PRAXIS Environmental Technologies, Inc.

Pneumatic Characterization of Gas Flow and Contaminant Concentrations in Unsaturated, Fractured Bedrock

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Overview

Problem:

Traditional characterization methods to support design of vapor extraction from fractured bedrock are indirect or cumbersome

Approach:

Measure vapor concentrations and air flow from individual fractures in fractured bedrock under applied vacuum, ie, SVE

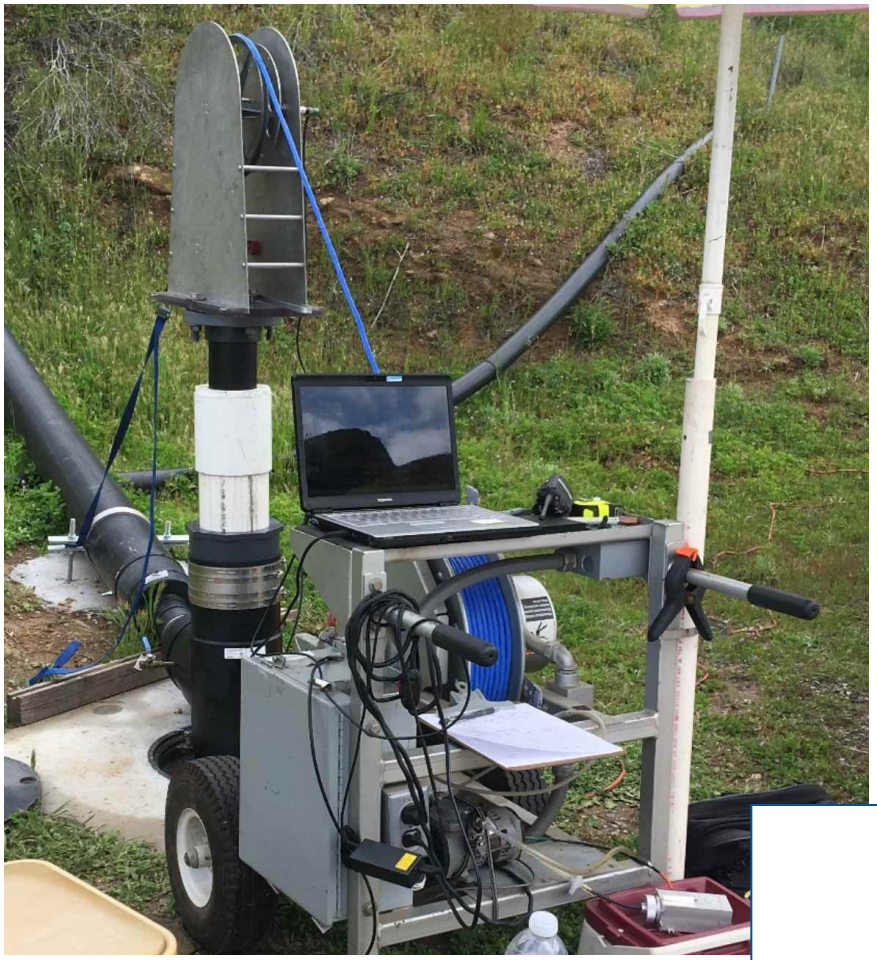
Purposes:

