CSM GRADS Conference
Poster 2017

Understanding CH4 Leakage from Pipelines as Affected by Soil Heterogeneity and Moisture

Melissa K. Mitton[1] , Kathleen M. Smits[1]

[1]*Colorado School of Mines, Golden, CO*

Advanced Research Projects Agency-Energy

ABSTRACT

Sub-surface transport of leaked natural gas from pipelines occurs through complex transport pathways due to soil heterogeneities and changes in soil moisture and is affected by variable atmospheric conditions such as winds, frontal passages and rain. For example, gas migration in a texturally heterogeneous soil system (e.g., in the presence of a low-permeability clay lens embedded in a sandy formation) will be markedly different from that of a homogenous soil system due to the different texture- (or porosity-) induced tortuosity effects. Although industry has made some progress on detection technologies themselves (i.e., sensors that can be used to measure gas concentration in the atmosphere), they have made limited progress on leak detection and quantification from pipelines due to the complexity of leakage scenarios in the field. This is, in part, due to the limited availability of experimental studies investigating subsurface methane migration under different subsurface and atmospheric conditions.

To better understand fugitive emissions from natural gas infrastructure, specifically from underground pipelines, we are developing a field testing facility to better quantify and locate leaks from pipelines. The test site includes four test beds designed to study different aspects affecting subsurface methane diffusion including; soil type, temperature, soil moisture, leak size, leak depth and direction. The site is equipped with subsurface and surface sensors to continuously monitor changes in these variables. Through reviewing previous studies on this topic, a decrease in spreading width and volumetric flux rate is expected as soil moisture increases. We also expect higher concentrations found beneath the pipeline and larger effects on concentration above the pipe from emission points directed along the horizontal plane than from those directed vertically.

Accompanying work will include numerical modeling of the field experiments to relate subsurface concentrations, to above ground concentrations, measured by most detection technologies and industry. These findings will better inform leak detectors of the leak severity before excavation, aiding with safety precautions and work order categorization for improved efficiency.

1. GOALS AND SCOPE

Modeling:

- ✓Develop and implement a numerical model for multiphase transport of methane gas in the subsurface
- ✓Study the effect of soil moisture and soil heterogeneity by comparing numerical results with experimental data

Experiments:

- ✓Develop and use a unique field scale three dimensional test bed equipped with a network of recent sensor technologies for continuous monitoring of moisture/temperature behavior
- ✓ Evaluate the affect of leak size, leak direction, leak depth, soil moisture content, and soil homogeneity vs heterogeneity on subsurface methane gas transport.
- ✓Generate subsurface methane plume concentration data to verify model

2. SENSOR SYSTEM

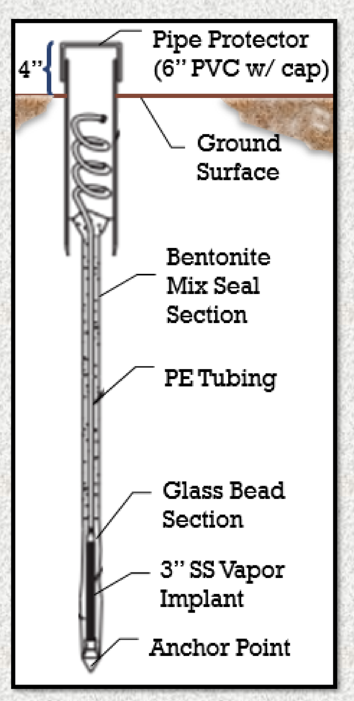
- ✧Soil Moisture (8 sensors per test bed at 4 depths)
- ✧Temperature (included in soil moisture sensors)
- ✧ Water Pressure (2 per bed)
- ✧Methane Concentration (selection in process)

Soil Parameter Sensors

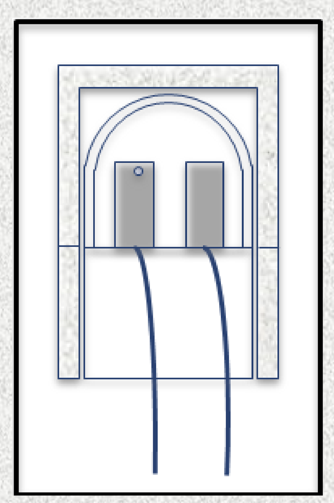
Soil Moisture (Decagon 5TM)

