



Smoldering Combustion (STAR and STARx): Adaptive Remedy Implementation in Complex Environments

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Company Profile

Savron is a multi-national provider of sustainable applied smoldering solutions (STAR/STARx)



Agenda

- Smoldering Combustion Introduction
- STAR/STARx Application Methods
- Adaptive Implementation Strategies
 - STAR – Heterogenous Soil Treatment
 - STAR – Complex Geologic Features
 - STAR – Supplemental Fuel (EVO)
 - STARx – Feedstock Variability
 - STARx – Surrogate Fuels (GAC & others)
- Summary



Introduction



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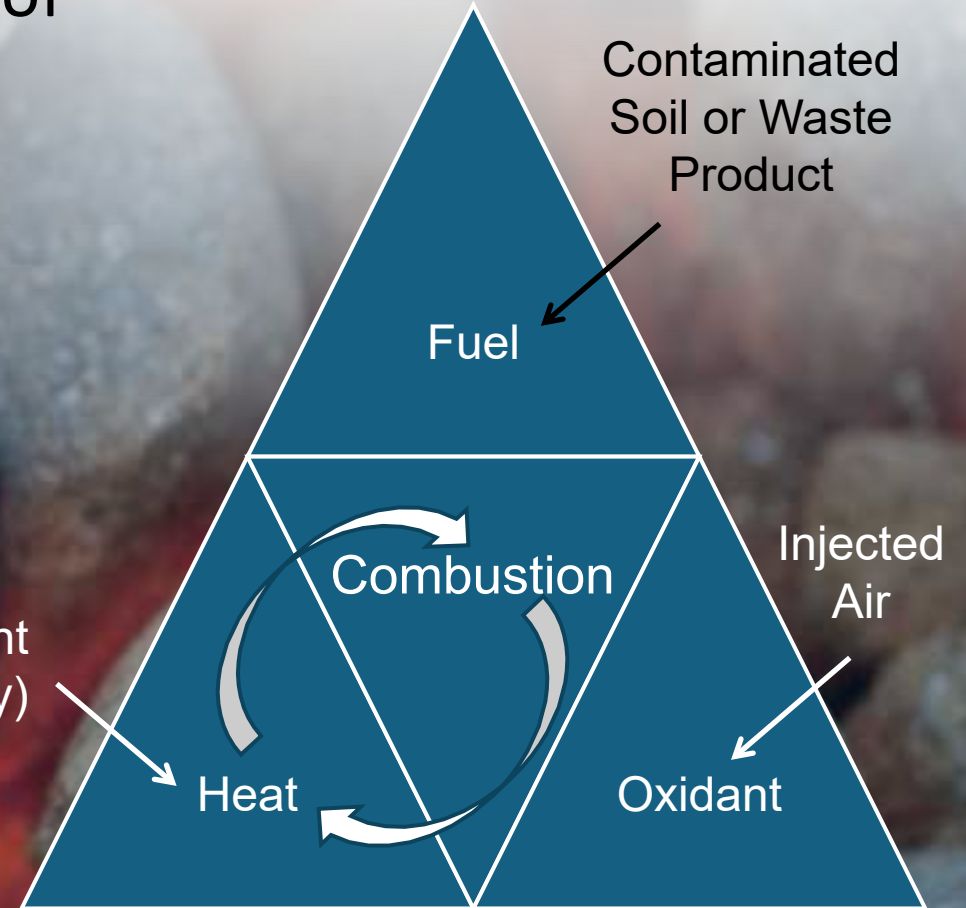
Smoldering Combustion

STAR and STARx are based on the process of smoldering combustion:

Exothermic reaction converting carbon compounds to $\text{CO}_2 + \text{H}_2\text{O}$

Heavy hydrocarbons, PFAS & other recalcitrant compounds

Heater Element
(for ignition only)



STAR / STARx is a flameless combustion process: smoldering is only possible within a porous matrix (i.e., soil)

Application Methods



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Application Methods

STAR

In situ (vadose zone & below water table)

Applied via ignition points & portable heaters



STAR_x

Ex situ (above ground)

Hottpad™ or STARxpress™ systems



STAR Applicability

- Silty sands and coarser
- Coal tar, creosote, hydrocarbons
- TPH > 3,000 mg/kg
- Example projects:
 - Coal tar MGP – NJ, IL, MI, Belgium
 - Navy Special Fuel Oil (NSFO) - VA
 - Petroleum Hydrocarbons – Canada, Taiwan
 - Gasoline / Diesel (with fuel surrogate) - MI
 - Creosote - WA



