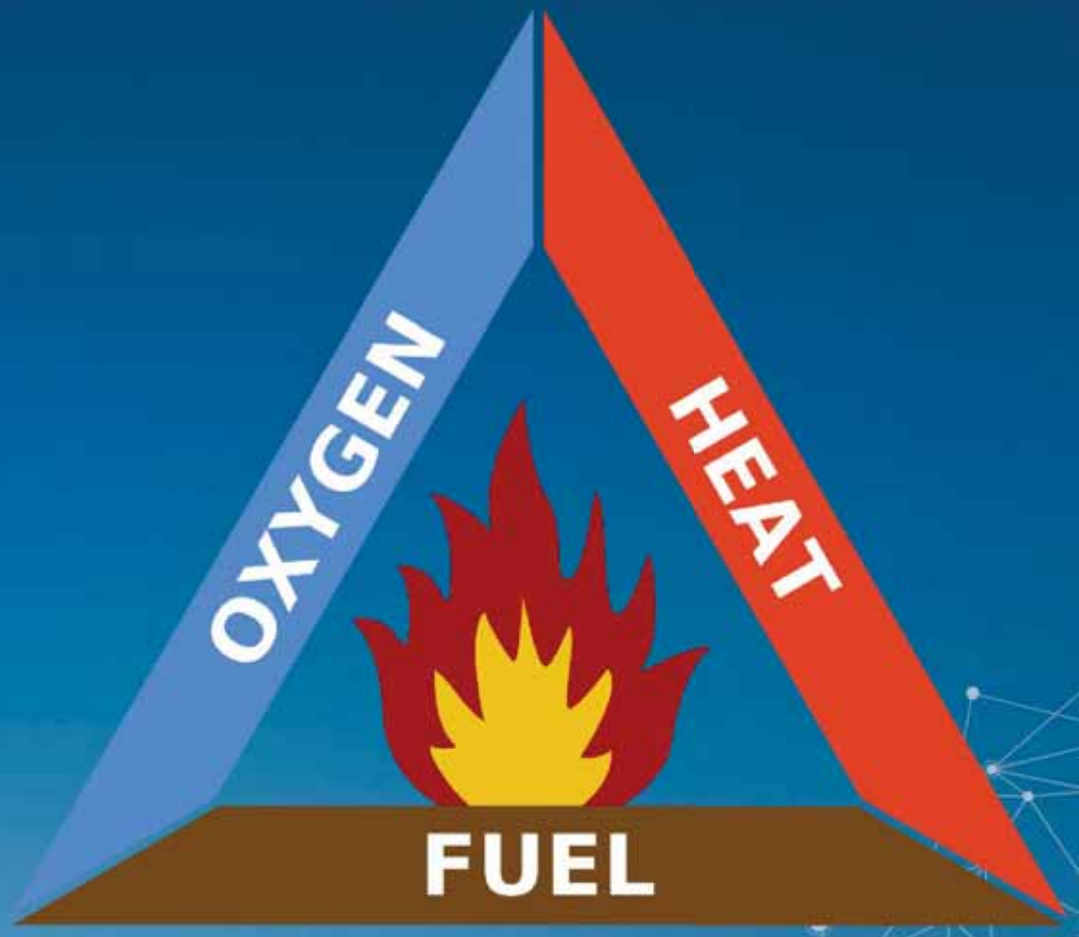
- Defining *Elevated Subsurface Temperature*
  - 100°F to 120°F
    - Expected Temperature Range
  - 120°F to 131°F
    - Somewhat warm but within regulatory constraints
  - 131°F to 145°F
    - Elevated but typically allowable as Alternative
    - Additional monitoring typical
  - > 145°F
    - Concerning
    - Trigger for EST

4 letter word starting with “F” FIRE

Elevated Subsurface Temperatures

The Basics

- Fire Triangle
  - Fuel
    - Organic Waste
    - Landfill Gas
  - Heat (Ignition)
    - Exothermic Reactions
  - Oxygen
    - Air Infiltration



Oxygen is the only leg of the fire triangle we can control

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Historical Approach

Typical Procedures

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Historical Approach

Typical Procedures

120°F - 131°F

- Typically monitoring extraction well once per month
- Additional monitoring may be performed near 131°F
- Carbon Monoxide monitoring may be performed
  - Typically colorimetric tubes
- Investigation of the area may be performed
  - Surface cover integrity
  - Possible sources for air infiltration
  - Vacuum application to gas extraction wells

Historical Approach

Typical Procedures

120°F - 131°F

131°F - 145°F

- Additional monitoring required
- Regulatory variance
- Carbon Monoxide monitoring required
  - Typically colorimetric tubes but may be laboratory analysis also

A higher operating value shall show supporting data that the elevated parameter does not cause fires or significantly inhibit anaerobic bacteria.
40 CFR 60.753(c)

Historical Approach

Typical Procedures

This is typically when steam or smoke is visually observed or the smell of burning is noted, may also be large depressions on the surface

120°F - 131°F

131°F - 145°F

>145°F

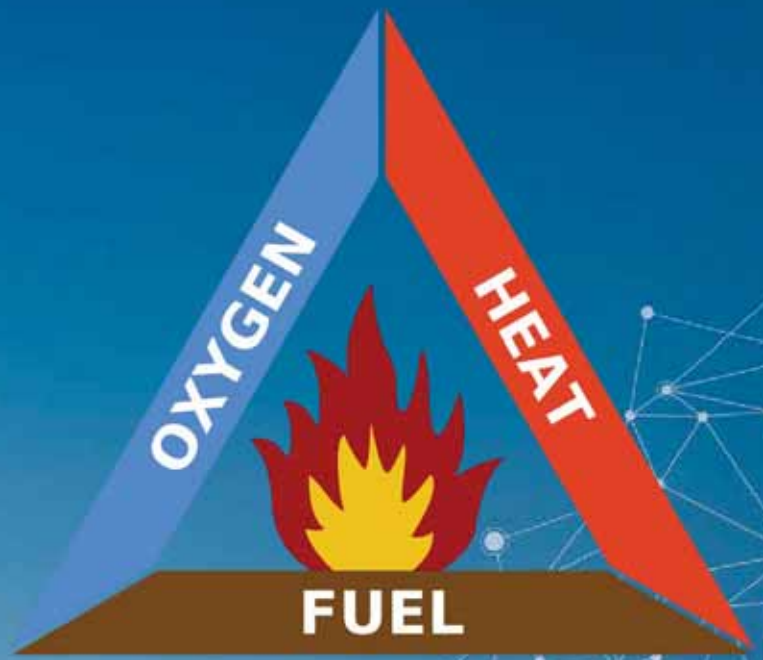
- Emergency response actions typically required
  - Closing gas extraction wells
  - Application of soil
  - Wetting surface
  - Water in the well casing
  - Digging up the area
- Follow up monitoring
  - Gas composition
  - Temperature
  - Carbon Monoxide