Pressure (Decagon MPS-6)

Methane Sensors

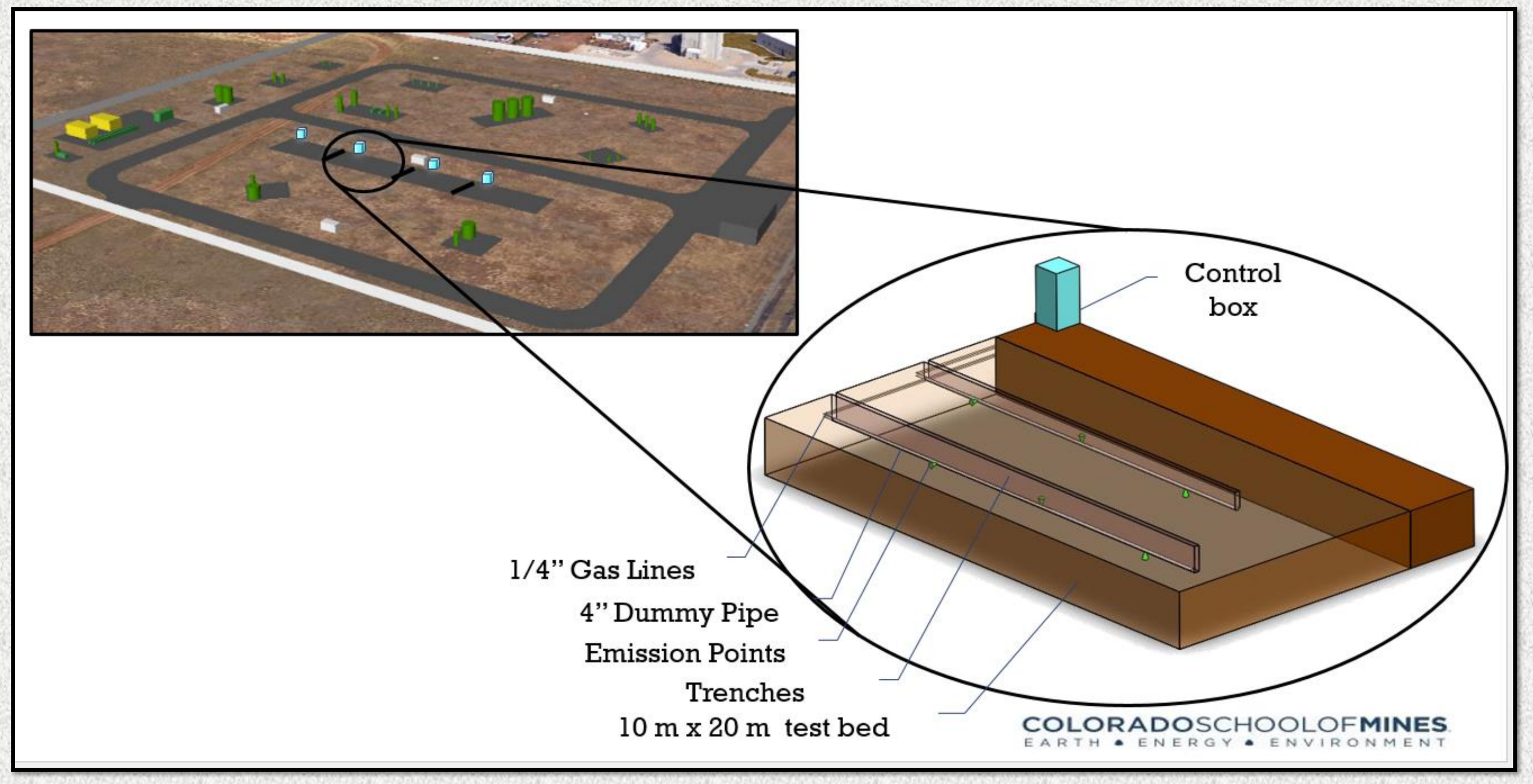


Manual Vapor Implant Soil Gas Sampler