STARx Applicability

- Silty sands and coarser
- Co-treatment of impacted soils and liquid organic wastes = significant cost savings
- TPH > 3,000 mg/kg
- Example Projects:
 - Hydrocarbon-impacted soil, Canada, Africa Taiwan & SE Asia
 - Oily sludge, USA & China
 - Chloronitrobenzene soil, Brazil
 - Tank bottom residuals, Australia
 - Oily sludge, Middle East & Caribbean
 - PFAS – Canada, USA



Smoldering Combustion Treatment



Adaptive Implementation Strategies



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STAR - Heterogenous Soil Treatment

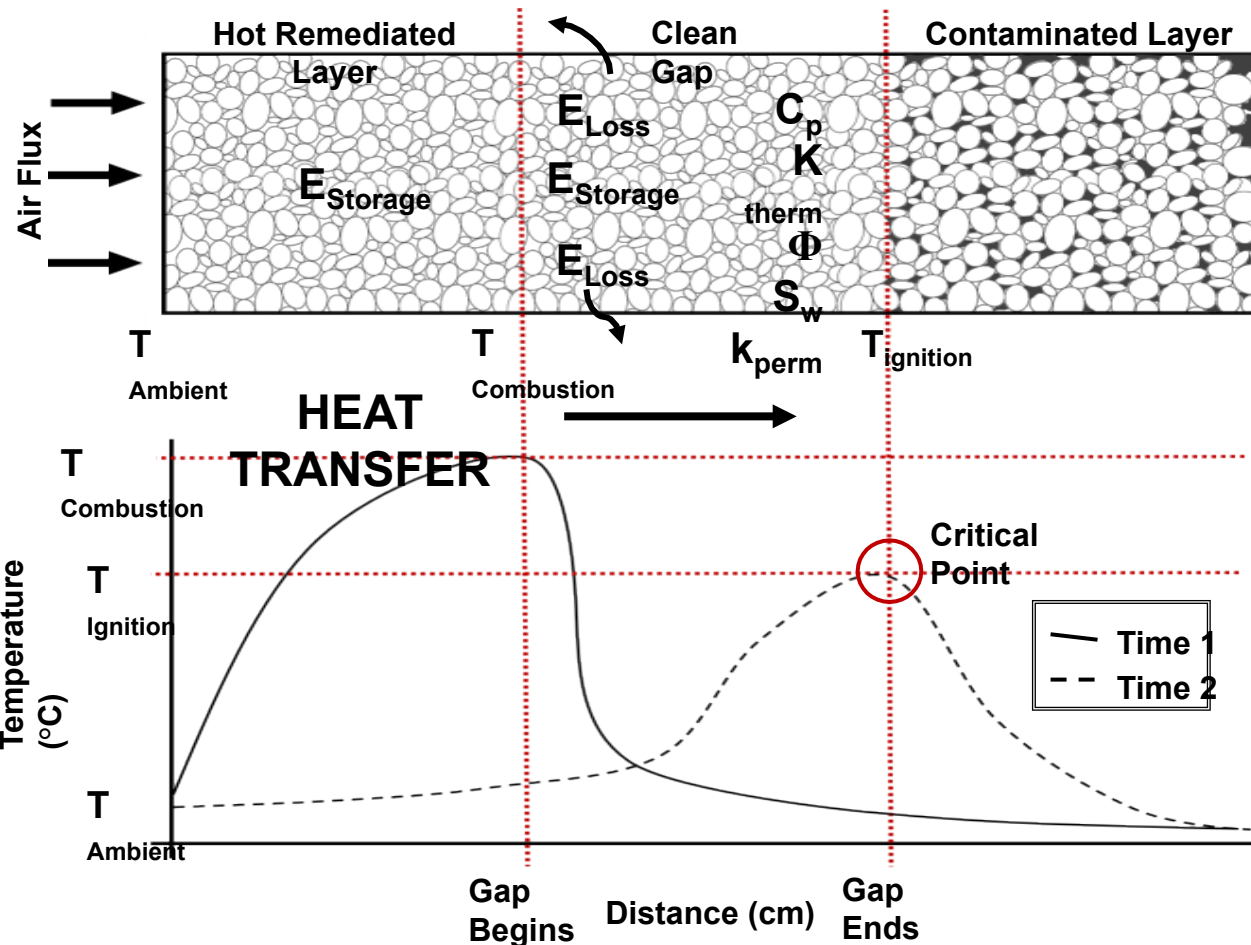
- Smoldering combustion typically requires continuous treatment zone
- Natural world is never straight forward!
- Heterogenous soils often include uncontaminated zones or less permeable clay layers