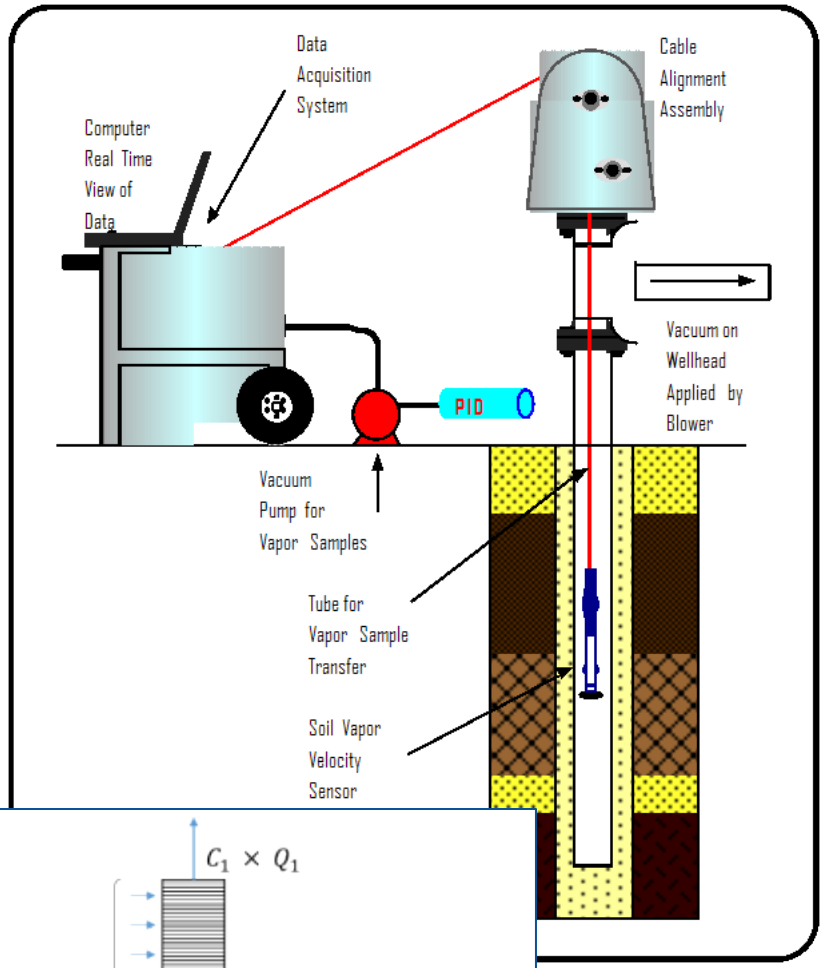
(1) Locate depth and quantify flow from productive fractures, and

(2) Estimate soil gas contaminant concentrations in vapors extracted from such fractures along an open corehole

(3) High resolution data for integration with other distant monitoring data

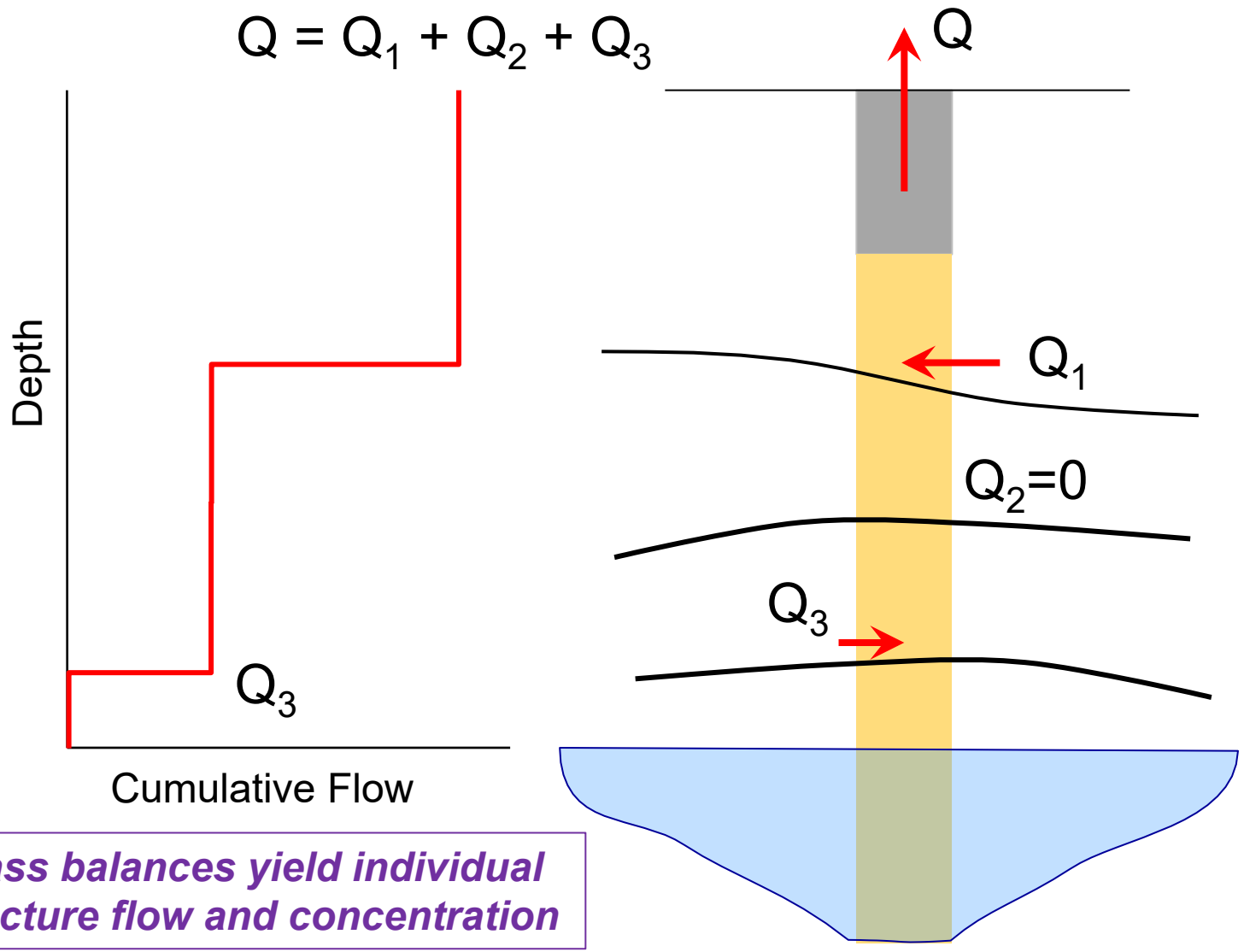
PneuLog® (Pneumatic Logging)