Autonomous Thermal Conductivity Sensor Schematic

4. SITE DESIGN

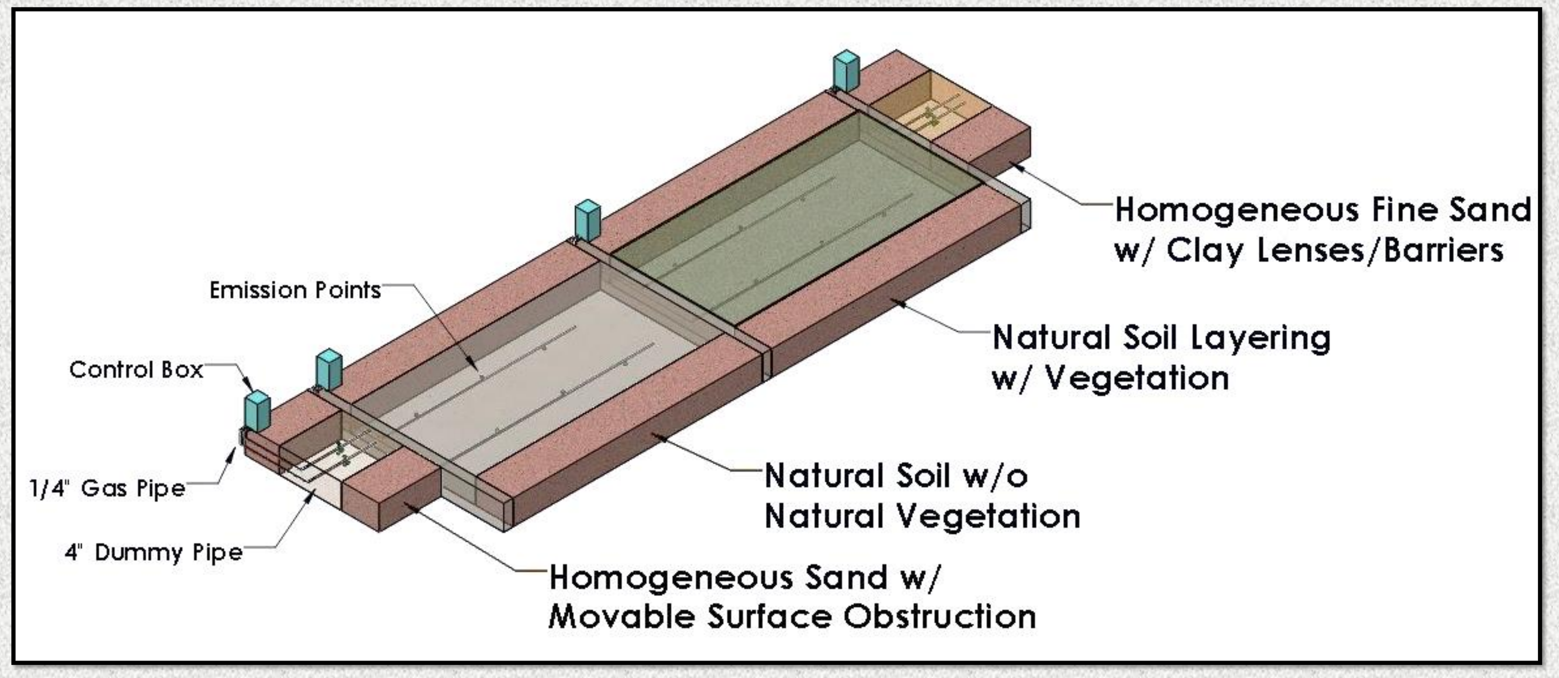


Each test bed will include:

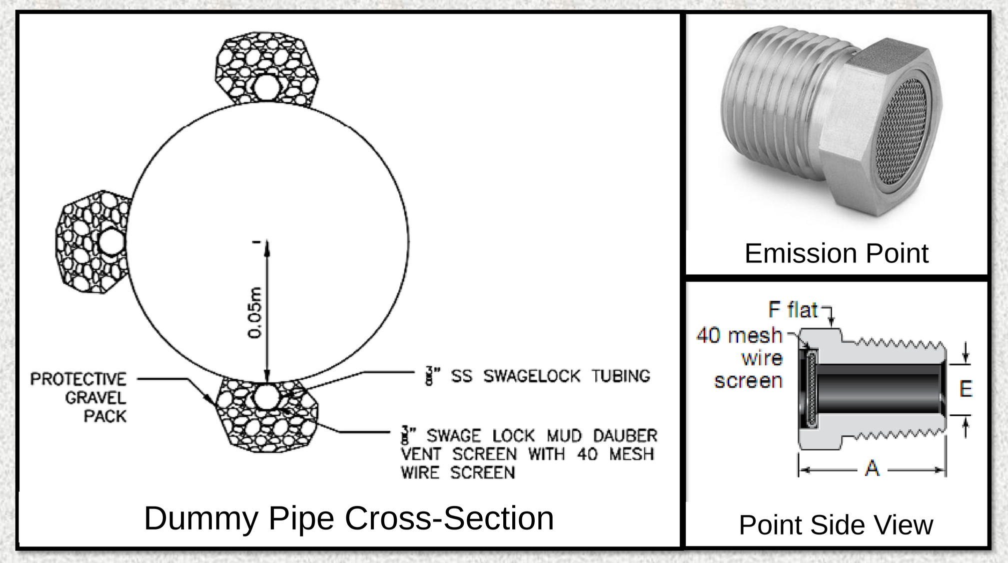
- ✧1 Control Box
- ✧2 "Dummy Pipes"
- ✧6 Emission Points
- ✧2 Different Depths (2 ft And 3 ft)*
- ✧3 Directions of Leaks

*Depths are based on minimum burial requirements for gathering, transmission, and distribution lines.

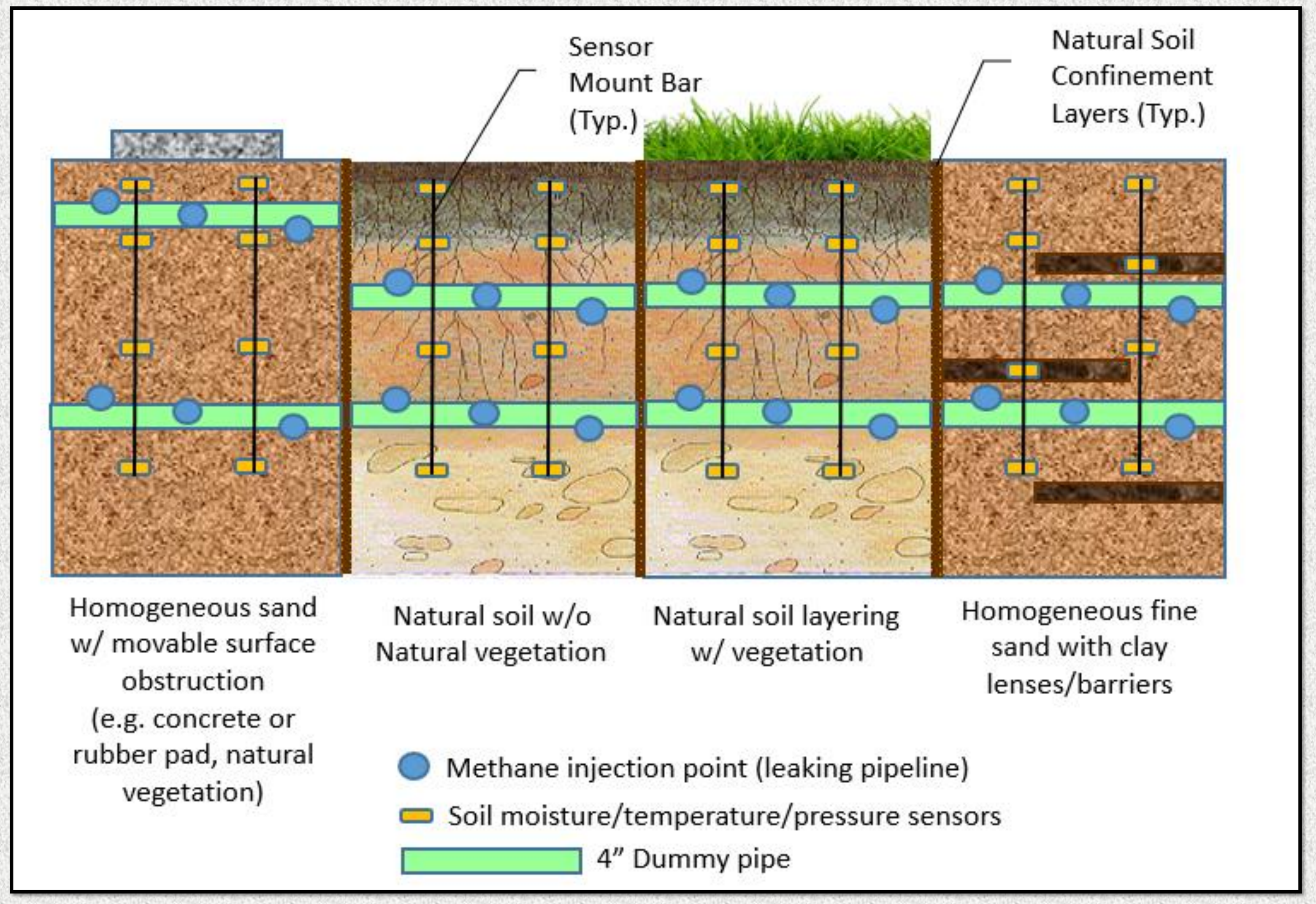
Trenches are used in the natural soil test bed locations because it is more indicative of real life installations and minimizes excavation



