Expedited Implementation of RCRA Corrective Action Process for Hexavalent Chromium: A Case Study

E. Carter, M. McCaughey, *P. Khambhammettu*, H. Fadaei, T. Blount (Arcadis),
T. Fortenberry (Albemarle Corporation)

June 6, 2024

Presentation Overview

Project Milestones

- New team formation (2015)
- Project planning (2015)
- Groundwater use survey (2016)
- Additional investigation (2016-2021)
- Current conditions report (2020)
- Corrective measure study (2021)
- Statement of basis/Final decision (2022)
- Corrective actions work plan (2021-2022)
- Environmental covenant (2022)
- Consent order (2022)
- Property sale (2023)
- Remedial actions (2024-2025)

ARCADIS

Project background

- Pigments manufacturing facility in Maryland
- Used hexavalent chromium from 1940s through 2000s
- Onsite and offsite hexavalent chromium impacts in an industrial/commercial land use area with distant agricultural land use
- Regulatory oversight by EPA III RCRA Corrective Action Program
- A property acquisition led to formation of a new project team, new property use goals, and new perspectives on the completeness of past environmental work

Presentation goals

- Discuss major site management considerations
- Present the remedial strategy steps towards accelerating remedial progress
- Review the updated conceptual site model and selected remedy
- Summarize major takeaways

Site Management Considerations

Initial site management considerations identified by the new project team include:

Consideration	Description
1. Incomplete conceptual site model	Data indicated the site was not adequately characterized warranting further investigation to assess current environmental conditions and potential receptor risks
2. Field work impacted by logistics and access	Initial onsite field work required coordination around active facility operations, while offsite investigation required access agreements.
3. Property use and ownership changes	Eventual facility shutdown & property sale
4. No formal regulatory agreement	Previous work was conducted voluntary without a signed agreement. EPA requested participation in a future consent order.
5. Potential loss of institutional knowledge	Pending retirement of existing EPA staff and site employees indicated potential loss of site knowledge and momentum

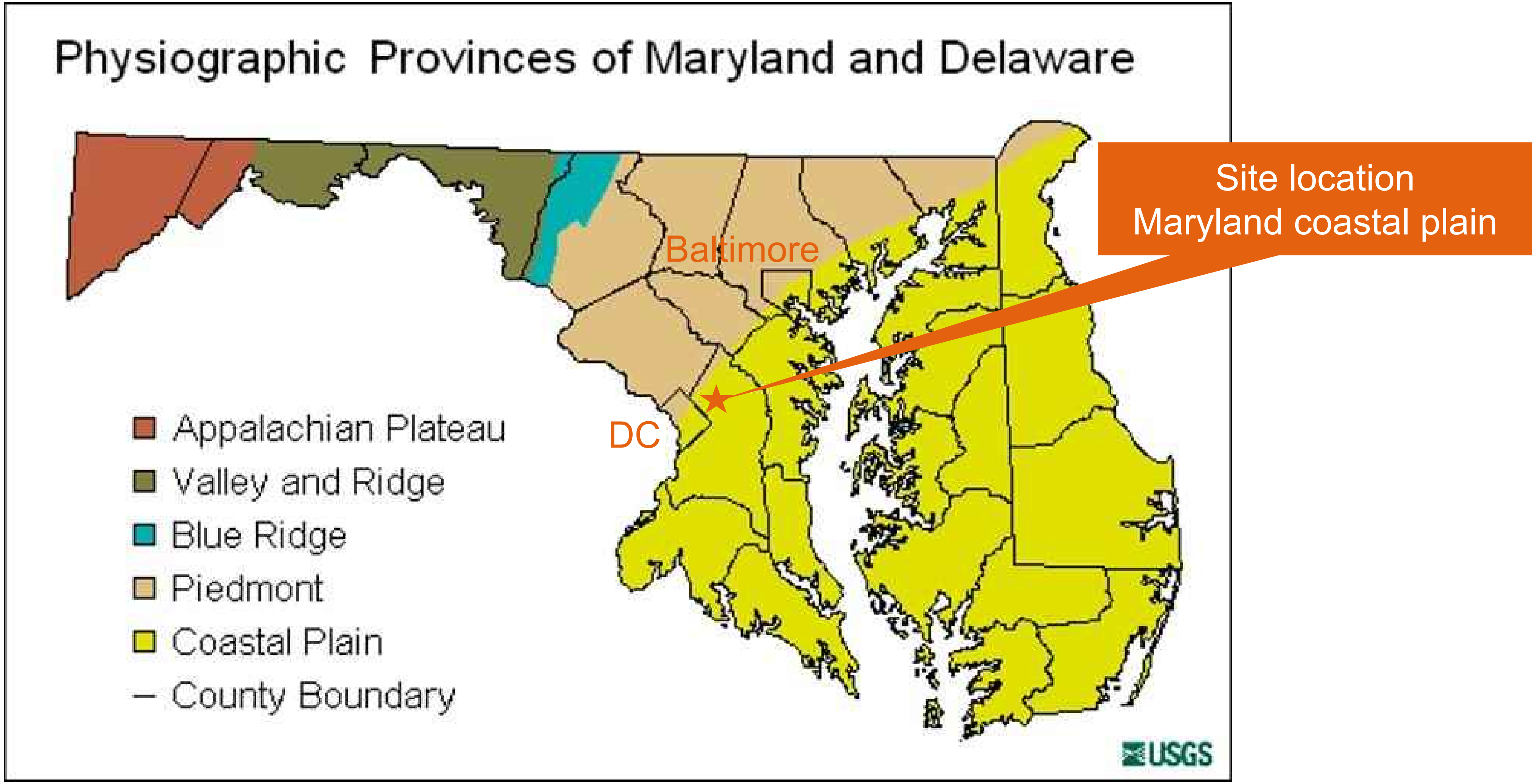
Remedial Strategy Elements

Step 1. Develop a *collaborative strategy* for accelerating the RCRA regulatory progress

Step 2. Collect necessary data to refine the *conceptual site model*

Step 3. Select a remedy offering *operational flexibility* to support future property sale and site redevelopment