$$C_{\text{soil gas}} \times (Q_1 - Q_2) = (C_1 \times Q_1) - (C_2 \times Q_2)$$

PneuLog® (Pneumatic Logging)



Mass balances yield individual fracture flow and concentration

Example Application #1 – Test Conditions

Corehole Parameters:

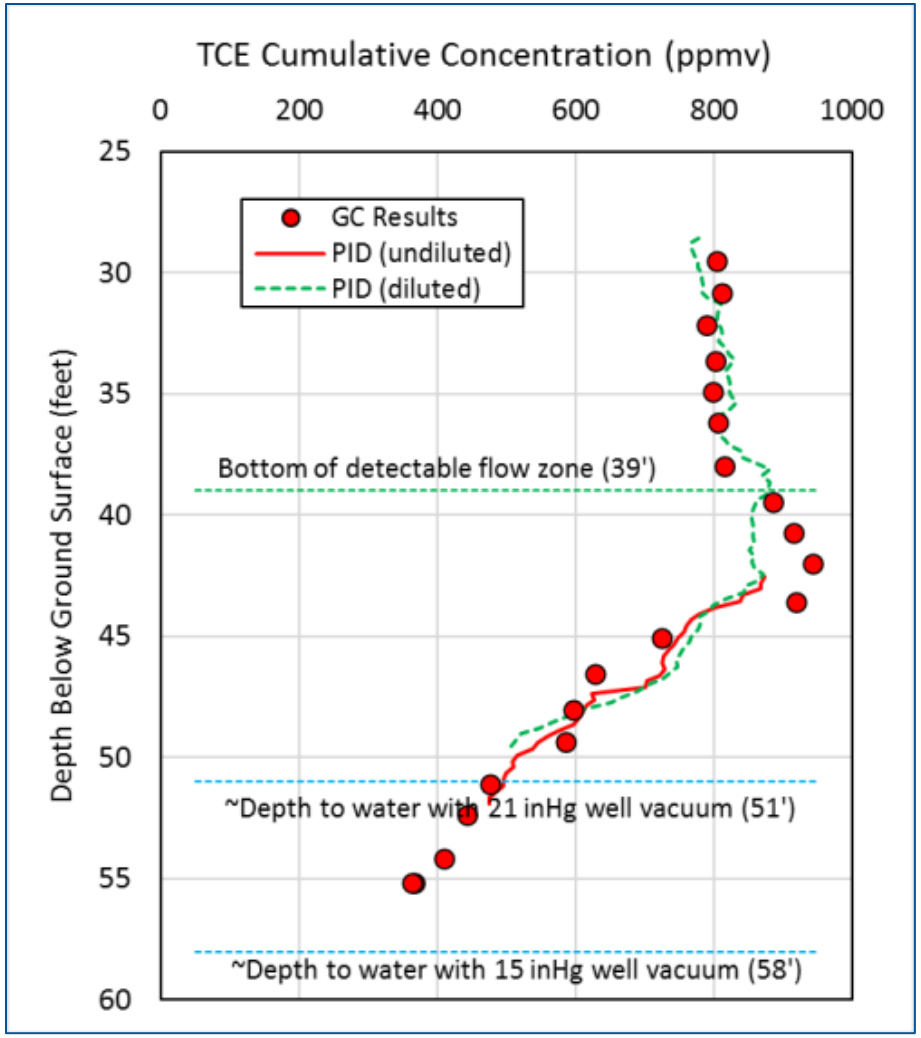
- 8-inch diameter steel casing from surface to a depth of ~30 feet below ground surface (ft bgs)
- Open (uncased) 6.5-inch diameter corehole from ~30 ft bgs extending into the underlying groundwater
- Water table encountered at ~75 ft bgs
- Primary contaminant of concern is trichloroethene (TCE)