Emission Point Detail:



Dummy Pipe Cross-Section | Emission Point | Point Side View

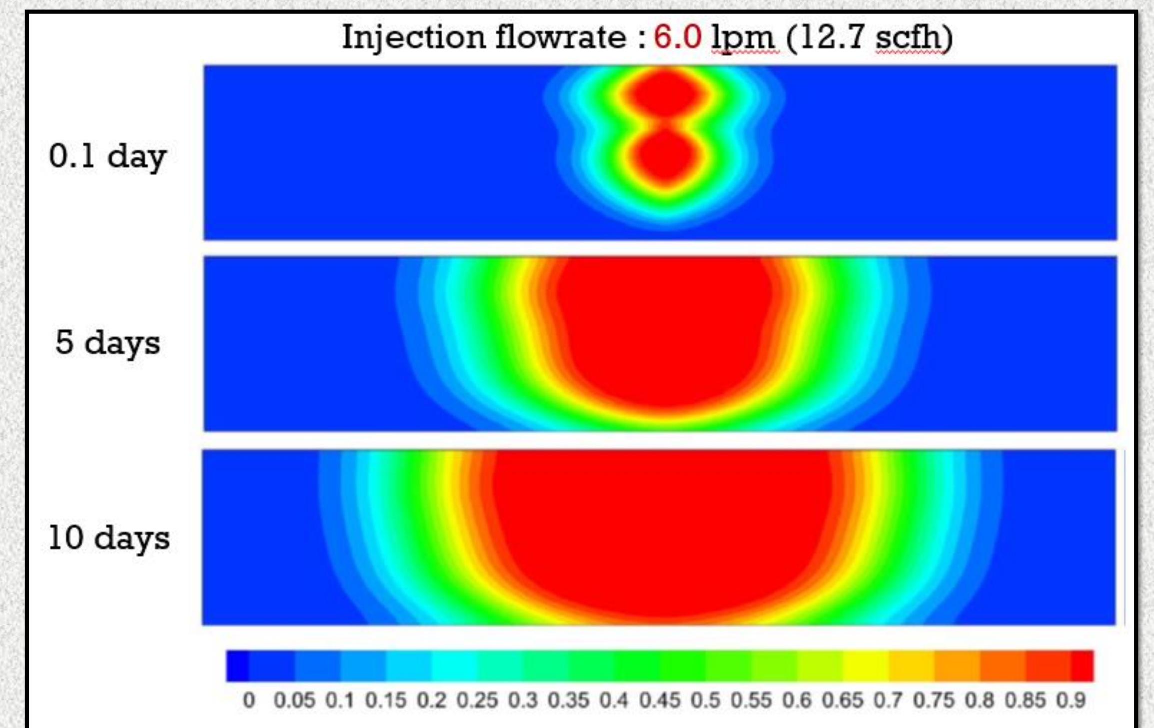


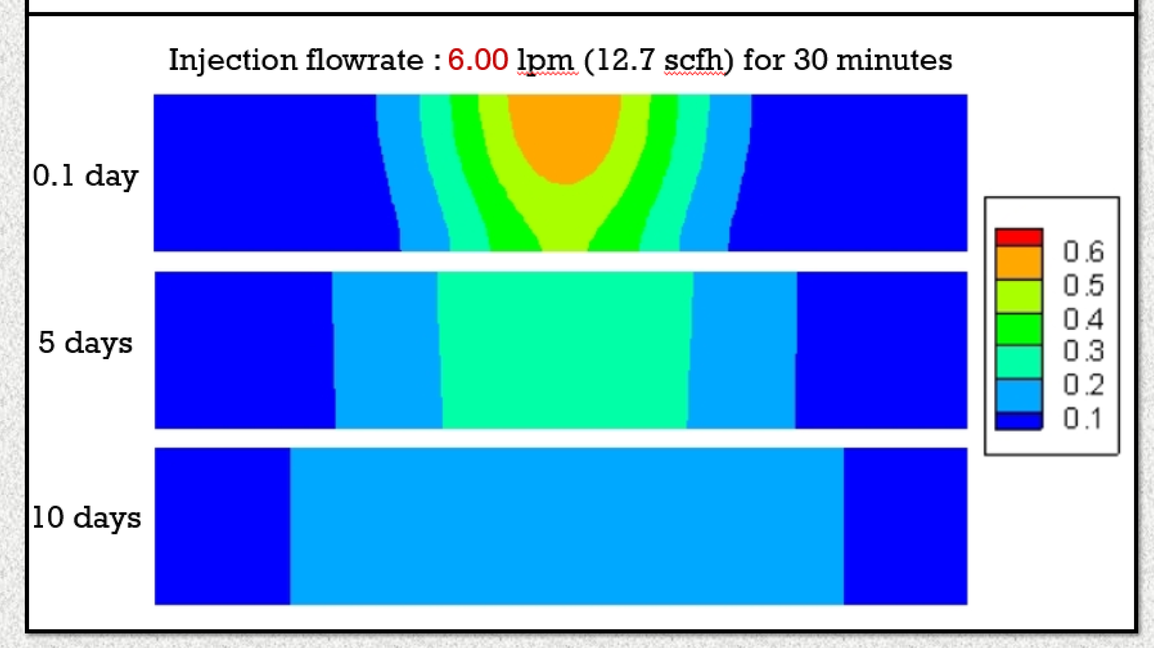
Soil and Surface Configurations:

- ✧3 Surface conditions
  - ✧Vegetation
  - ✧No vegetation
  - ✧Movable surface obstruction
- ✧2 Natural soil beds with disturbed soil trenches
- ✧2 Concrete sand beds
  - ✧Natural sand mixture

5. PRELIMINARY MODEL RESULTS

Some preliminary modeling was done in TOUGH 2 to ensure the emitted methane would remain inside the test bed dimensions (top figure) and to calculate how long the methane would stay inside the soil structure after flow was shut off (bottom figure). Soil parameters for a similar soil type to field conditions (Bonny Silt) and a methane concentration of 50000 ppm was used in the simulation. Concentrations are shown as a mass fraction.





6. IMPLICATIONS

- ➢Validated transport model for natural gas pipeline
- ➢Model will allow for better leak categorization and preparation to dispatch repair work.
- ➢Increased understanding of transport mechanisms for natural gas and what influences its behavior

ACKNOWLEDGMENTS

This research was funded by the ARPA-E MONITOR project. I would also like to thank Kathleen Smits, my advisor, for all of her insights and assistance and Ali Moradi for his assistance and knowledge of numerical modeling.