Site Location



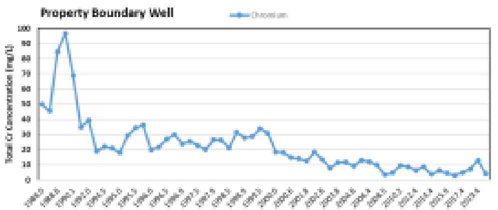
Site Background

- Pigments production from 1940s through 2019
- Hexavalent chromium use discontinued in 2008
- Mixing/production occurred above ground with self-contained wastewater lines and sumps
- Pigments usage – coloration of paints, coatings, plastics, building materials

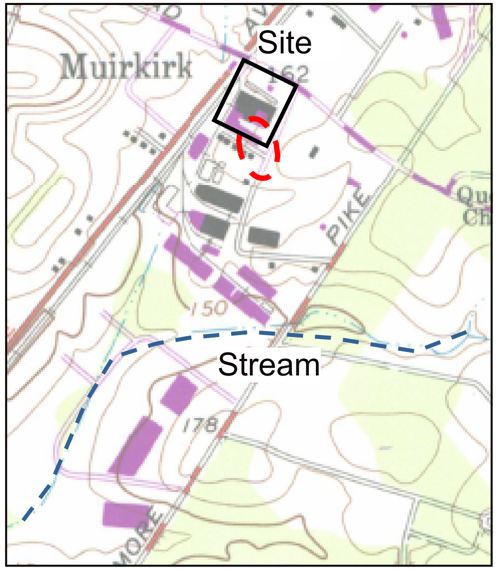
Site Background

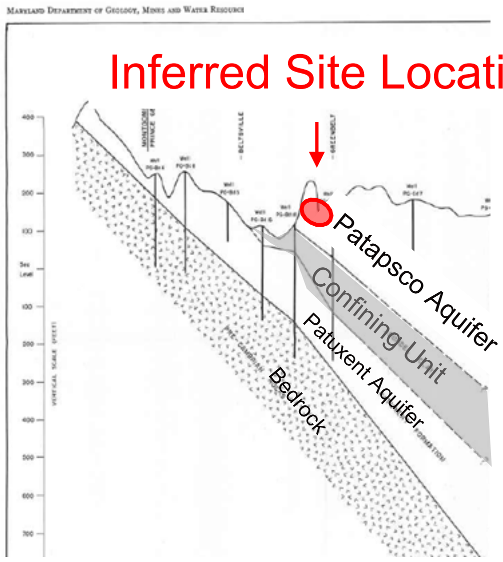
- Slowly declining chromium trends at property boundary
- Presumptive MNA remedy for groundwater developed in late 1990s/early 2000s
- Mid 2010s regulatory request for plume delineation (prior to new team engagement)
- Offsite chromium results (within 800 ft from facility) were higher than expected (1 to 2 mg/L)
- Generated questions about conceptual site model led to project review

Inherited conceptual site model	Data gaps identified during project review
1. Shallow plume underlain by regional confining unit	Not vertically delineated
2. Slow groundwater system	Historical aquifer test results not consistent with lithologic descriptions
3. Presumed source (off-spec containers) was removed	Former manufacturing areas were not well characterized
4. Plume attenuates prior to discharge to local stream	Plume not delineated; no hydrologic data indicating stream discharge
5. No groundwater users	Last survey was 16 years earlier



Inherited conceptual site model

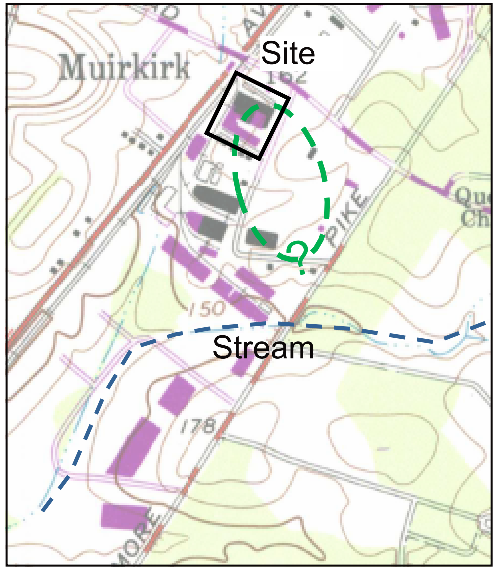


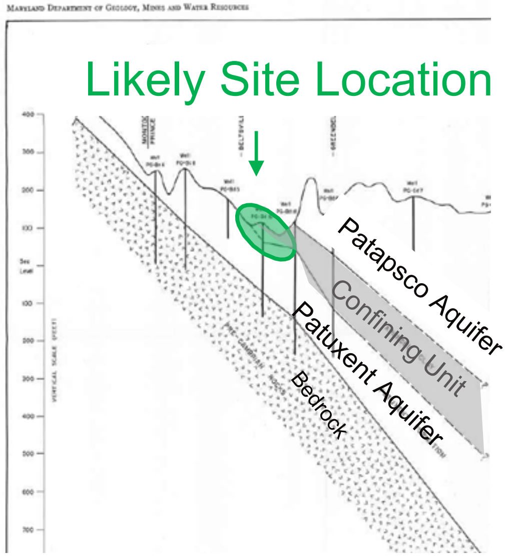


Outcropping aquifer overlies a regional confining unit

Small local plume

Data gaps identified during project review





Regional confining unit may outcrop downgradient of site

Potential for larger and deeper plume

Step 1 – Collaborative Strategy To Accelerate Progress

- Agree to work voluntarily and collaboratively until the Final Decision is approved and then pursue a Consent Order for remedy implementation
- Routine engagement with RCRA CA Program Manager during staff transitions
- Develop the Corrective Action Objectives early to identify receptor data gaps and guide the site characterization program. Continue to refine the CAOs until Corrective Measures Study is finalized

Corrective Action Objectives

Development

- CAOs developed based on these components
- Media impacts focused on soil and groundwater; no surface water, air, or waste media impacts
- Receptor category impacts focused on human health, cross-media transfer, and resource restoration
- Relative priority/timeframe ranking assigned to each receptor risk