STAR – Gap Jumping Clean Soils

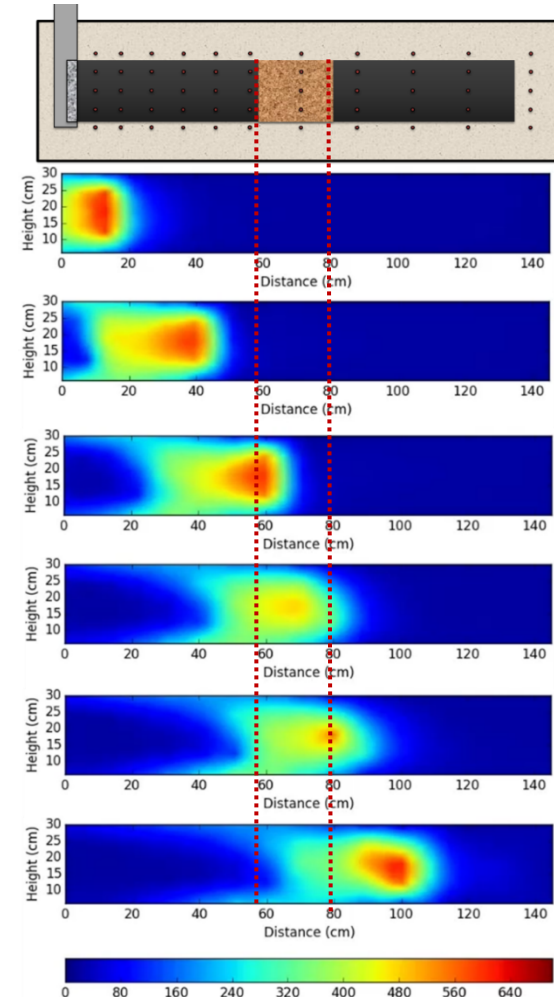
Mitigation Strategy

Heat transfer across gaps can “re-ignite” contaminants



Case Study – USEPA / EPRI

~1-2 foot gaps can be crossed



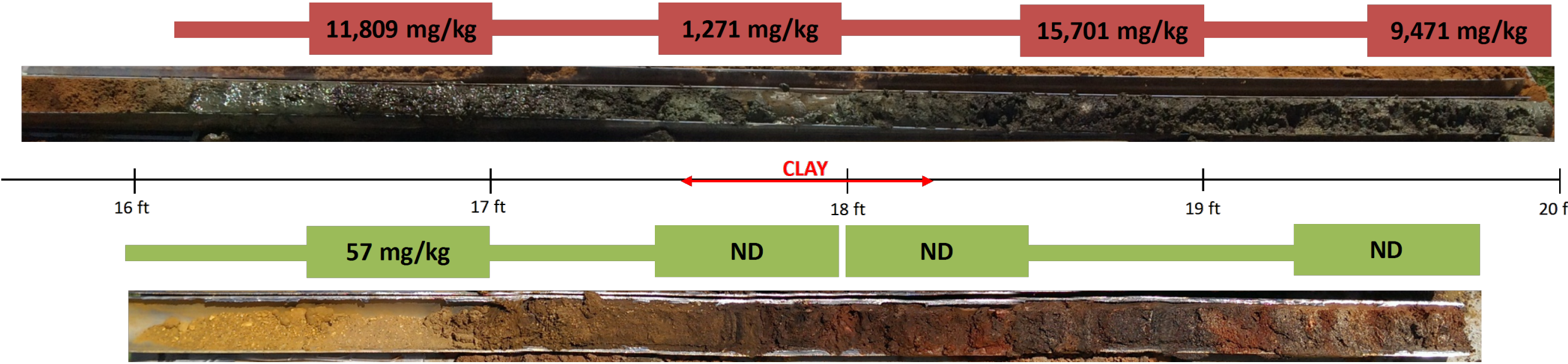
STAR – Less Permeable Clay Layers

Mitigation Strategy

STAR not suitable for clay
(Silts and coarser materials viable)
However, can tolerate some clay layers /
lens

