BATTELLE 2023 SEDIMENTS CONFERENCE

NAPL Mobility at the Newtown Creek Superfund Site – Multi-Stage Testing Results and Data Evaluation

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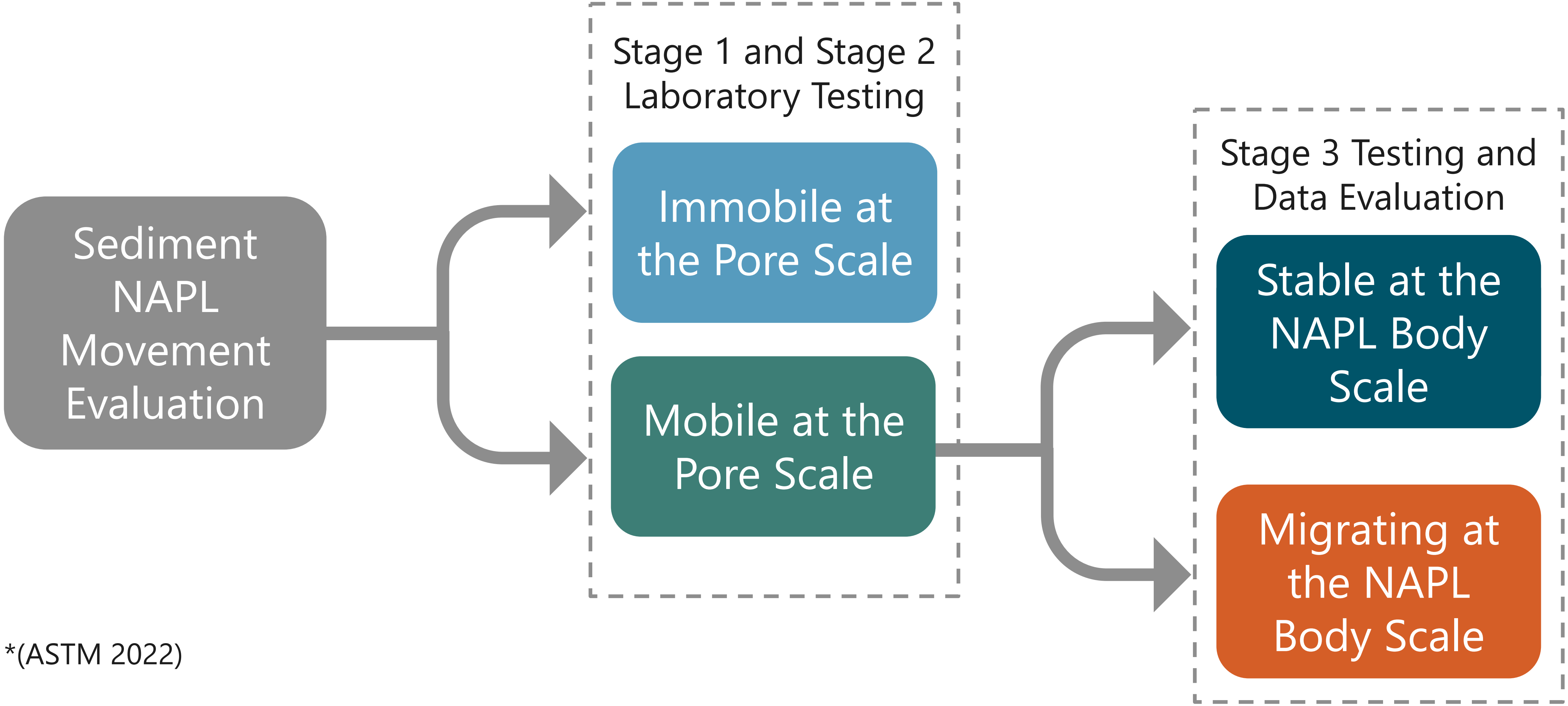
ANCHOR QEA

NAPL Movement Evaluation

Tiered Approach Similar to New ASTM Guide E3282*



*(ASTM 2022)

CHALLENGE

Characterize potential for NAPL movement in sediment and native materials via advection in a large system with a range of NAPL conditions and porous media

CHALLENGE

Project Background

- 3.8-mile-long urban waterway
- Soft, organic silty sediment overlies firmer native materials, including alluvium and glacial deposits
- NAPL identified in soft sediment and native deposits
  - Previous USEPA-approved investigations delineated NAPL-containing areas and depths*

Newtown Creek Superfund Site

* NAPL field identification methods were consistent with NYSDEC field guidance and similar to those presented in the new ASTM Guide E3281 (ASTM 2021).