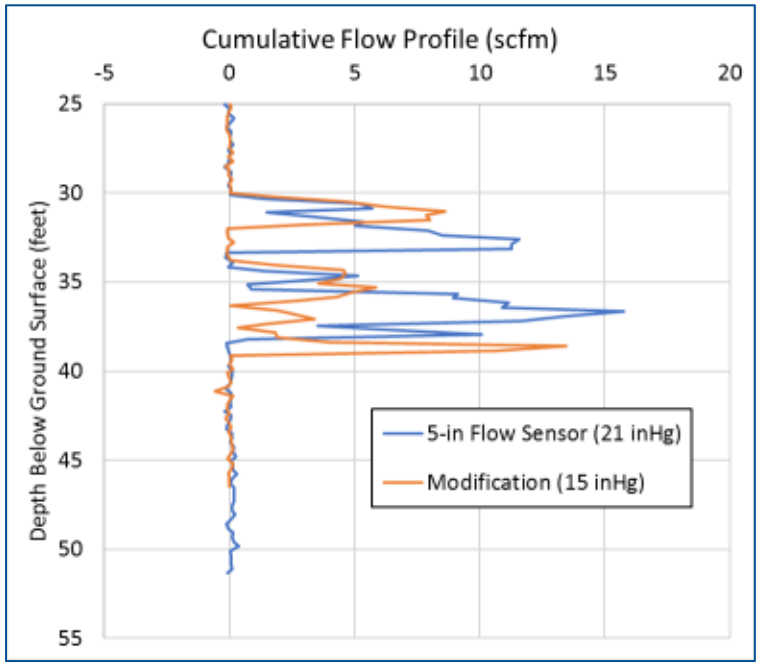
Test Conditions:

- Applied vacuum of 21 inHg yielding flow of 20 scfm
- Applied vacuum of 15 inHg yielding flow of 16 scfm

High vacuums yielded low flows from fractures

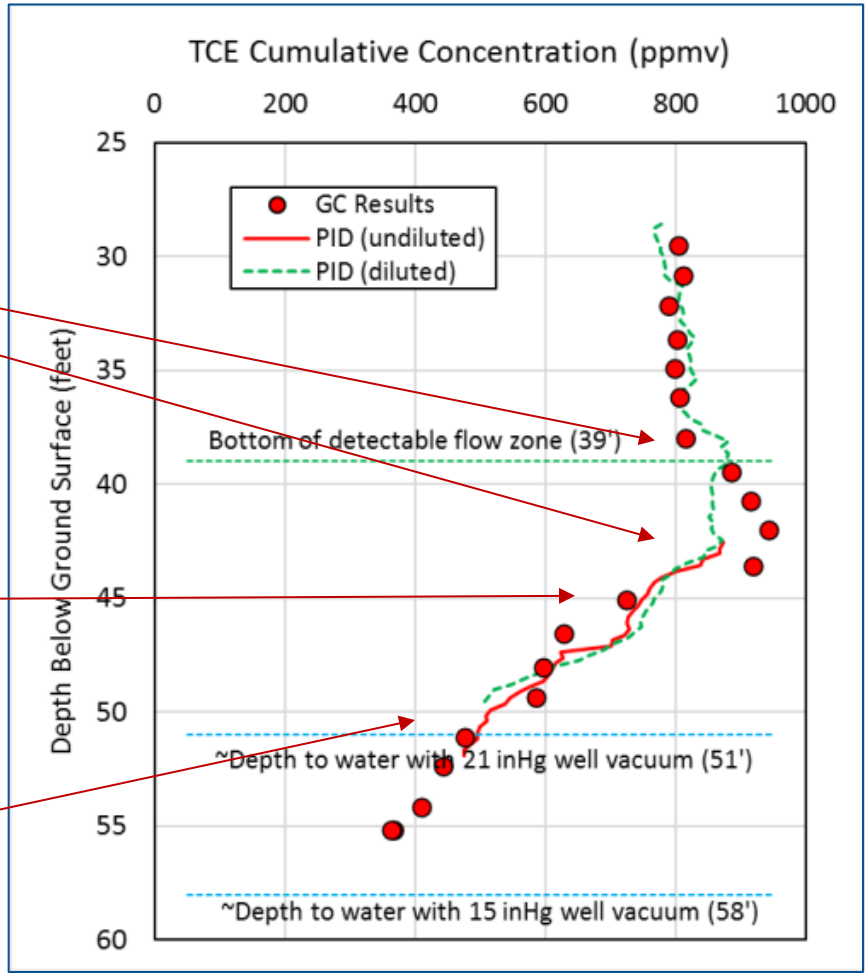
Example Application #1 - Measurements





Threshold velocity (~ 1 ft/sec) was not attained but concentration changes were highly informative