Case Study – NSFO, VA

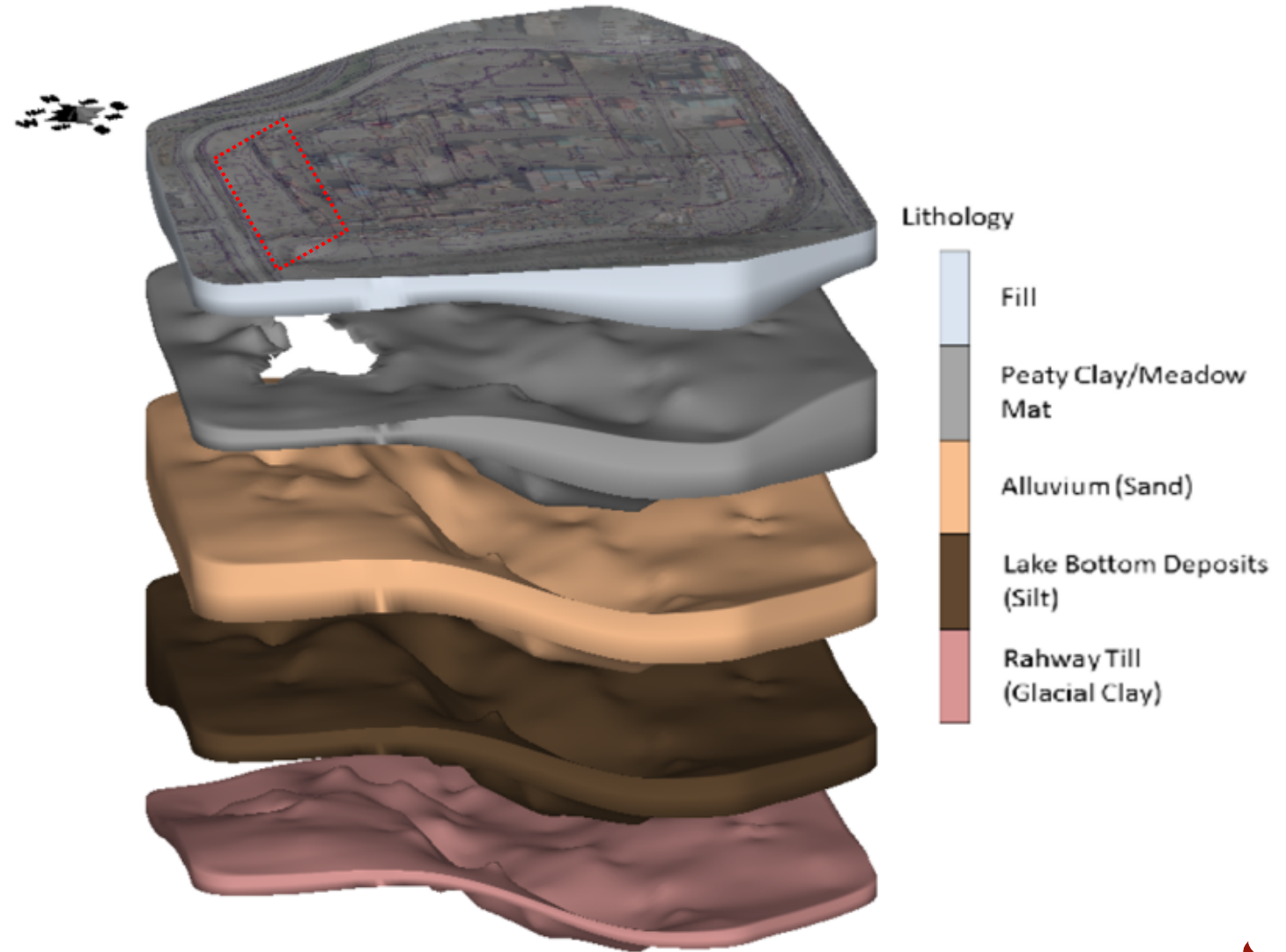
NSFO contamination ~ 16–21 ft. bgs.
Clay layer ~ 18–19 ft. bgs.
IP screened below clay 20–21 ft. bgs.