Media
Soil
Groundwater
Surface Water
Air
Waste

Receptor Categories
Human Health – Residential
Human Health – Non-Residential
Ecological
Cross-Media Transfer
Resource Restoration

Receptors
Residents
Construction Workers
Site Workers

Major takeaways

- Existing controls prevent direct contact; include in final remedy
  - Paved surface serves as engineered barrier
  - Property zoned for industrial/commercial use
- Additional investigation warranted to develop CMS remedial alternatives for source control and groundwater restoration
- Groundwater use survey warranted to evaluate receptor risk
- Additional controls warranted to prevent drinking water exposure
  - Onsite groundwater. Environmental covenant
  - Offsite groundwater. Notifications

Pathway Scenario or Goal
Prevent direct contact exposure
Prevent drinking water exposure
Prevent soil to groundwater leaching
Attain drinking water standards in plume

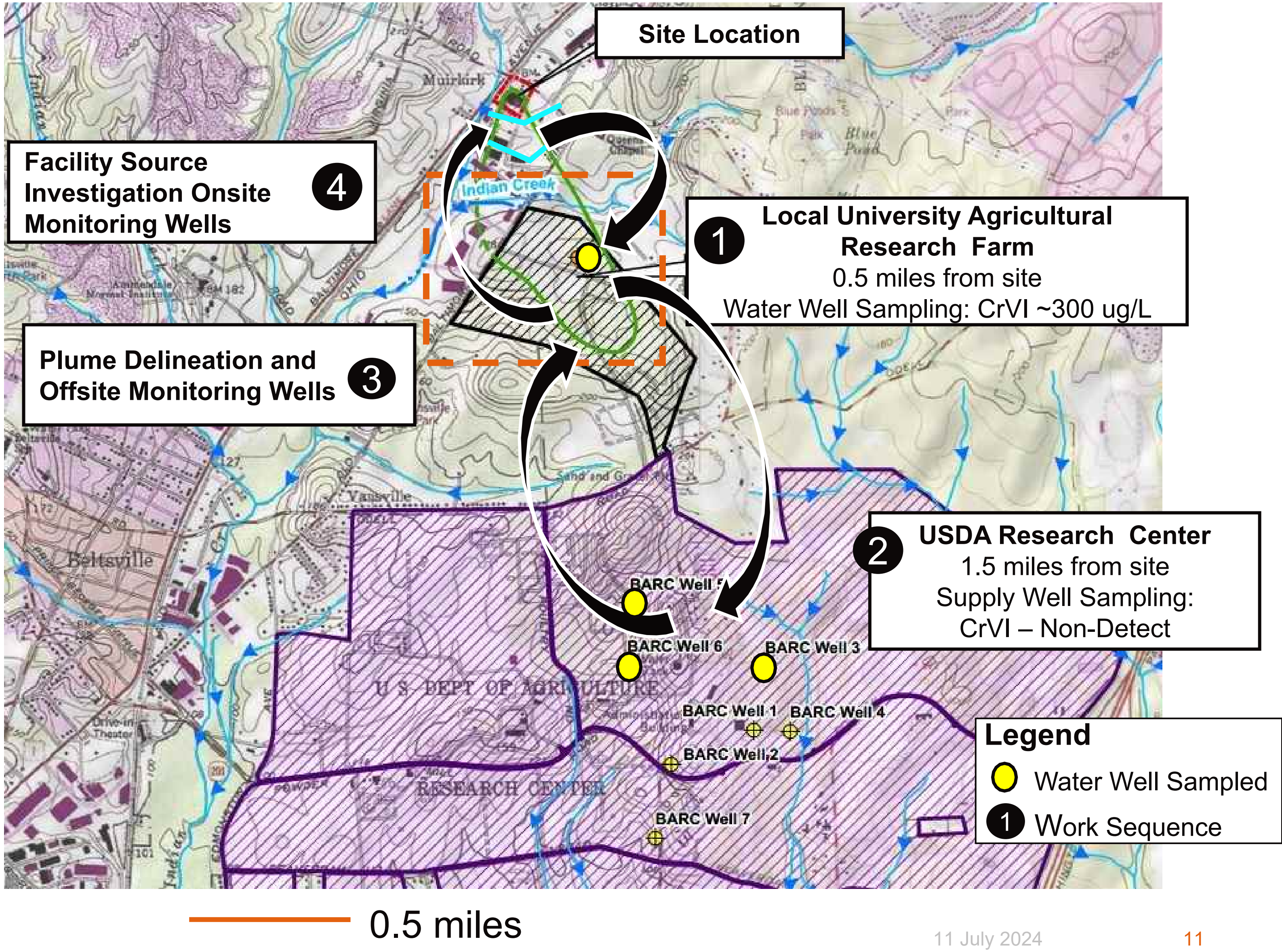
Relative Priority/ Timeframe
1 = short-term
2 = intermediate
3 = long-term/final
4 = existing control in place

Step 2 – Refinement of the Conceptual Site Model

- **Desktop reviews.** Desktop review of regional geologic, hydrogeologic and well records helped refine conceptual site model prior to additional investigation
- **Leapfrog site characterization approach.** Initially focused on offsite groundwater receptor risk and plume delineation, then stepped back to complete onsite source investigation after the facility closed.
- **Vertical aquifer profiling.** Conducted vertical aquifer profiling to confirm vertical extent of contamination prior to well installation. When needed, used a tracer to confirm collection of representative groundwater samples while reducing purge volumes
- **Aquifer testing.** Performed slug tests across the plume to characterize aquifer hydraulic conductivity to determine groundwater velocity.