Historical Approach

Summary

- Historical approach is reactive
  - Wait for the issue to be identified and then respond
- Typical response reduced air infiltration or reducing heat
  - Close nearby gas wells
  - Soil cover added to area
  - Soil maintained in a moist condition
  - Added water to the well casing

Adding water to the well casing has become more controversial due to possible chemical reactions that can occur between water and previously disposed of reactive waste streams



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Case Study

Testing the Approach

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Case Study

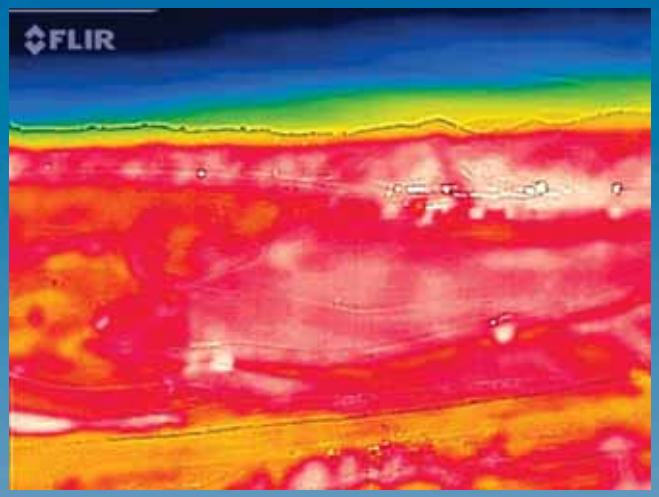
Initial Request

- LF operator contacted Tetra Tech - recently excavated area exhibiting signs of Elevated Subsurface Temperature (EST)
  - Smell of burning
  - Slight smoking
  - Area has experienced similar conditions in the last 2-3 years
- Tetra Tech was asked to:
  - Identify any additional Areas of Concern
  - Confirm the extent of the Areas of Concern
  - Mitigate the Elevated Subsurface Temperature Areas of Concern
  - Perform follow up monitoring to confirm the issues were corrected

Case Study

Thermal Imaging Basics

- Some basics about thermal imaging
  - It is not as expensive as it once was in the past
  - If aerial thermal imaging is used it must be verified with ground-based follow up
  - Uses variances in surface temperatures to provide visual differences
  - Can be skewed by surface fluctuations (grass versus dirt, for example)
  - Experienced users can reduce the likelihood of false positives



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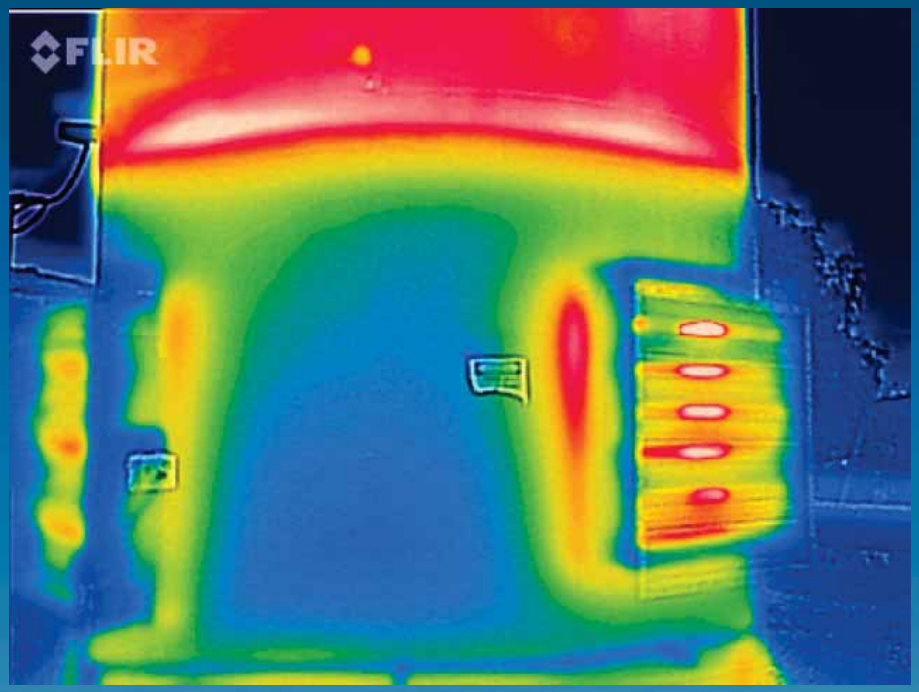
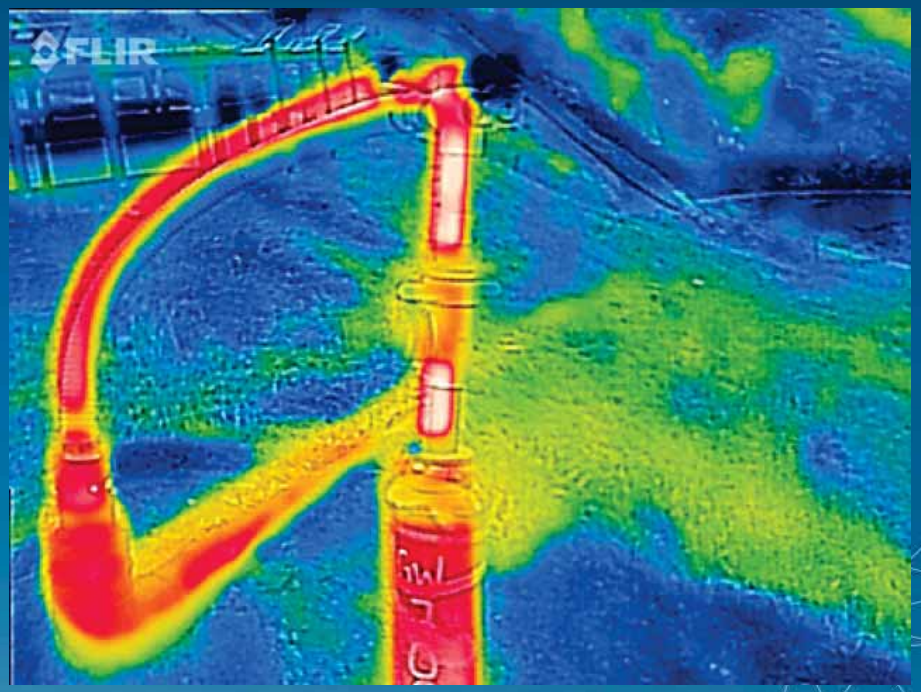
Case Study