STAR – Complex Geologic Features

Project Details

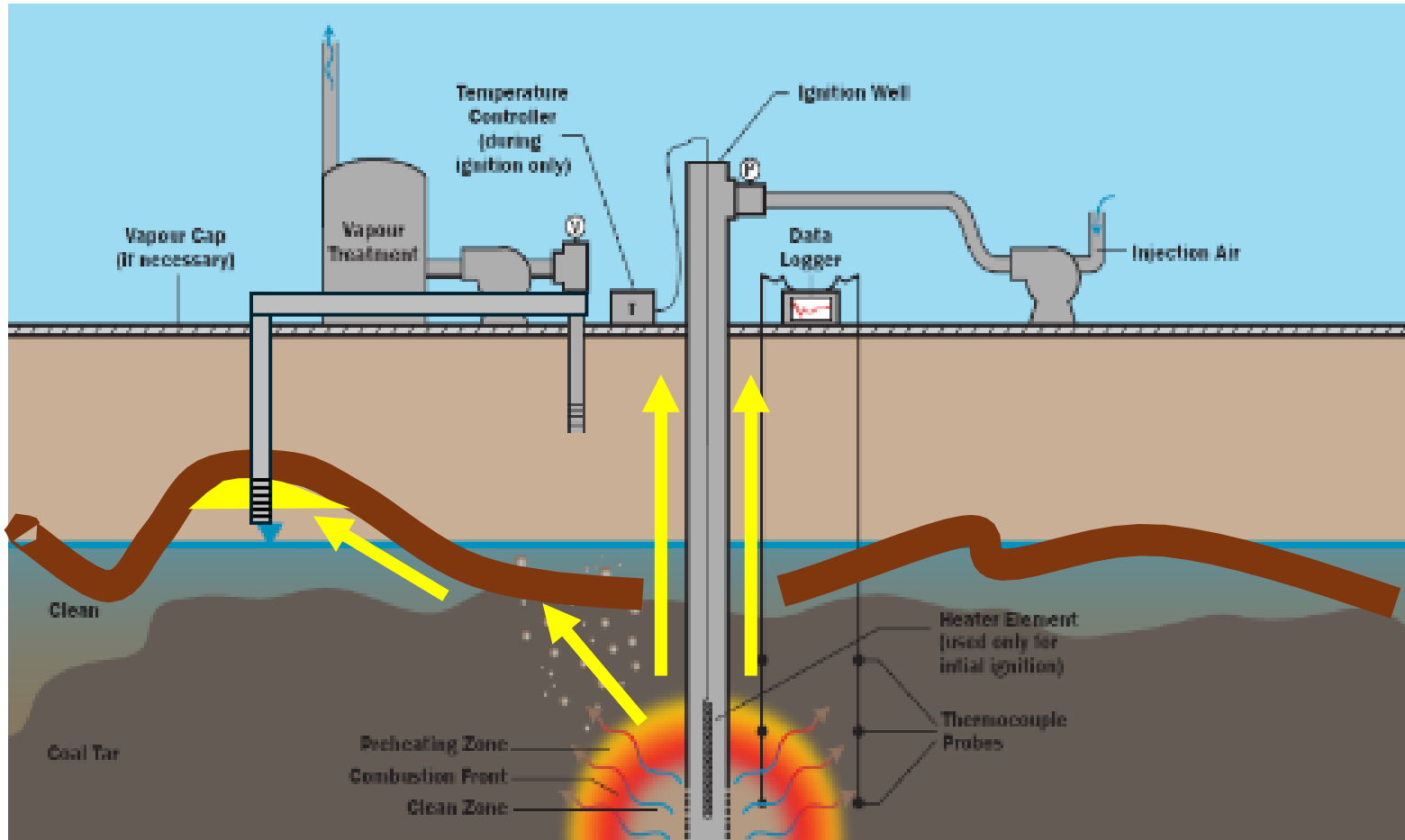
- 44-acre coal tar impact Site
- Fill and Alluvium targeted by STAR
- Separated by undulating, inconsistent Peaty Clay/Meadow Mat
- “Reverse flooding” - Injection air & combustion gases found to migrate laterally due to buoyancy and underlying topographical features



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STAR - High Volatility (DRO, GRO)