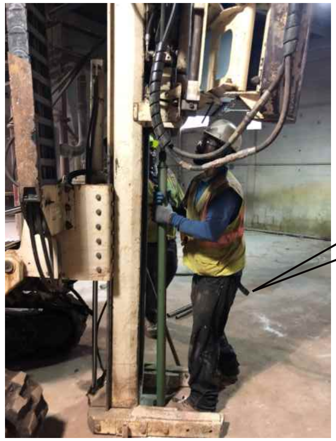
Desktop Review & Characterization Approach

- Site located within regional aquifer (Patuxent) outcrop area
- Downgradient area overlain by regional confining unit
- Offsite groundwater impacts may be larger than previously interpreted
- Distant irrigation wells identified
- Decided to sample wells to guide offsite plume delineation program
- Chromium detected 0.5 miles downgradient in inactive irrigation well



Drilling Tailored To Location And Objective

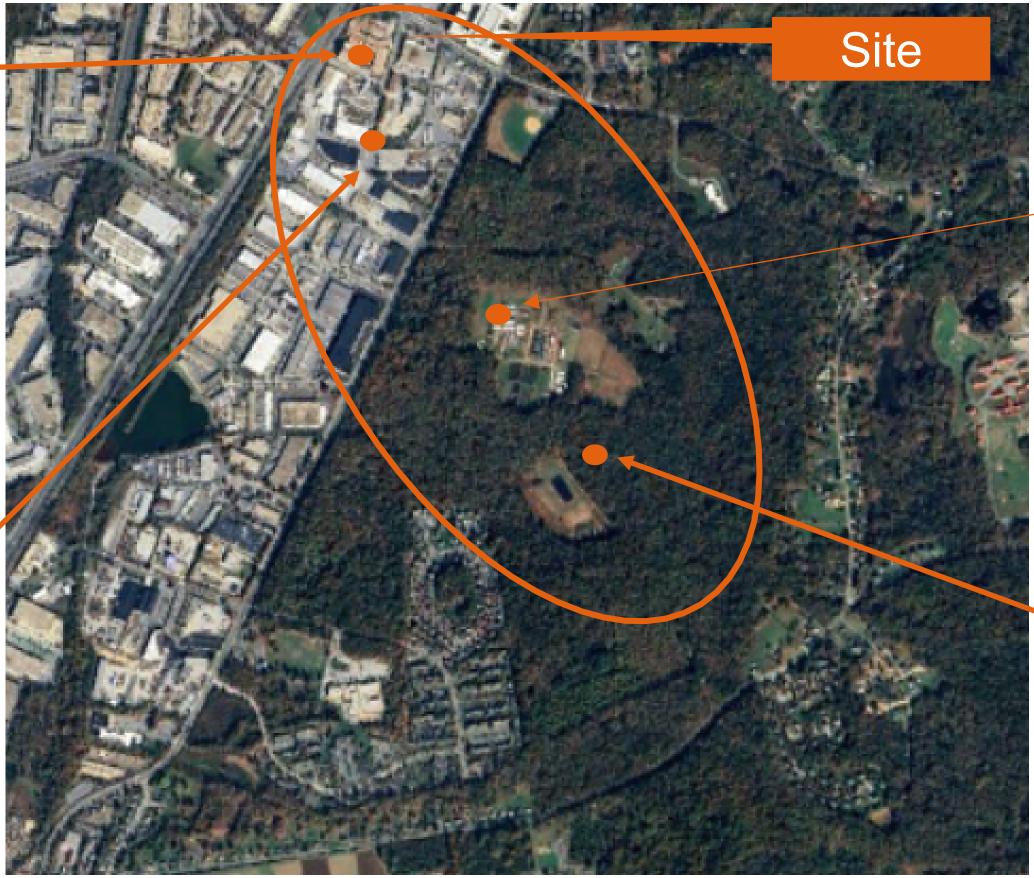
Shallow Drilling Inside Buildings (Direct-Push Track Rig)



Green staining on soil coring

Shallow Well Installation (Hollow-Stem Auger Truck Rig)

Large Investigation Area



Deeper Profiling / Well Installs in Developed Areas (Sonic Truck Rig)

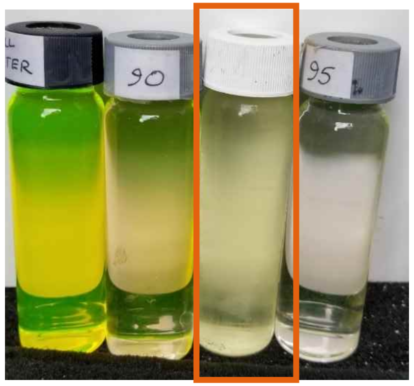
Deeper Profiling/ Well Installs in Wooded Areas (Sonic Track Rig)

Vertical Aquifer Profiling

- Vertical aquifer profiling conducted with sonic drilling methods due to target depths (> 50 ft)
- Continuous soil logging with 3 to 6 groundwater samples per location
- <u>Drilled dry at most locations</u>
- When water was used, used a fluorescent tracer to determine when to stop purging
- Tracer results indicate purge samples were > 90% groundwater

Sonic Drill Rig during VAP Sampling

Visual Field Comparison



Black top: drilling water batch sample

Gray tops: 90% and 95% dilution of drilling water (for reference)