Thermal Imaging Basics





Variances between the temperatures in the pictures are used for the colors in the image

Case Study

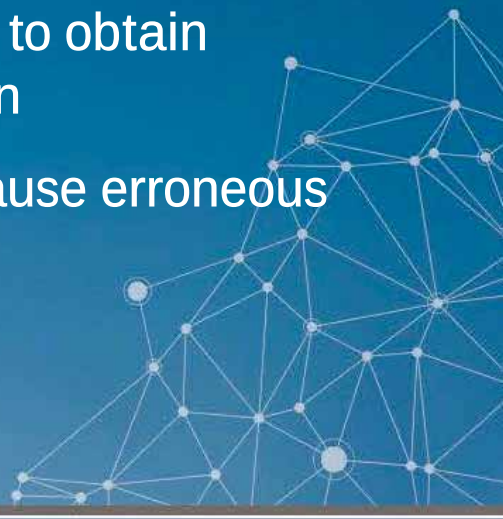
Thermal Imaging Basics

Pros

- Provide additional detail about the possible size of an area of concern
- Identify other possible areas of concern
- Quick to deploy
- Relatively low cost (compared to extensive field work)

Cons

- Not in real time
- Requires FAA Drone license
- Can cause false positives
- Can be misleading to people unfamiliar with the process
- Requires calibration and syncing in by office personnel to obtain useable information
- Field of view can cause erroneous results



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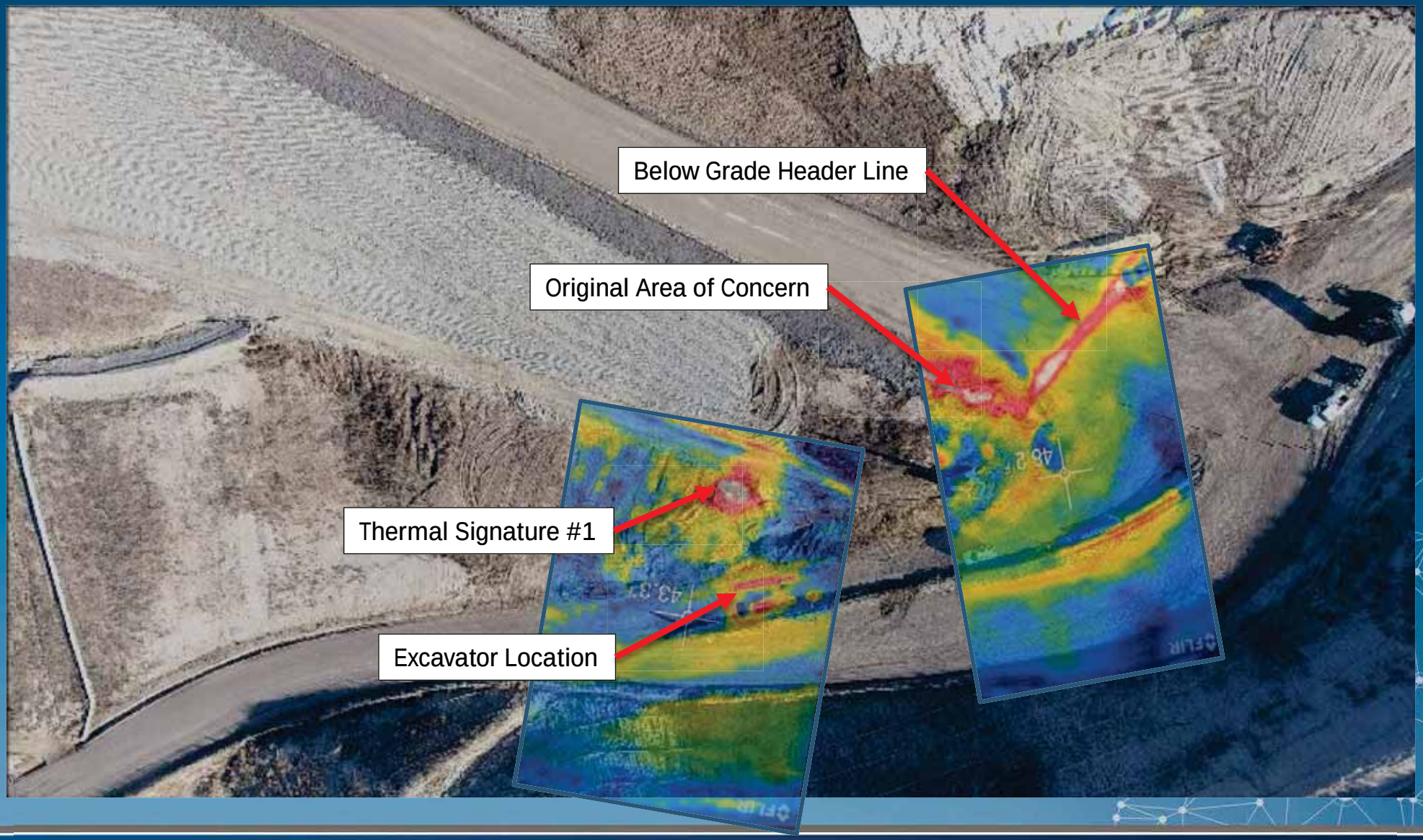
Case Study