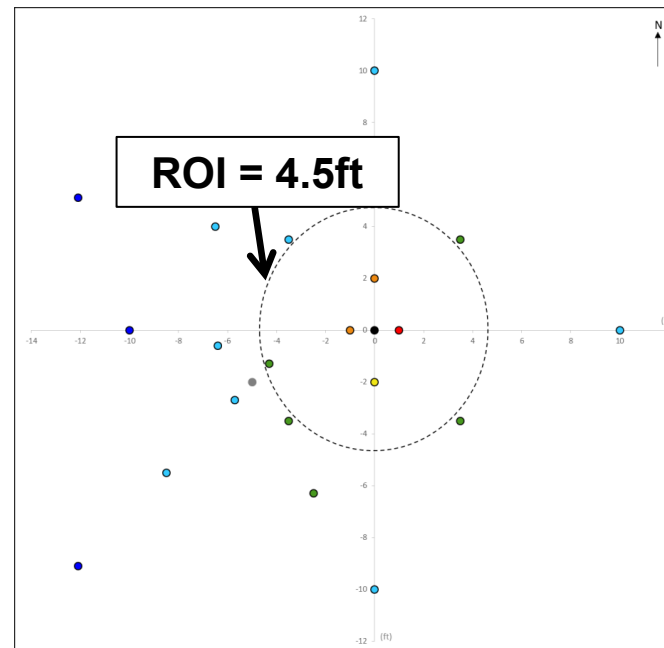
Mitigation Strategy

- Target low-volatility compounds
 - Coal tar, creosote, heavy hydrocarbons
- Use of surrogate fuels (Emulsified Vegetable Oil [EVO])
 - Enhance thermal desorption via EVO smoldering
 - Powered activated carbon (PAC) also can be added

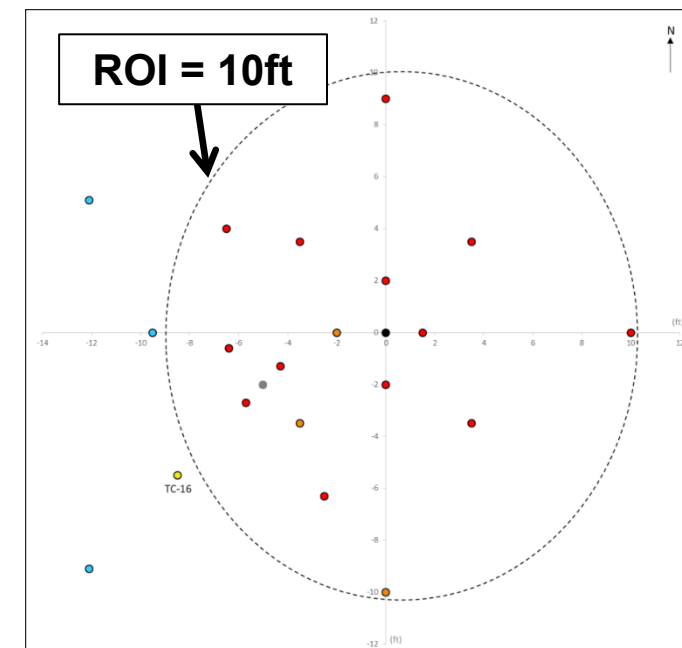
Case Study – Former Refinery, MI

GRO/DRO impacted fine sands

Compare “Standard” v. “EVO-enhanced” STAR



“Standard” STAR



“EVO-enhanced” STAR



STARx - Feedstock Variability

- **Feedstock Characteristics**
 - Sludge vs. pumpable oil
 - Viscosity and volatility
- **Sludge access difficult due to overlying pumpable oil**
- **Caused product mobilization during treatment**
 - Downwards into modules
 - Upwards into cap material
- **Increases risk of unintended flaming combustion**

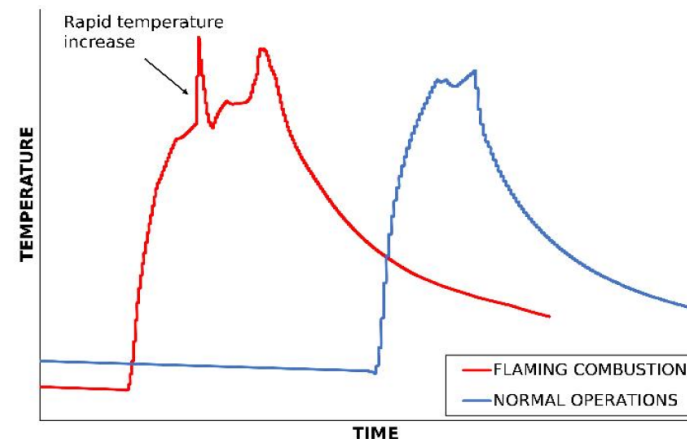


FIGURE 1: Example c-channel temperature data for comparison of plenum flaming combustion vs. normal operating conditions