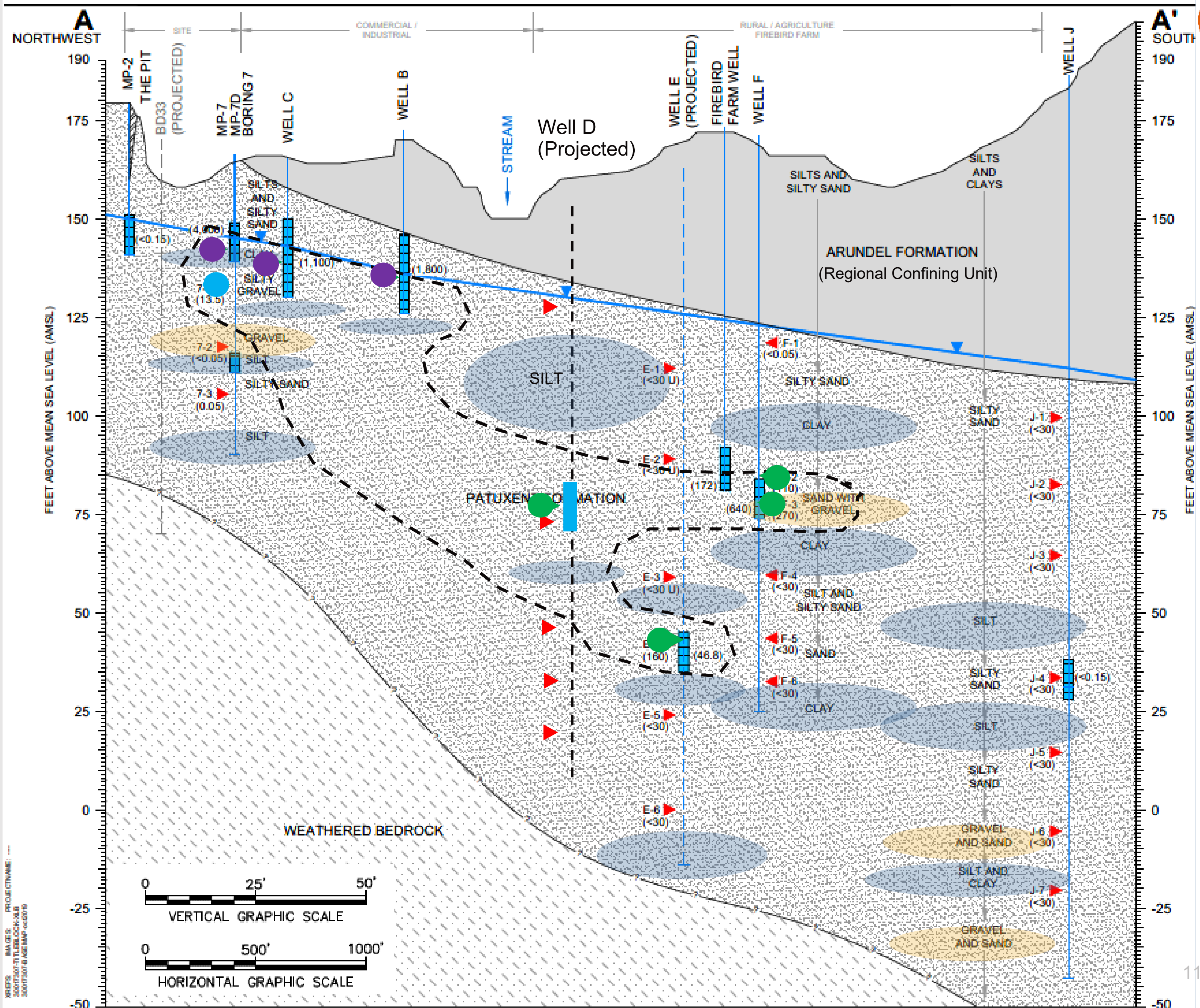
White top: groundwater purge sample (for comparison to visual standards)

Method Note:

- Previously, Arcadis developed a field method to collect representative groundwater samples during sonic drilling, based on work at Fort Meade, Maryland
  - *Using Tracers to Quantify Drilling Water Influence and Obtain Representative Groundwater Samplers* (McCaughey, Divine, Gefell, and McGrane, Groundwater Monitoring & Remediation, 2015)
- This method was adapted for this study

Cross-Section Along Plume Length

- Locations influenced by logistics/access
- VAP samples (3 to 6 per boring)
- Plume confined off-site
- No groundwater to surface water pathway
- 3+ years of well sample results consistent with VAP sample results

