Conceptual Site Model Development for Migration of MGP Tar and Related Groundwater Impacts in a Highly Deformed Fractured Rock Unit

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Session: Fractured Rock Site Characterization
Regional Setting and Site Location
Former Manufactured Gas Plant (MGP), Cohoes, New York
Primary impact associated with Manufactured Gas Plant (MGP) operations was the release of tar, which typically behaves as a DNAPL.

Tar is source of dissolved-phase constituents to groundwater such as benzene, toluene, ethylbenzene, xylenes, and naphthalene.
Purpose of Presentation

• To describe development of a Conceptual Site Model (CSM) for groundwater flow, DNAPL (tar) migration, and dissolved-phase constituent migration in highly-deformed sedimentary rock sequence at a former MGP, including discussion of:

  - The value of a phased and iterative investigation approach; and
  - How understanding the regional structural characteristics of the rock facilitates conceptual model development and guides the investigation.
Bedrock-New York
From: Rogers, Isachsen, Mock, & Nyahay, 1990

PLATE 2 GEOLOGIC MAP
AND CROSS SECTIONS

Taconic Frontal Thrust

Cohoes
Taconic Mountain Building Event
Schematic Cross-Section

West

Cohoes Bedrock

East

Basinal shale, flysch, and melange
Continental Crust

0 Km (Future edge of Autochthon)

(Taconic) continental rise facies rocks (accretionary prism)

Slope-rise sediment

>100 km (Shelf-Break)

(Modified from Hayman and Kidd, 2002)

(From Lim, et al, 2005)
Cohoes Mélange – Outcrop Near Site

- No continuous bedding evident
- No systematic fracture patterns evident
Bedrock at the MGP Site

- “Cohoes Mélange” Lithotectonic Unit
- Originally bedded shale and mudstone unit with some sandstone and siltstone beds
- Deformed in shear zone during Taconic mountain building event (Ordovician Period)
- Ductile and brittle deformation: Faults, folds, disrupted bedding, closely-spaced cleavage
- No continuous marker beds remain for stratigraphic correlation; Nearly uniform lithology
- Low-grade metamorphism
- Matrix: Low porosity and permeability
Cohoes Mélange – Outcrops Near Site

- Cleavage planes
- Veins indicating reverse displacement
- Highly deformed – folded cleavage
- Disrupted bedding
- Outcrops in river
- Sandstone Block
- Shale Matrix (closely spaced cleavage)
Locations for Bedrock Evaluation/Wells: Initial Phase of Investigation

Bedrock evaluation and well location, initial phase

Line of cross-section
Bedrock Evaluation Approach at Individual Locations: Field Data

Geophysical Logs (Field Output)

**Geophysical responses**
- MW-20R1 screen
- MW-20R2 screen

**Caliper**

**Fluid Res**

**Temp**

Packer Pressure Test K (cm/s)

**Hydraulic Conductivity (cm/sec)**

- MW
- MW-20R2 screen
- MW-20R1 screen

**Shallower flow zones**

**Bedrock core** from approximate depth of geophysical indicators and transmissive zones identified during packer pressure testing
During initial phase: At wells with greatest dissolved-phase concentrations, the water-bearing fractures intersecting the screen plotted on an east-dipping plane.

- Geometry of plane is similar to thrust faults in region.
- Projected plane down-dip and along strike to plan subsequent drilling to evaluate this potentially continuous fracture zone.
Thrust Fault Elevation Contours

Contour units:
feet, NGVD

Scale
(approximate)

0 100 ft
Cohoes Mélange Outcrops: Thrust Fault
Cohoes Mélange Outcrops: Thrust Fault
3D Visualization Model

Mining Visualization Software
EVS/MVS Version 9.93
(release date 12/10/2014)
C Tech Development Corporation

Site

Gas Holders
(Excavated into bedrock)
3D Visualization Model

Cross-Section View Toward North
(Vertical Exaggeration 5x)

Ground Surface
Top of Bedrock
Site
Mohawk River Channel
Thrust Fault
3D Visualization Model

Cross-Section View
Toward North
(No Vertical Exaggeration)

Ground Surface
Top of Bedrock

Thrust Fault
Shallow position of thrust fault zone beneath western part of site, and its intersection with top of rock surface and gas holder excavation into rock, facilitates entry of impacts into fracture zone.
3D Visualization Model

Cross-Section View Toward North (Rotated)
(Vertical Exaggeration 5x)

Thrust Fault
(view from below)
3D Visualization Model

Cross-Section View Toward Southwest
(Vertical Exaggeration 5x)

Thrust Fault
**Cross-Section B-B’ (West to East)**

- Beneath Site, hydraulic head is lowest in thrust fault zone
- To east, under river, vertical hydraulic gradient is upward from thrust fault zone toward river
Pumping Tests-Short Term

• Four short-term pumping/recovery tests (±6-hr pumping) were conducted over course of investigation.