Identify Additional Areas

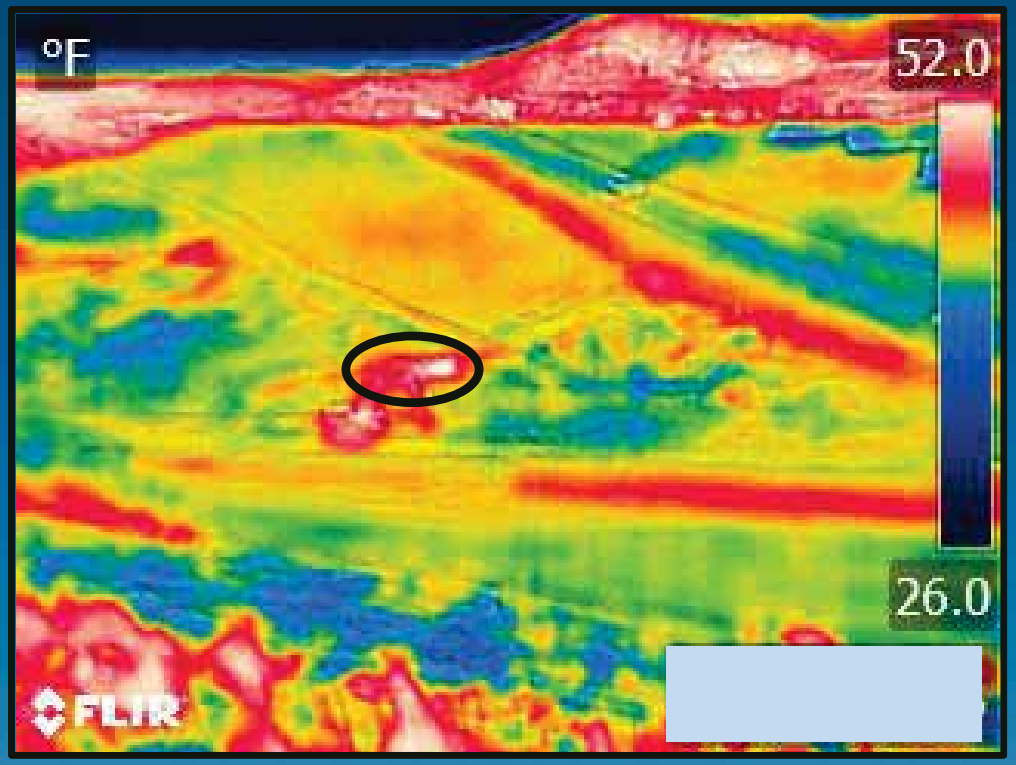
Case Study

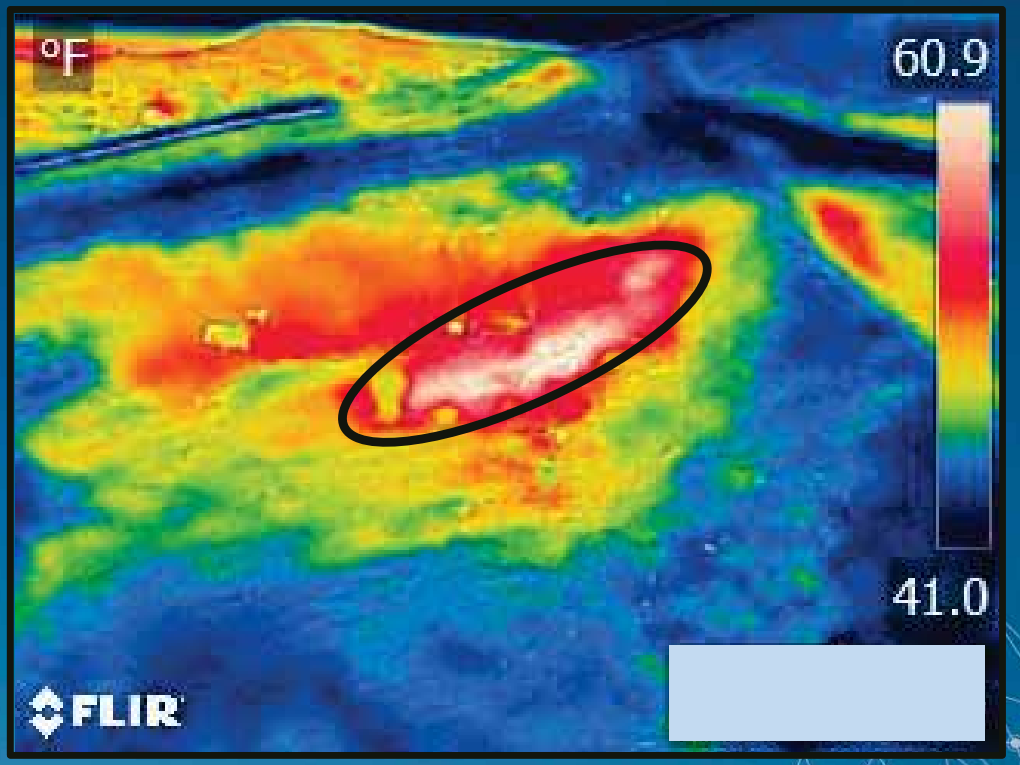
Identify Additional Areas



Case Study

Identify Additional Areas

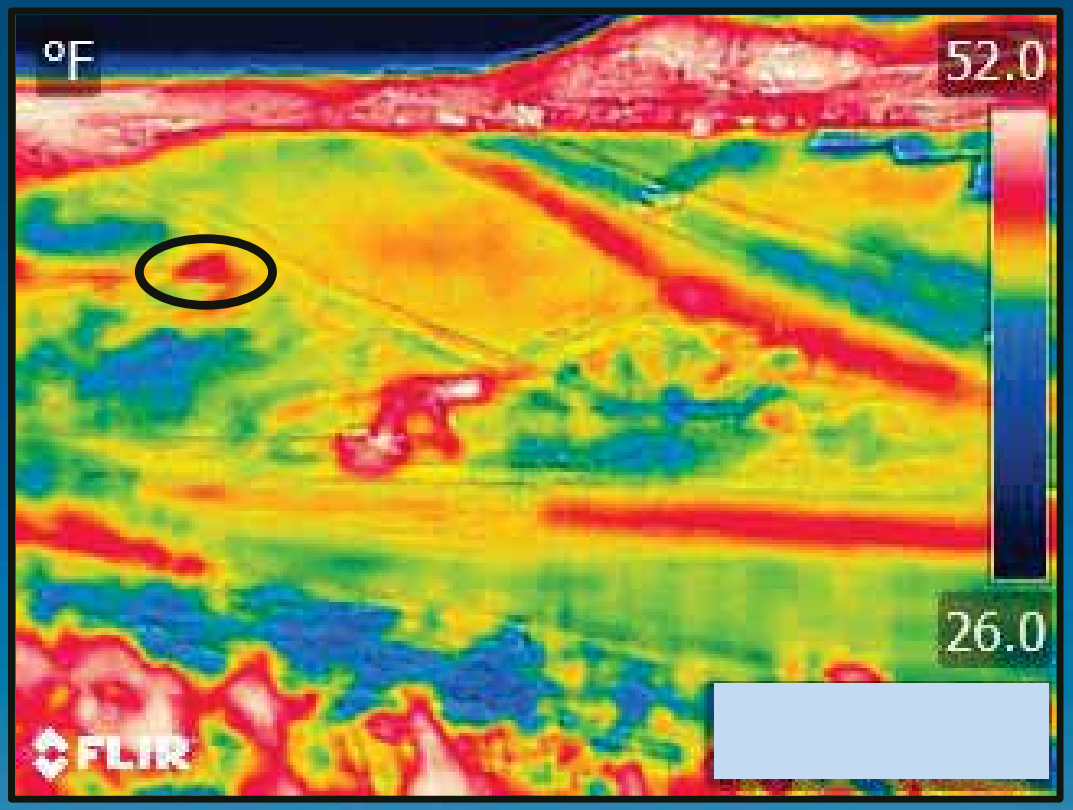




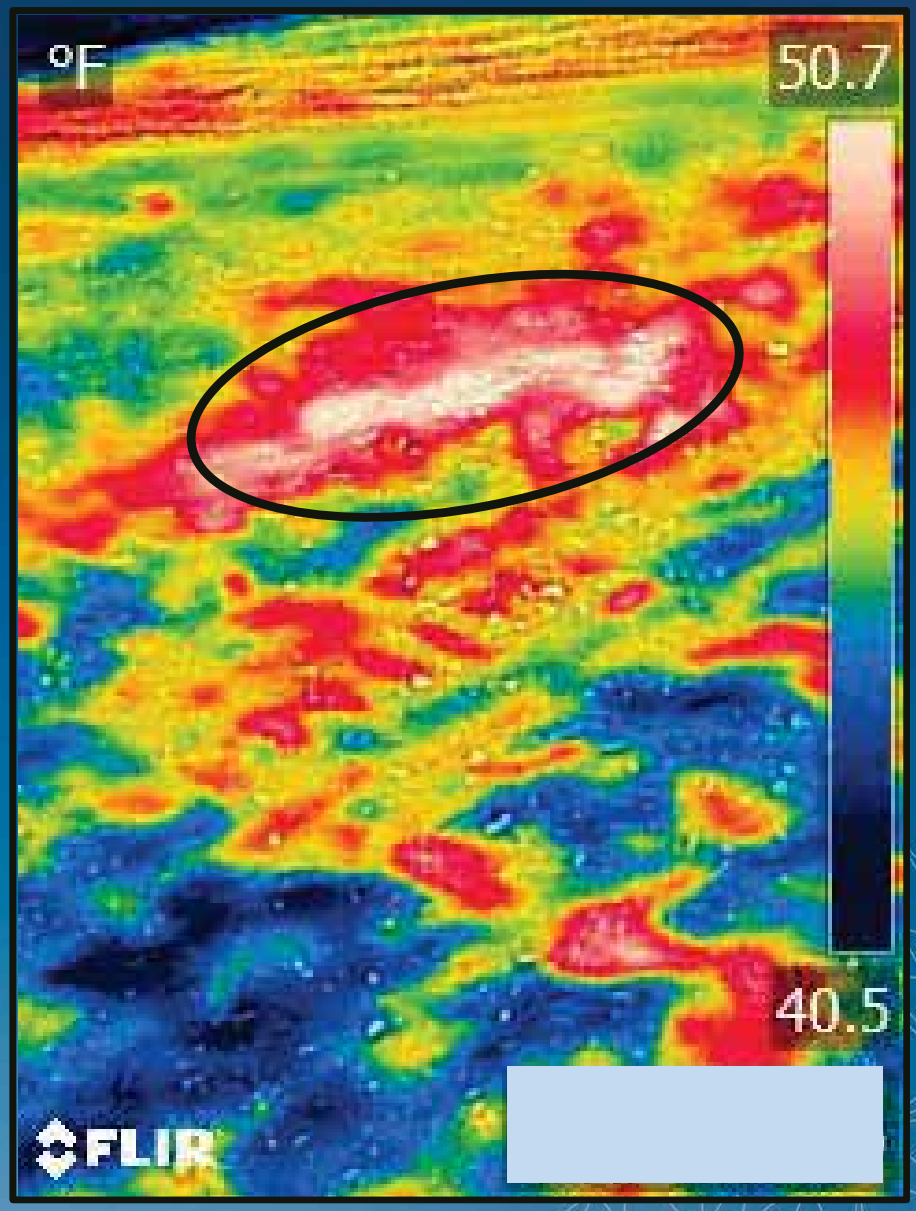
Thermal Signature #1

Case Study

Identify Additional Areas