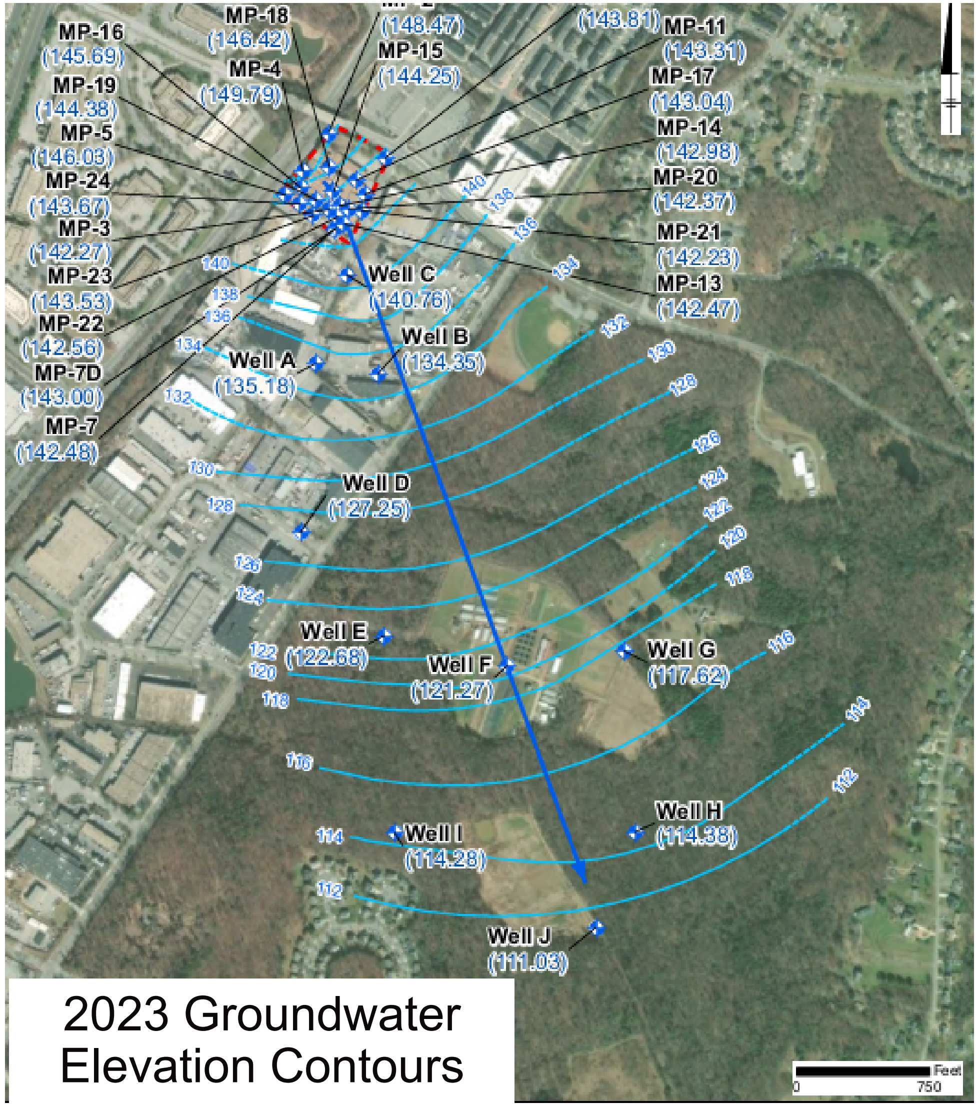


VAP Sample Results – Hexavalent Chromium

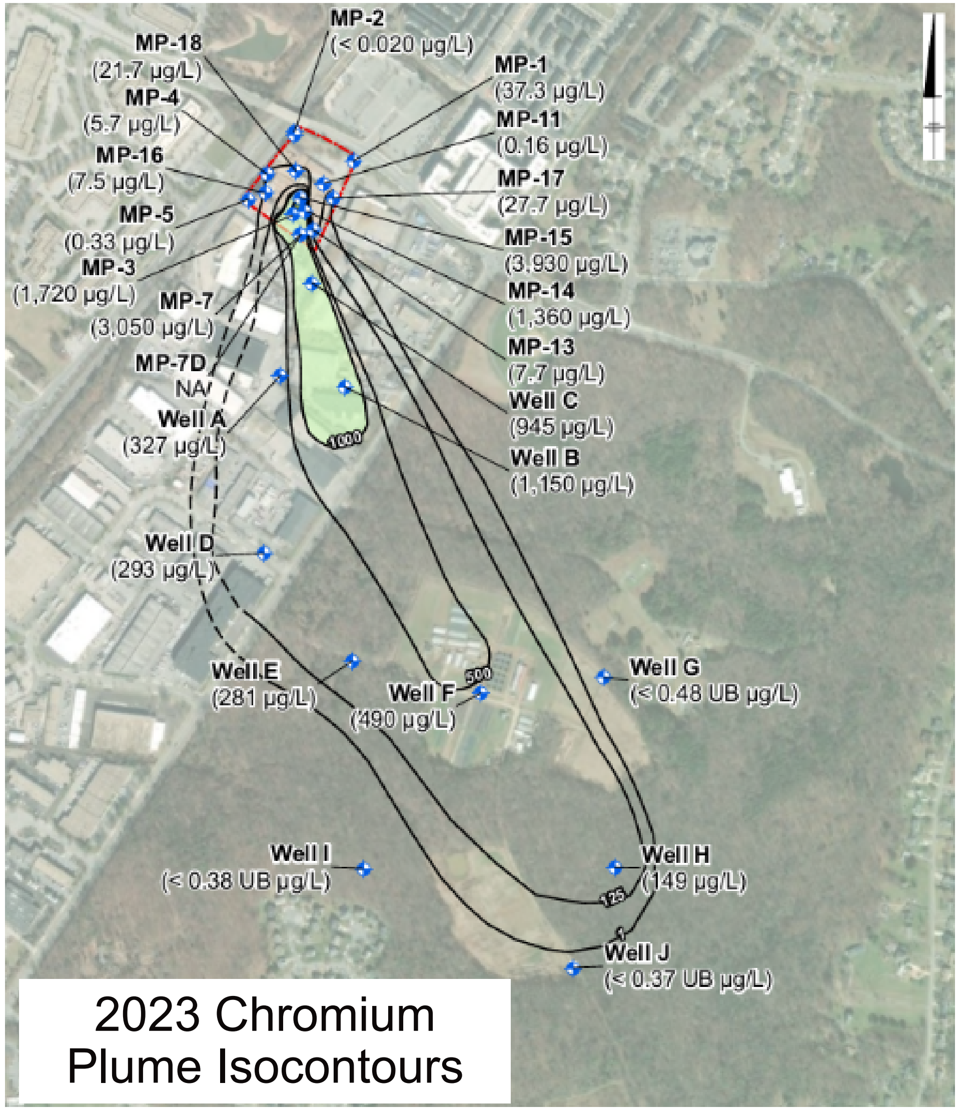
- Non-detect
- < 100 ug/L
- 100 to 500 ug/L
- 500 to 1,000 ug/L
- > 1,000 ug/L