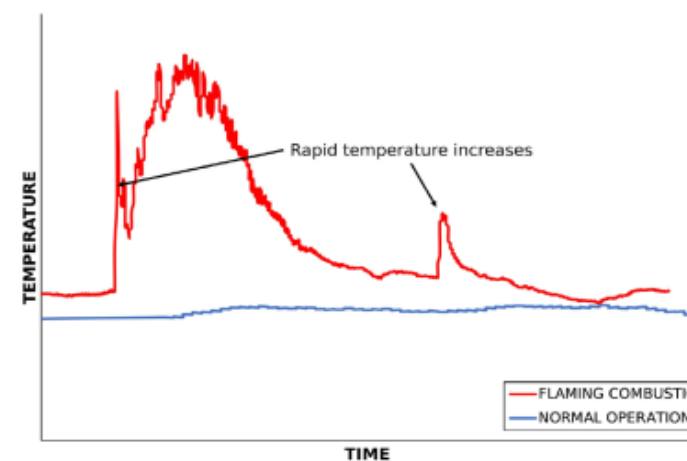


FIGURE 1: Example of hood space temperature data for comparison of hood space flaming combustion vs. normal operating conditions

STARX - Feedstock Variability

- **Procedural:**

- Extended bake out procedure
- Updated injection air protocol
- Improved material handling operator training
- Feedstock Enrichment Plan

- **Engineering Design:**

- Supplemental air duct covers
- Side wall flow diverters
- Improved rate of change alarm functionality



STARx – Surrogate Fuels (GAC & others)

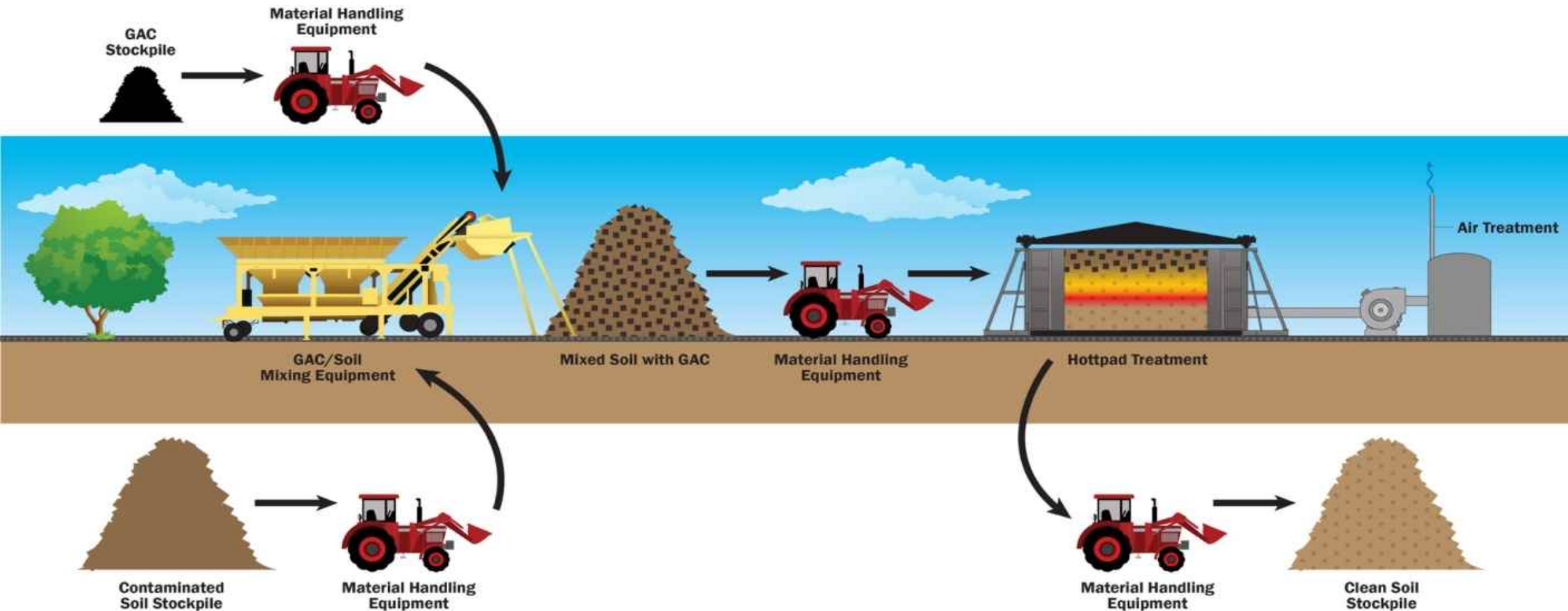
Required for hydrocarbon site soils with less than ~3000 mg/kg or contaminants with low calorific value (chloronitrobenzene, PFAS, etc.)