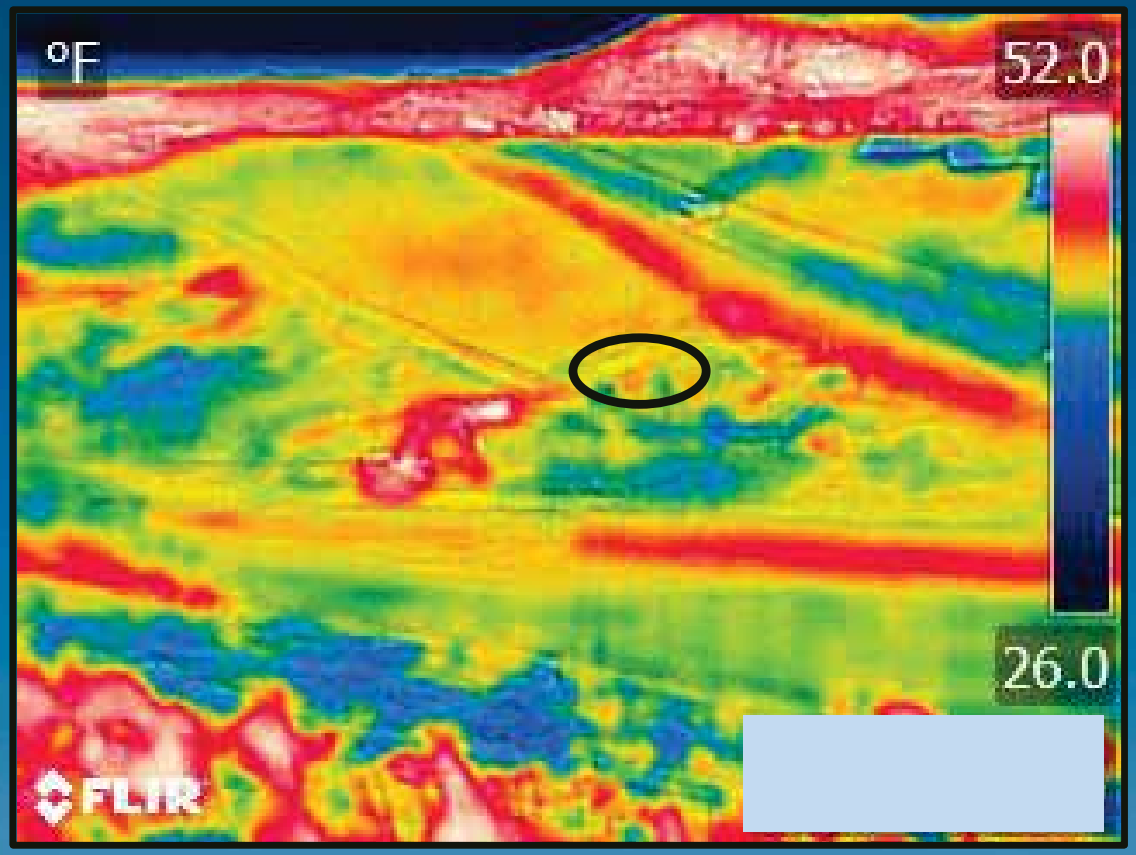


Thermal Signature #2

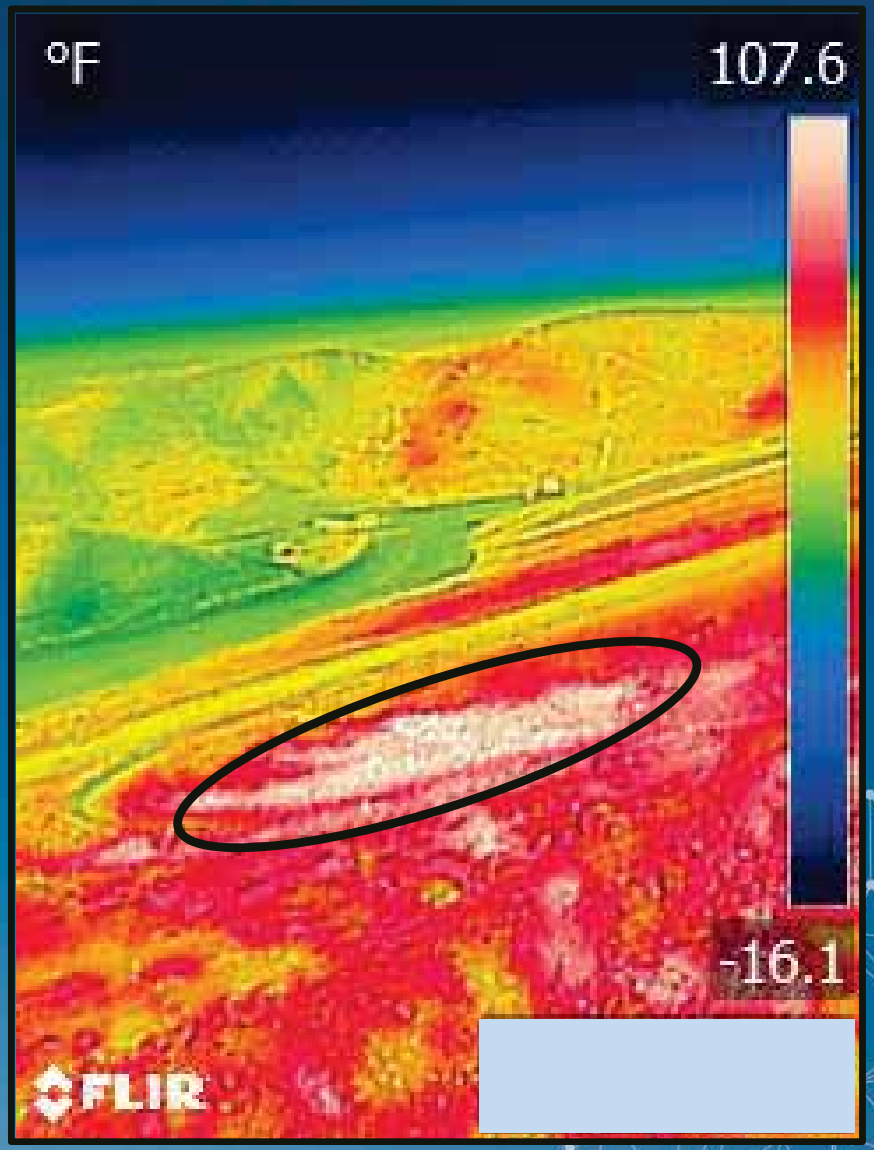


Case Study

Identify Additional Areas



Thermal Signature #3



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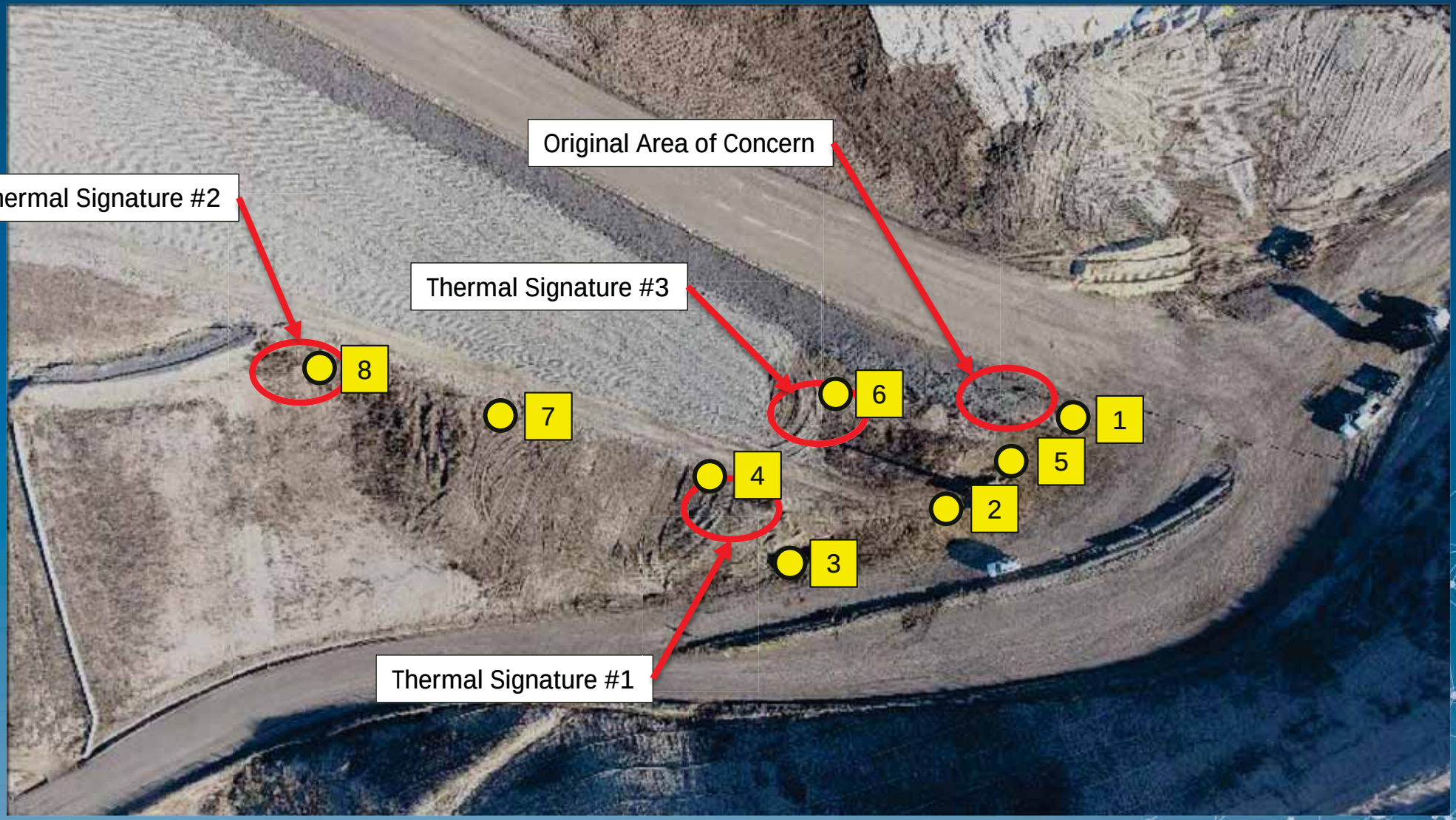
Case Study

Confirm the Extent



Case Study

Confirm the Extent

- Temporary Monitoring Probes had the following performed prior to mitigation activities for confirmation of Elevated Subsurface Temperatures:
  - Methane
  - Carbon Dioxide
  - Oxygen
  - Balance
  - Temperature
  - Carbon Monoxide

Case Study

Confirm the Extent

Monitoring Point	Temperature (°F)	Carbon Monoxide (PPM)	Methane (% by Volume)	Carbon Dioxide (% by Volume)	Oxygen (% by Volume)	Balance (% by Volume)
TMP-1	152	480	57.4	39.5	0.0	2.6
TMP-2	115	50	52.1	34.8	0.0	13.1
TMP-3	115	100	59.7	40.3	0.0	0.0
TMP-4	188	150	61.5	38.5	0.0	0.0
TMP-5	152	300	59.9	39.5	0.0	0.3
TMP-6	115	100	59.0	41.0	0.0	0.0
TMP-7	143	60	59.7	40.2	0.0	0.1
TMP-8	107	50	59.4	39.3	0.0	1.3