Example Application #1 - Interpretation

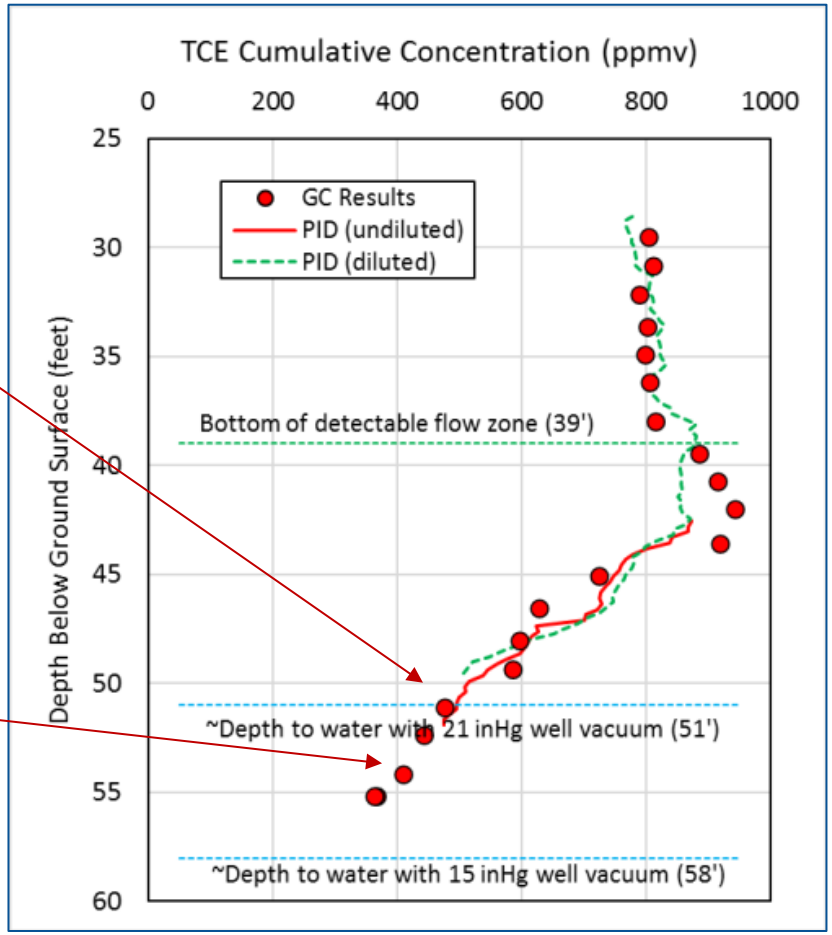


Visual inspection provides little insight regarding fracture flow

Example Application #1 - Interpretation

Fracture at ~50.5 ft bgs

Large fracture at ~54.5 ft bgs did not produce significant flow after being exposed



Reduction in vacuum (21 to 15 in Hg) resulted in proportional reduction in extraction rate (20 to 16 scfm) and lowered the water table

Example Application #1 - Summary

- Fractures correlate with TCE concentration changes and vapor flow
- Primary TCE and flow extracted from 39 – 43 ft bgs interval
- Lack of flow resolution below 20 scfm prevents estimation of the TCE mass flux contribution from individual fractures
- Application of high vacuum (> 18 in Hg) submerges fractures below ~51 ft bgs. However, reduced vacuum (and corresponding reduction in water table rise) did not result in a significant increase in flow
- Large fracture at ~54.5 ft bgs provided a small contribution to flow and TCE extraction when exposed

Example Application #2 – Test Conditions

Corehole Parameters:

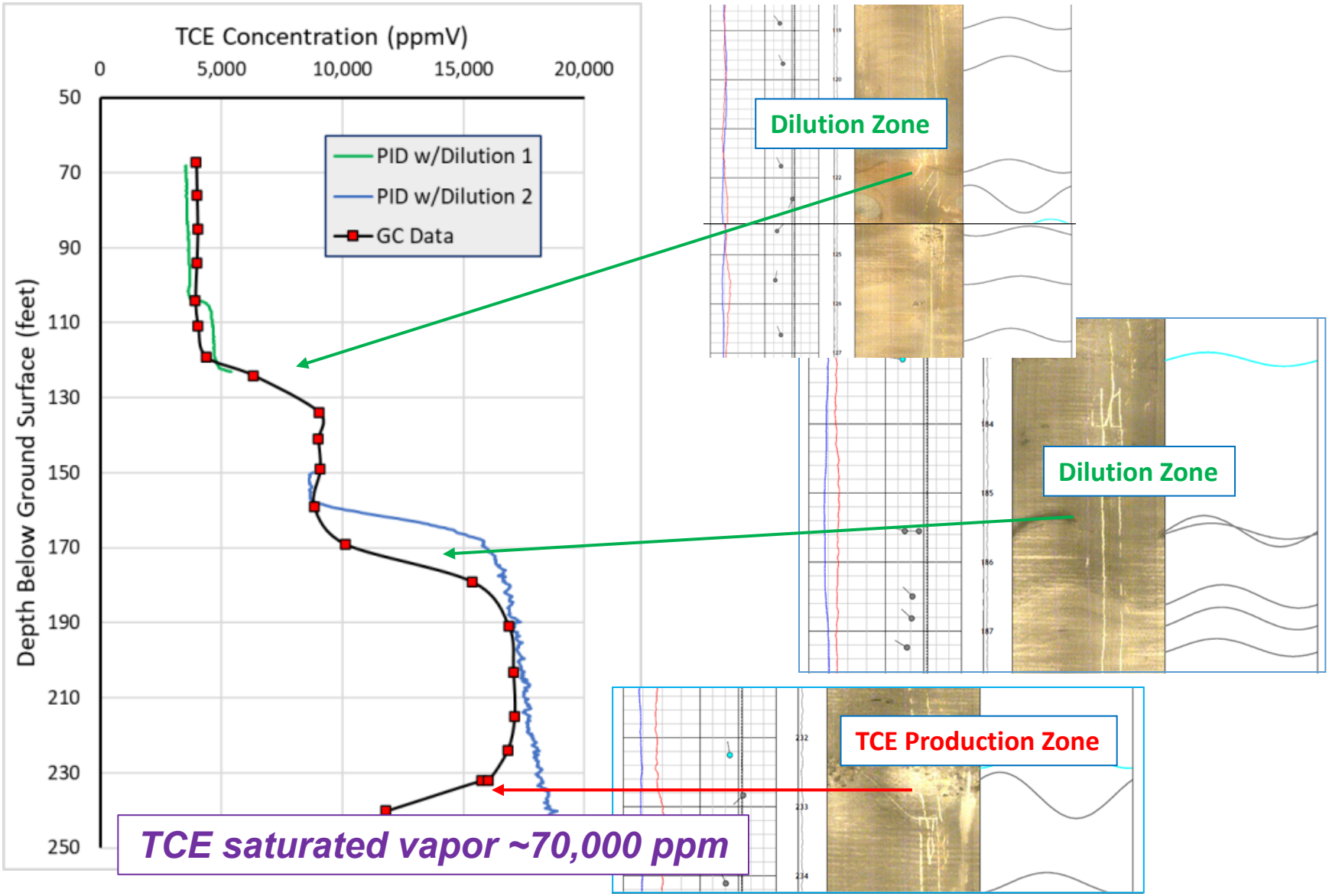
- 8-inch diameter steel casing from surface to a depth of 66 feet below ground surface (ft bgs)
- Open (uncased) 6.5-inch diameter corehole from ~66 ft bgs extending into the underlying groundwater
- Water table encountered at ~250 ft bgs
- Primary contaminant of concern is trichloroethene (TCE)

Test Conditions:

- Applied vacuum of 7.7 inHg yielding flow of <20 scfm

Moderate vacuum yielded low flow from fractures

Example Application #2 - Measurements



Example Application #3 – Test Conditions

Corehole Parameters:

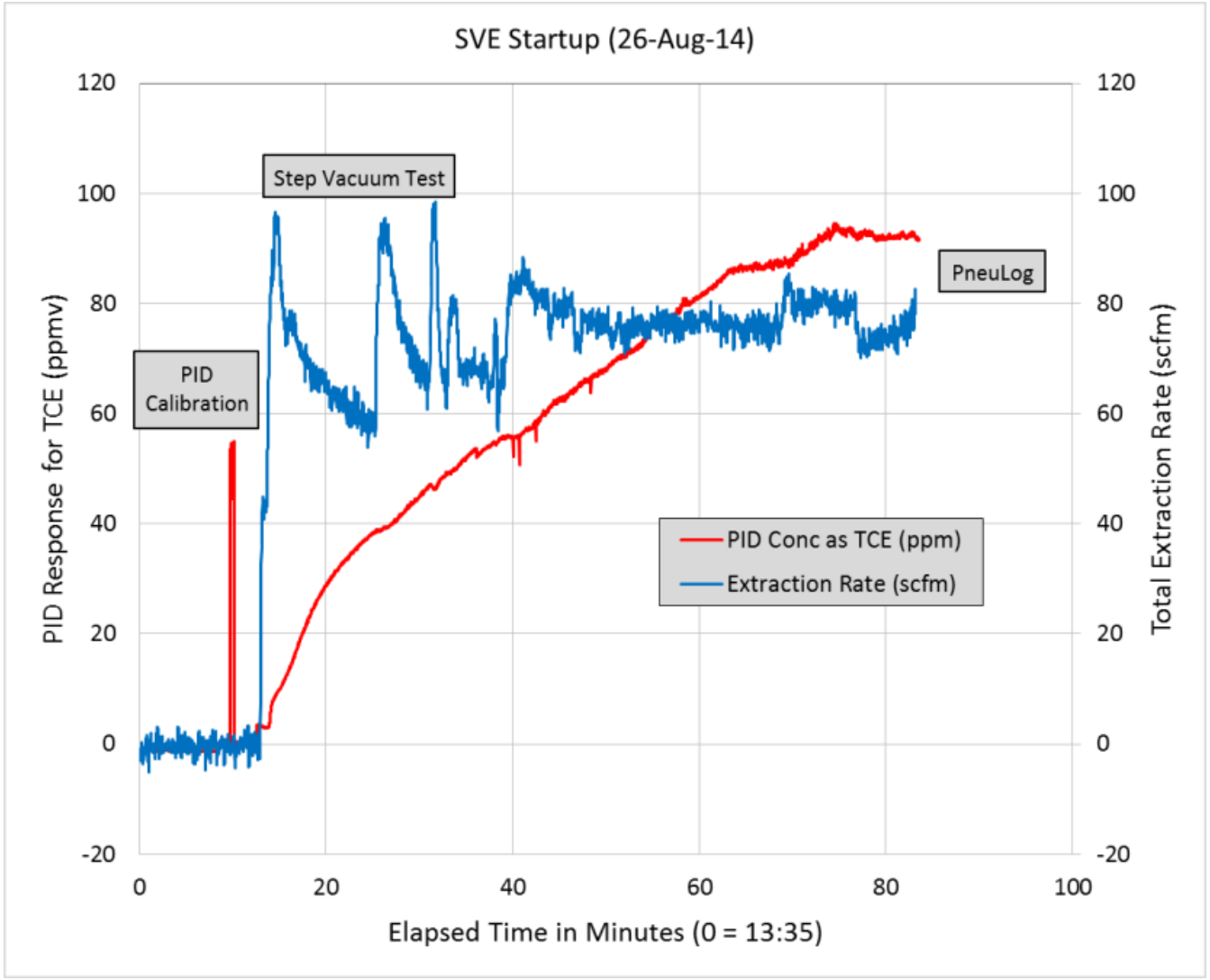
- 10-inch diameter steel casing from surface to a depth of 30 feet below ground surface (ft bgs)
- Open (uncased) 8-inch diameter corehole from 30 ft bgs extending into the underlying groundwater
- Water table encountered at ~179 ft bgs
- Primary contaminant of concern is trichloroethene (TCE)

Test Conditions:

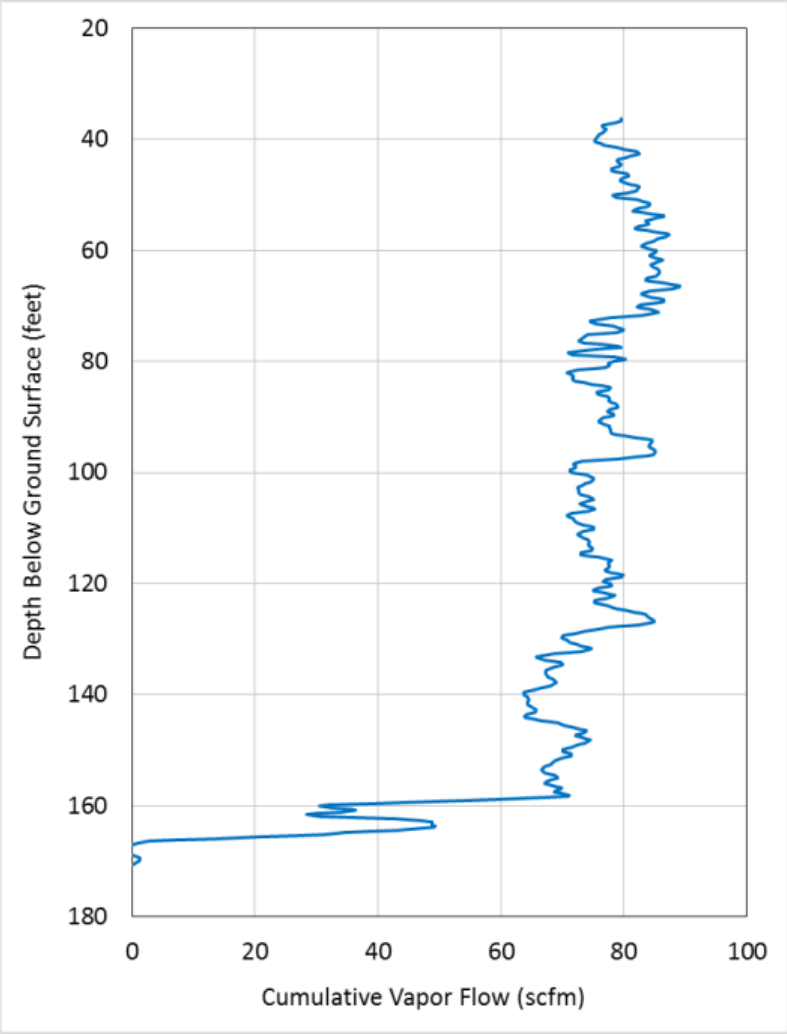
- Applied vacuum of 6 inHg yielding flow of 80 scfm