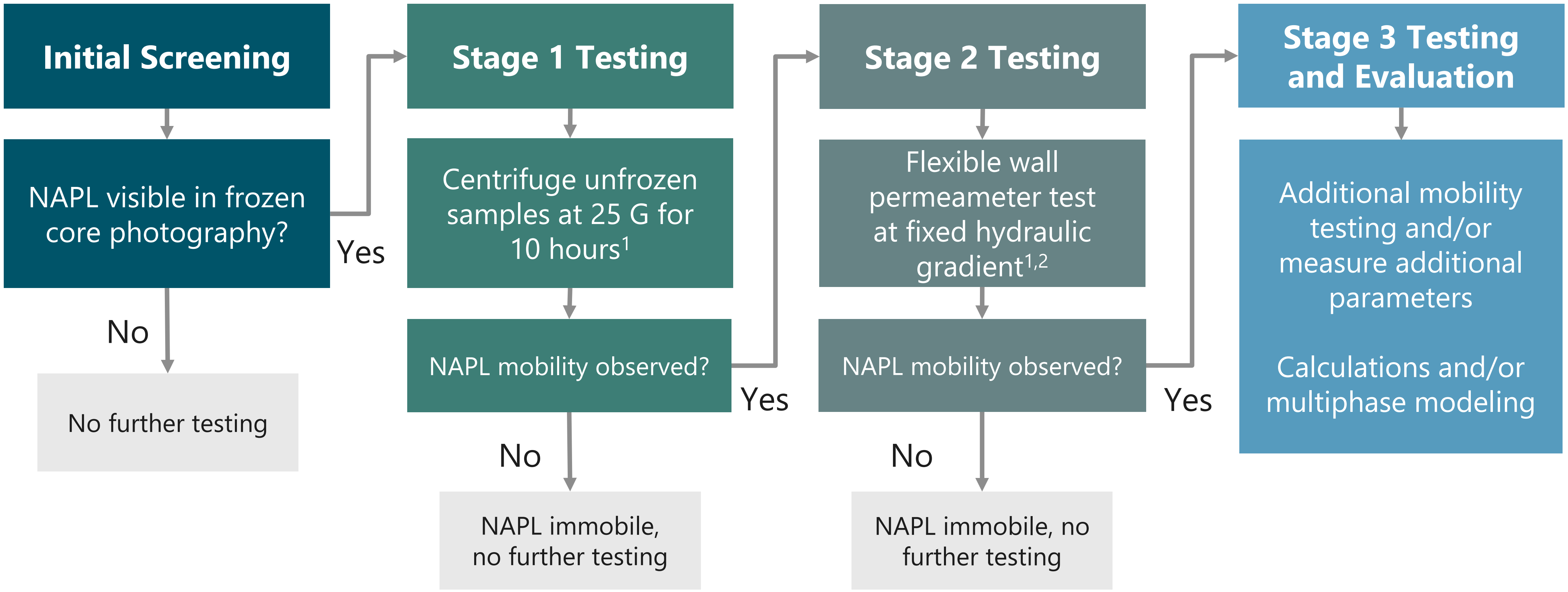
CHALLENGE

NAPL Mobility Assessment Objectives

- Support FS evaluation of remedial technologies and alternatives
- Characterize potential for NAPL movement via advection—in sediment and underlying native materials—in two types of areas delineated based on previous work
  - Potentially mobile (field screening indicated a relatively higher potential for NAPL mobility)
  - Likely immobile (field screening indicated NAPL mobility unlikely)

Tiered, three-stage laboratory testing and data evaluation process used to characterize NAPL movement potential

Staged NAPL Mobility Testing



Notes:

1. Measurements include initial and final pore fluid saturations, total porosity, specific gravity, and dry bulk density.
2. Testing of selected core samples will be performed at a hydraulic gradient between 0.5 and 4.