• Purpose-Qualitatively assess degree of hydraulic connectivity between:
  - Potential bedrock water-bearing zones screened at individual wells at different locations (lateral connectivity)
  - Potential water-bearing zones identified at an individual location (vertical connectivity)
Short-Term Pumping Tests to Evaluate Hydraulic Connectivity

Cross-section

MW-17R
Pumping Well

Pumping rate = ±1 gpm

335 ft

MW-19R1

MW-19R2

Drawdown vs. Time

Greater degree of hydraulic connection between wells screened in east-dipping fracture zone
Lateral Groundwater Flow along Fault

Generalized direction of groundwater flow in thrust fault zone.

Fault elevation contour (ft. NGVD)
NAPL or Potential NAPL in Bedrock above Fault

- NAPL observed in bedrock well or in rock core
- NAPL potentially in vicinity of bedrock well screen based on dissolved-phase concentrations

Approximate area of DNAPL in overburden on top of bedrock (primarily residual, locally saturated)

Fault elevation contour (ft. NGVD)
NAPL or Potential NAPL in Fault

- NAPL observed in bedrock well or in rock core
- NAPL potentially in vicinity of bedrock well screen based on dissolved-phase concentrations

Generalized direction of groundwater flow in thrust fault zone.

Fault elevation contour (ft. NGVD)
Naphthalene in Bedrock Groundwater above Fault

Naphthalene Concentrations in µg/L
ND- Not detected

Fault elevation contour (ft. NGVD)
Naphthalene in Groundwater in Fault

Generalized direction of groundwater flow in thrust fault zone.

Naphthalene Concentrations in µg/L

ND- Not detected

Scale (approximate)

Fault elevation contour (ft. NGVD)
Summary:
Extent of Impacts in Bedrock Groundwater

• East of the Site, potential DNAPL and high dissolved-phase constituent concentrations are at depth within east-dipping thrust fault zone.
• No detections of MGP-related constituents in groundwater above the thrust fault east of site.
• Dissolved-phase constituent concentrations decrease within thrust fault zone downgradient of the potentially DNAPL impacted areas.
• Bedrock groundwater eventually discharges to the river.
• Biased-high mass flux evaluation indicates no impact to surface water in river. Surface water sampling supports this conclusion.
Findings – Key CSM Components

- Identified a shallowly eastward-dipping, continuous fracture zone that serves as a water-bearing zone in bedrock.
- The geometry of this zone is similar to low-angle thrust faults identified elsewhere in the Cohoes Mélangé.
- The thrust fault zone is the primary control on lateral groundwater flow and dissolved-phase constituent migration from the site in rock, and also influences DNAPL (tar) distribution.
- Other water-bearing fractures were identified above and below that are as not as continuous. These are typically, to varying degrees, hydraulically connected to the more continuous thrust fault-related zone.
- Beneath the site, the thrust fault approaches/intersects the top of bedrock surface, facilitating entry of site constituents into this zone.
Implications for Remedy Development

• Demonstrated no complete exposure pathways related to impacts in off-site bedrock.

• Developed well network to confirm lack of complete exposure pathways and for MNA evaluation.

• Identified on-site remediation targets in overburden to cut-off potential for continued migration of impacts from overburden into thrust fault.
Conclusions

This case study demonstrates the value of a phased investigation approach for developing a CSM for impacts in highly deformed fractured rock sequences, wherein:

• Findings from individual investigation locations are integrated with an understanding of the regional bedrock structural setting;
• Existing CSM is tested during each phase of investigation;
• CSM is updated, as needed, after each phase of investigation; and
• Phased investigation and CSM updates continue until level of uncertainty in CSM is reduced to acceptable level for project objectives.
References


Questions?