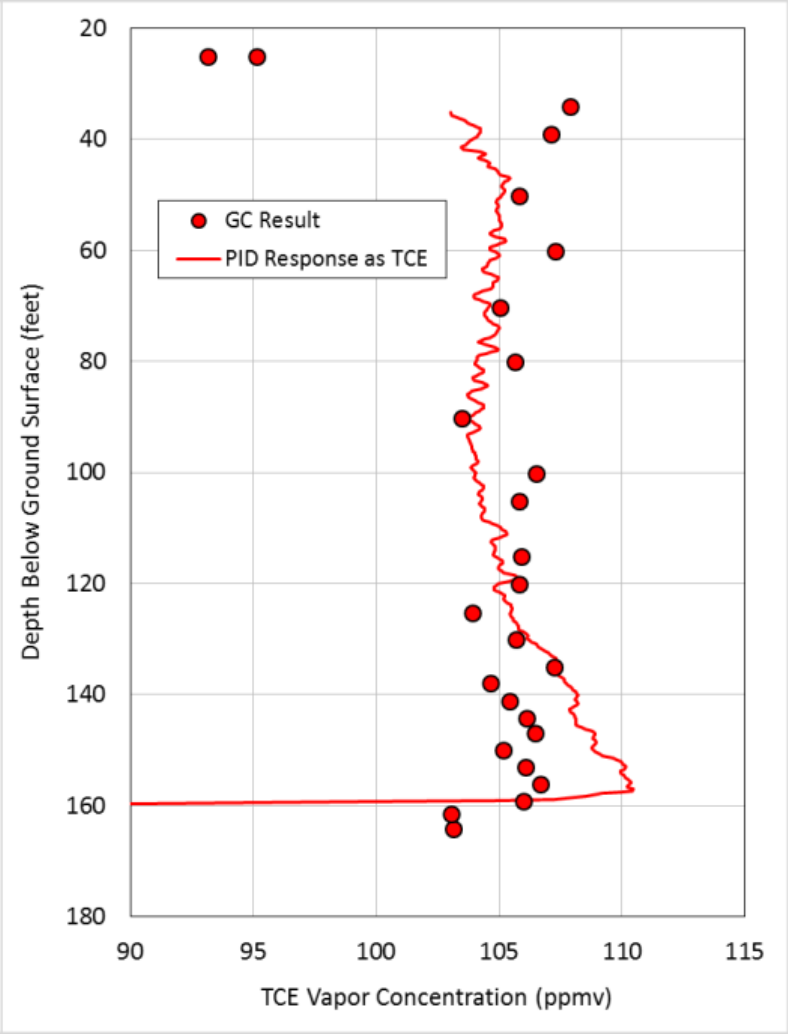
Moderate vacuum yielded typical SVE flow

Example Application #3 – Measurements



Example Application #3 – Measurements





Fracture(s) at ~159 ft bgs produced >80% of total flow

Key Points

- **Straightforward method to characterize flow & concentration from individual fractures**
  - *Visual inspection provides limited information*
  - *Vastly improves interpretation of wellhead readings*
- **Integration with surrounding subsurface monitoring should be highly useful**
  - *High resolution data from the corehole should correlate with vacuum and concentration data in monitored fractures*
  - *Flow into the corehole is likely asymmetric and complex*