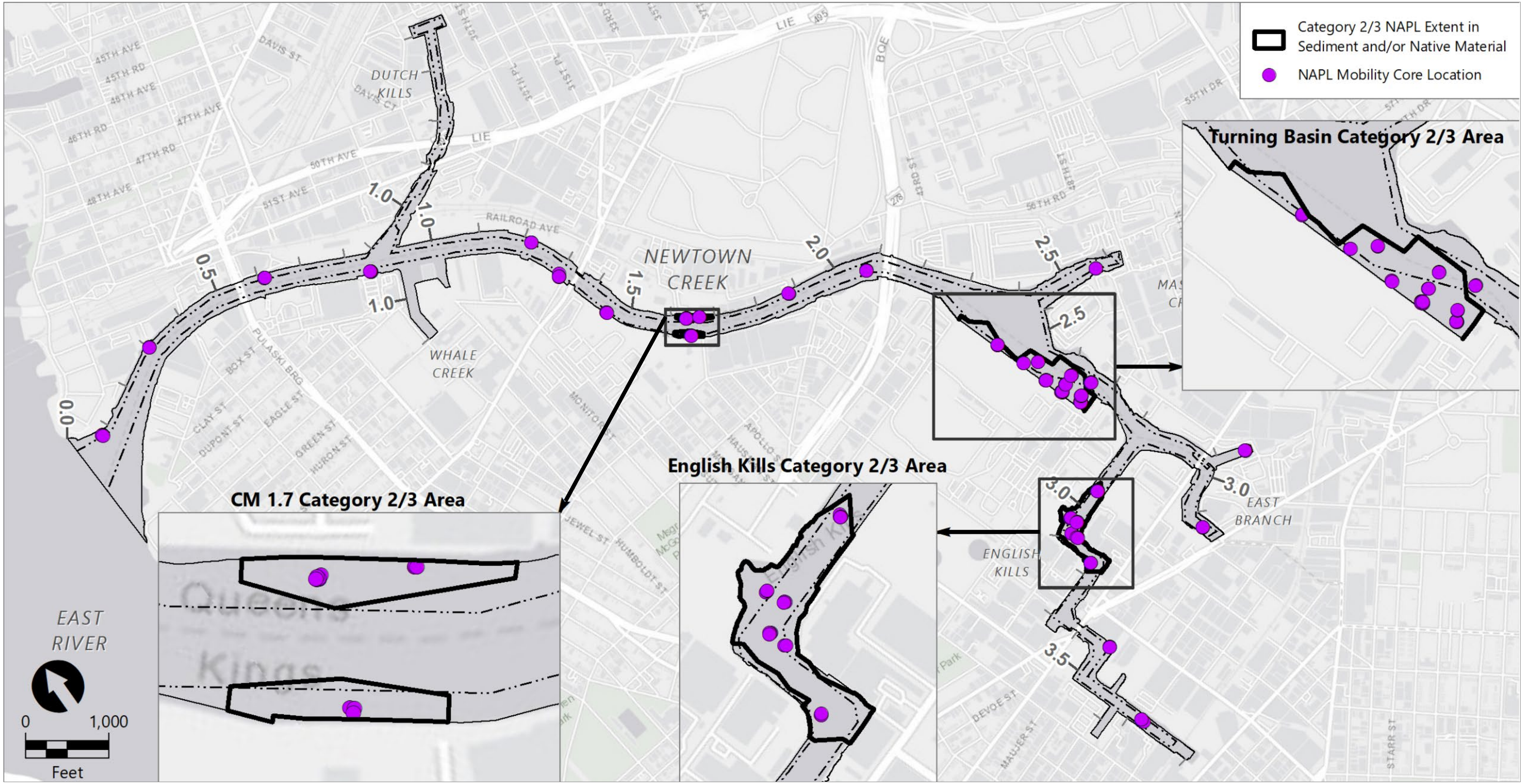
Extent of Sampling and Testing Program

- 33 core stations and 103 cores total
- At least three cores collected at each station through sediment to, or into, native material
- More than 430 core sections slabbed and photographed under white light and ultraviolet light
- Intervals with most notable NAPL presence selected for laboratory NAPL mobility tests