- Potentially required for large heterogenous site soil stockpiles
- Mass loading tuned to required treatment temperatures (PFAS >900 °C)
- Waste biomass (South America)
 - Eucalyptus Bark
 - Coconut Husk
- Granular (GAC) and Powdered Activated Carbon (PAC)
 - Co-treatment of waste filter media
- Anthracite



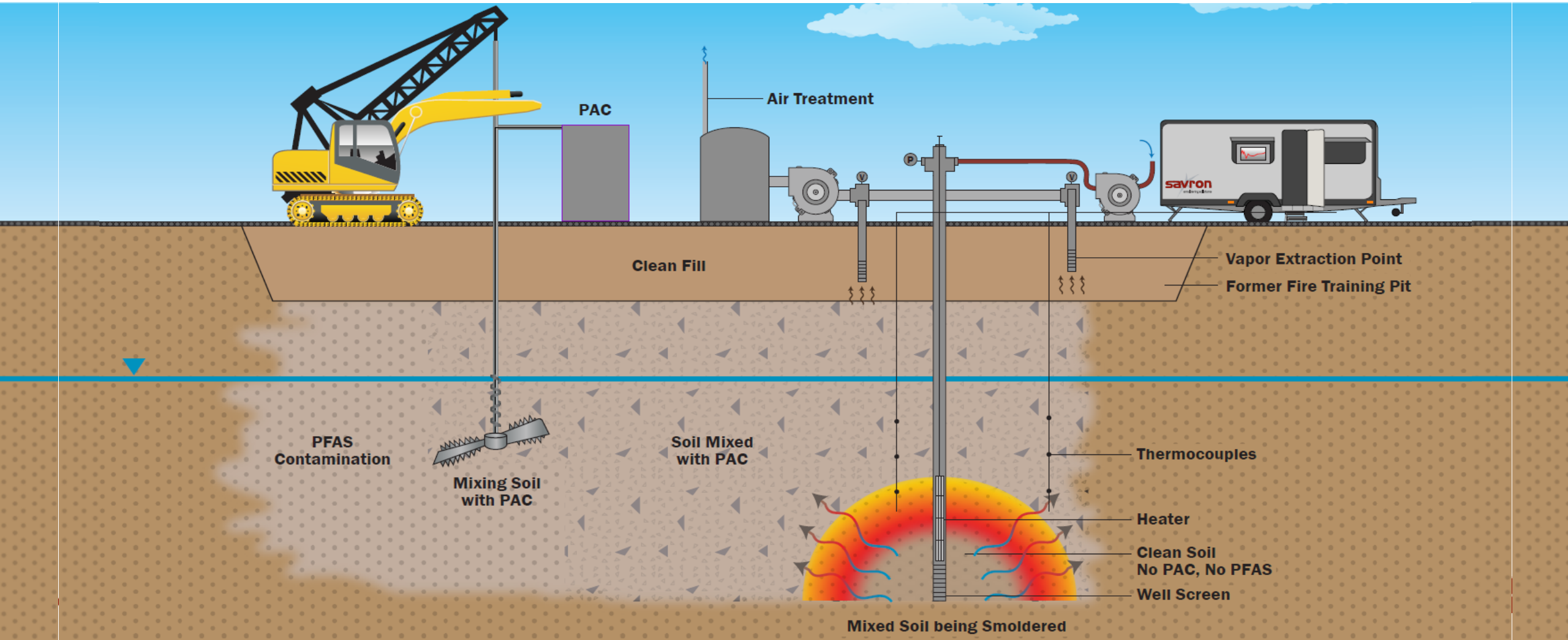
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Summary

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- Effective and Robust
 - Rapid on-site treatment, complete destruction of contaminants
- Safe and Sustainable
 - Self-sustaining process = less energy use
- STAR deployable in complex heterogeneous site soils
- STARx equipment and control protocols adaptable to meet feedstock requirements
- Surrogate fuels are used to destroy high volatility, or low energy content contaminants and site soils with varying contaminant distributions
- Surrogate fuels offer co-treatment opportunities for Clients with multiple waste streams



Questions?
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