ARCADIS

Expanded Well Network Monitoring Results



2023 Groundwater Elevation Contours



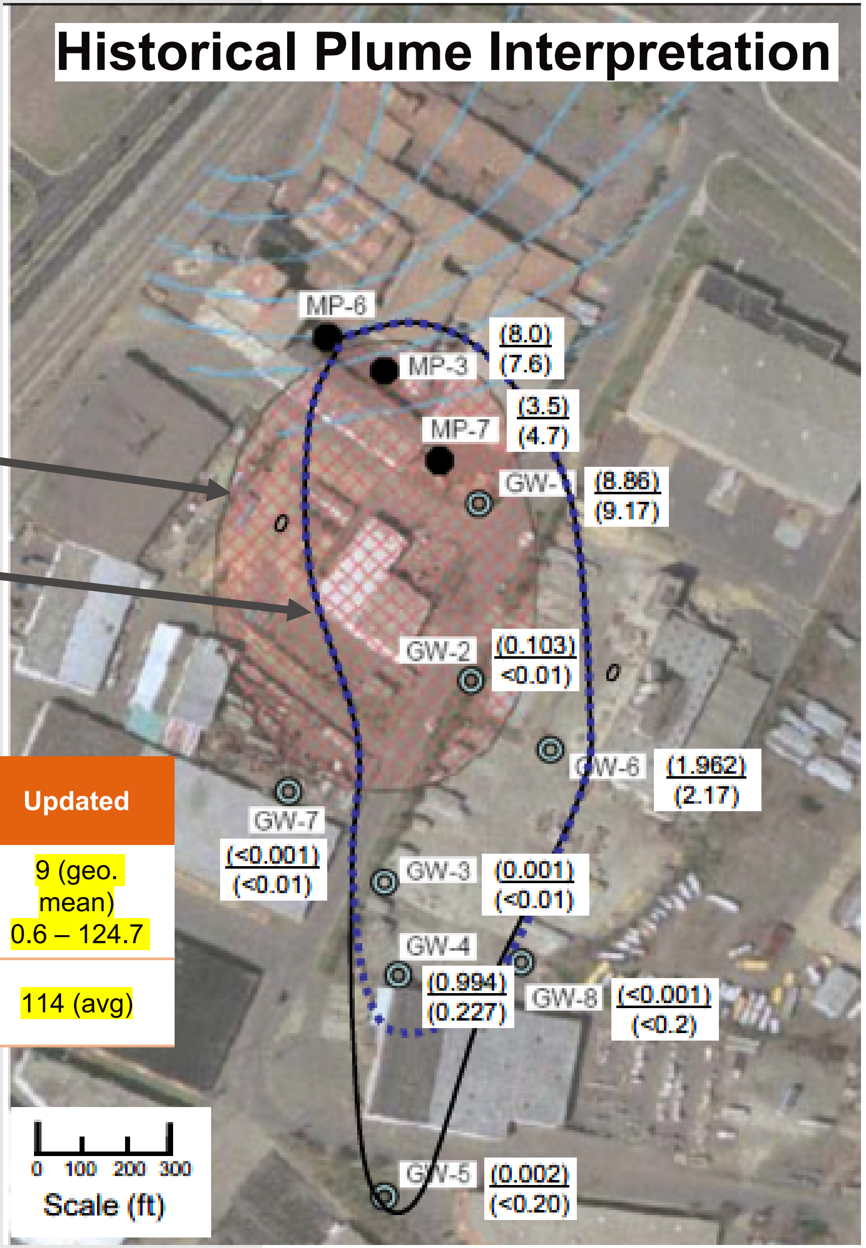
2023 Chromium Plume Isocontours

Site-wide chromium isocontours and groundwater elevation contours

Plume dimensions

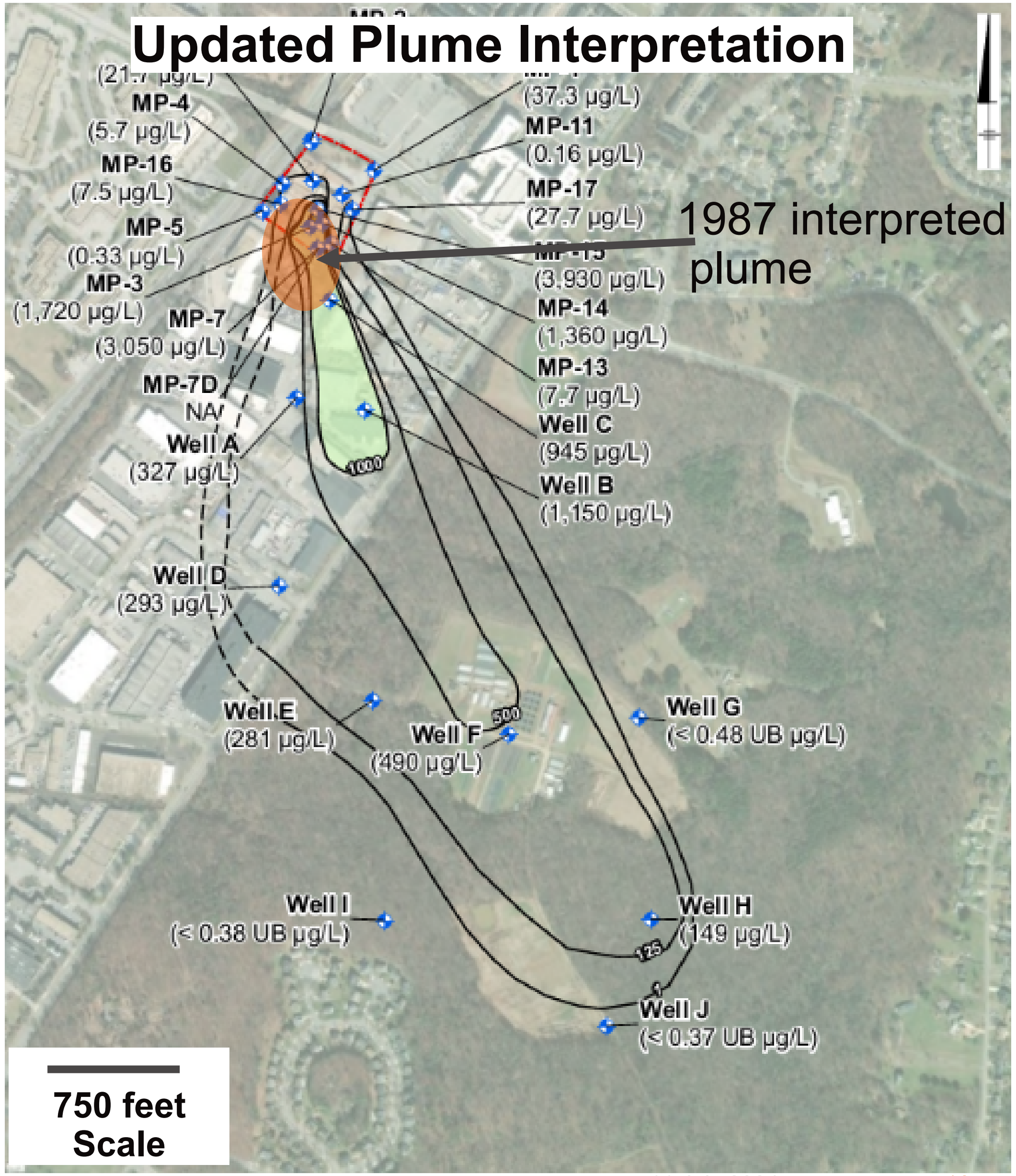
- ~ 0.8 miles length
- 115 acres
- 6.5-acre plume core

Updated Conceptual Site Model



1987 interpreted plume

2008 interpreted plume



Parameter	Units	Historical	Updated
Hydraulic conductivity	ft/day	0.93	9 (geo. mean) 0.6 – 124.7
Bulk gw velocity	ft/year	12	114 (avg)