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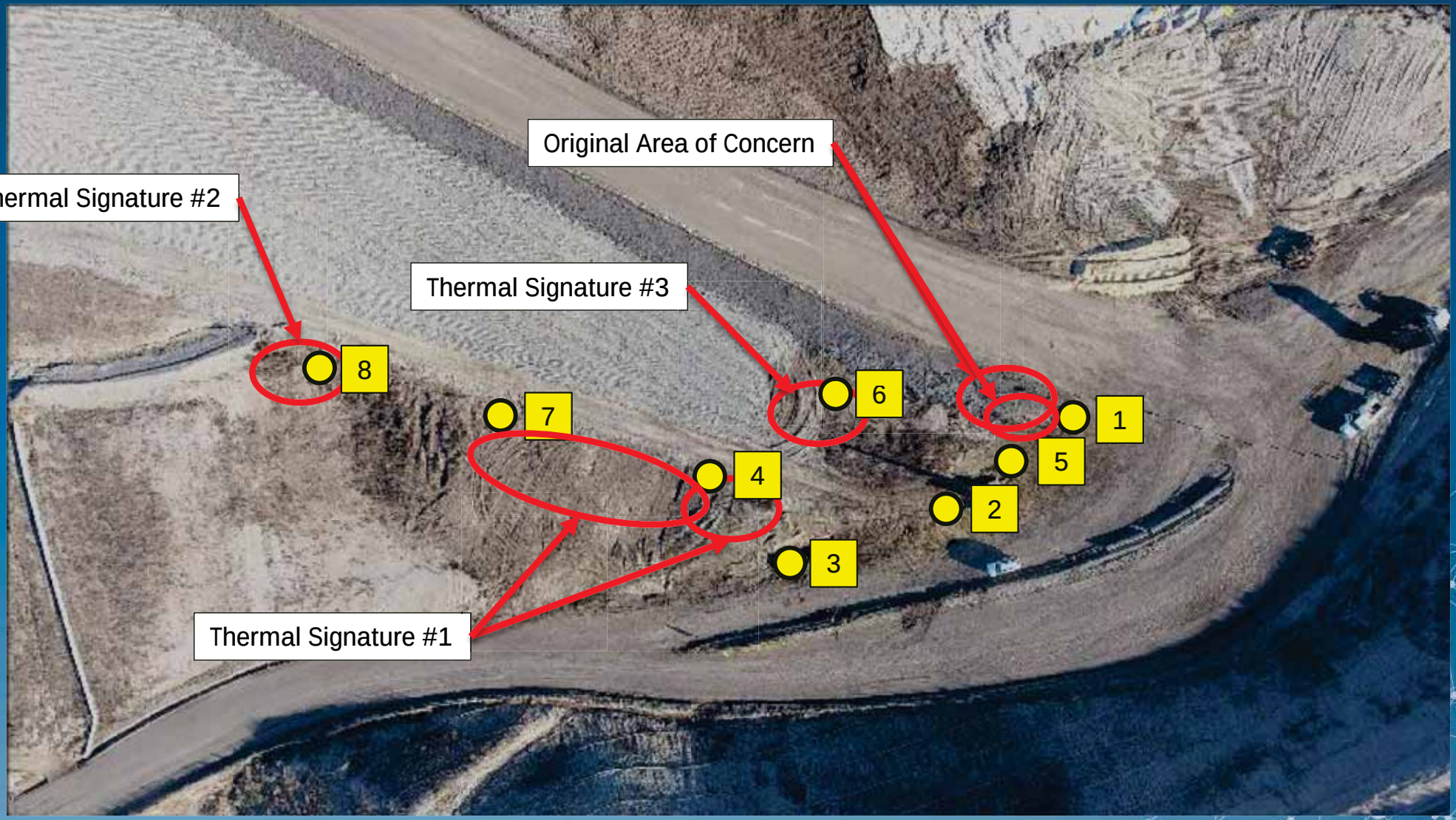
Case Study

Confirm the Extent



Case Study

Mitigating the Issue

- After confirming the two (2) Areas of Concern, mitigation strategies were analyzed
- A multi-faceted approach was selected:
  - Injection of liquid carbon dioxide
  - Application of additional soil to surface
  - Wetting of the surface
  - Compaction of the soil surface

Case Study

Mitigating the Issue

Case Study

Mitigating the Issue

- Liquid CO_2 Fun Facts
  - Delivery typically occurs between –60°F to 0°F and a pressure of 100 to 600 PSI
  - Serious health hazard for inhalation, cryogenic injury and severe frostbite
  - Approximately 8.5 ft^3 of gas is created for each pound of liquid CO_2
  - Sudden change in temperature or pressure will cause dry ice snow to form
  - Rapid discharge of liquid CO2 through a line will cause a build-up of static electricity

Liquid CO2 Injection is dangerous!!!

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Case Study

Mitigating the Issue

Soil Placement and Compaction

Case Study

Mitigating the Issue

Liquid CO2 Injection Well Construction

Case Study

Mitigating the Issue

Liquid CO2 Injection Well Installation

Case Study

Mitigating the Issue

Liquid CO2 Injection

Case Study

Mitigating the Issue

Liquid CO2 Injection

Case Study

Mitigating the Issue

Liquid CO2 Injection

Case Study

Mitigating the Issue

Liquid CO2 Injection

Case Study

Confirm Effectiveness

- Additional monitoring after the injection of liquid CO_2 was performed to confirm the effectiveness of the mitigation measures
- Monitoring included:
  - Methane
  - Carbon Dioxide
  - Oxygen
  - Balance
  - Temperature
  - Carbon Monoxide

- Monitoring was performed regularly for a period of one month

Case Study

Confirm Effectiveness

- Gas monitoring indicated Carbon Dioxide concentrations greater than 94% by volume in some nearby Temporary Monitoring Points
- Carbon Monoxide concentrations were found to decrease over 60% within 24 hours of the injection
- Temperatures reduced an average of 12% over a 20 day period
- Continued monitoring has not indicated any evidence of the elevated subsurface temperature event

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Closing

Summary

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Closing

Summary

- Thermal imaging has the potential to identify areas of elevated subsurface temperatures
  - Limited to shallow areas
  - Requires experience to interpret results
- Liquid CO_2 Injection was successful in mitigating the subsurface elevated temperature areas at this particular landfill
  - Can be dangerous
  - Needs to be designed and operated properly
  - Has multiple benefits for this application
- More testing is required to fully evaluate the processes effectiveness but preliminary results were exceptional

Lee Daigle – lee.daigle@cornerstoneeg.com
Chris Peters – chris.peters@cornerstoneeg.com

Thank you

Questions

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