Step 3 - Remedy Selection to Support Future Property Sale and Site Redevelopment

Soil	
Process Option/Technology Evaluated*	**Selected Remedy Component****
No action	
Institutional controls (environmental covenant and material management plan)	X
Capping (maintain existing engineered barrier)	X
Excavation (soil hotspots)	X
In-situ treatment (biological or chemical via infiltration gallery)	

*Corrective Measure Study

** Final Decision

Groundwater	
Process Option/Technology Evaluated*	**Selected Remedy Component****
No action	
Institutional controls (environmental covenant w/ groundwater use restrictions)	X
Capping (maintain existing engineered barrier)	X
Monitored natural attenuation	X
In-situ treatment (biological or chemical treatment via injection wells)	X

*Corrective Measure Study

** Final Decision

ARCADIS

In-situ Treatment Approaches

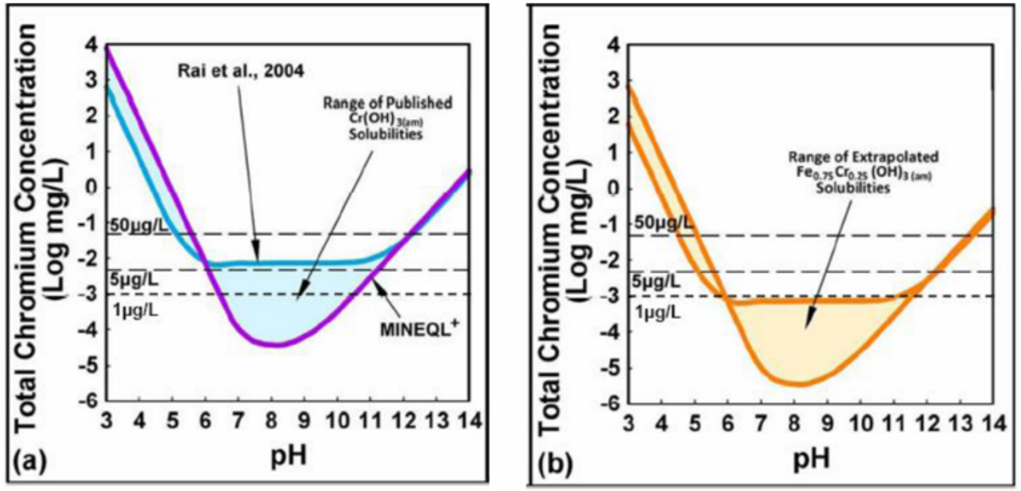
- Chromium is a redox sensitive metal
  - Trivalent chromium – Cr(III)
    - Prevalent in natural soils
    - Low solubility in the circum-neutral pH range
  - Hexavalent chromium – Cr(VI)
    - Mobile under oxidizing conditions
    - Generally soluble across pH

- The use of biological or chemical reagents is a common treatment approach for Cr(VI) in groundwater

- During in-situ treatment, Cr(VI) is transformed to low-solubility Cr(III) precipitates.

Chromium Precipitate Solubility Curves

Chromium Oxides — Iron-Chromium Oxides



- $Cr(VI)_{(aq)}$ + 3e- = $Cr(III)_{(s)}$
- $Cr(III)_{(s)}$ has low solubility, but depends upon mineral form

Common In-Situ Treatment Approaches for Cr(VI) Reduction to Cr(III)

	In-Situ Biological Sequestration	In-Situ Chemical Sequestration
Reagent	Organic carbon (e.g., molasses, lactate, emulsified vegetable oil)	Reducing agent – reduced iron or sulfur (e.g., polysulfide, ferrous sulfate, dithionite)
Cr(VI) Reduction Process	Direct microbial reduction or indirect by reduced iron / sulfur generated in-situ	Direct chemical reduction by reduced iron / sulfur
Cr Sequestration	Cr(III) hydroxides and iron-chromium hydroxides, sorption	

Final Remedy Development

Highlights of remedy operational flexibility and project accelerators

- Developed **a site-specific action level** for hexavalent chromium
  - No established USEPA MCL for hexavalent chromium
  - USEPA Regional Screening Level (0.035 ug/L) near analytical detection limit
  - Developed action level based on a mid-risk range ($1x10^{-5}$) = 0.35 ug/L
- Fully delineated the plume and **began routine groundwater monitoring before approval of the Final Decision** and Corrective Action Work Plan to confirm plume wide trends
- Selected **in-situ groundwater treatment** as the groundwater treatment remedy to provide flexibility to pursue either biological or chemical treatment based on site conditions/performance monitoring results
- Conducted a **short injection test to collect operational parameters** to support the groundwater remedial design in the Corrective Action Work Plan, which also included injection of a biological amendment at one location

Summary and Major Takeaways

- **Summary**
  - Proceeded from investigation to remedy selection and work plan approval in less than seven years
- **Major remedial progress accelerators**
  - Early voluntary and collaborative stakeholder engagement created an atmosphere of trust leading to accelerated document review and decision making
  - Use of initial low-cost approaches (such as desktop reviews, site visits, and virtual meetings) played an important role in rethinking the inherited conceptual site model
  - Early development of Corrective Action Objectives guided the field investigations and overall remedial strategy
- **Current status**
  - Property sale completed in 2023
  - Demolition and remedial actions planned for second half of 2024

Our Team

Prashanth Khambhammettu, PhD

Principal Environmental Engineer
Hydrogeology/Modeling

Hanover, MD

23 years of experience /
5 years with Arcadis

Prashanth.Khambhammettu@arcadis.com

Erika Carter, PhD

Principal Geoscientist
Remediation Geochemist

Hanover, MD

25 years of experience /
17 years with Arcadis

Erika.Carter@arcadis.com

Additional Co-Authors:

<u>Arcadis U.S. (Hanover, Maryland)</u>

- Matt McCaughey, Principal Geologist
- Hilda Fadaei, PhD, Project Env. Engineer
- Tim Blount, Env. Engineer

<u>Albemarle Corporation (Charlotte, North Carolina)</u>

- Trey Fortenberry, Environmental Manager

The End