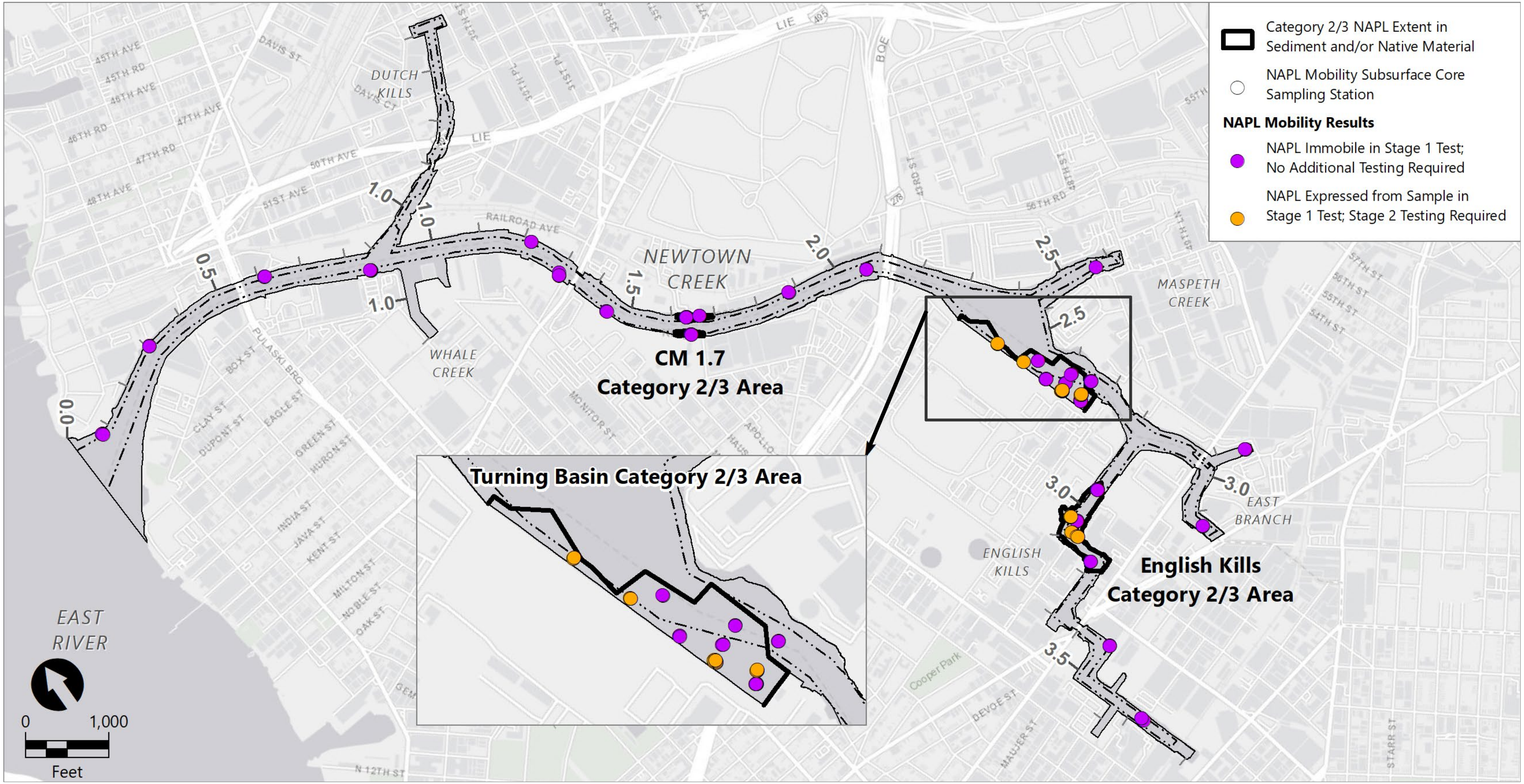
Extent of Sampling and Testing Program

- **Stage 1** – centrifuge tests (n = 81)
  - Gradient more than 100 times greater than the highest instantaneous upward hydraulic gradient measured in the Study Area
- **Stage 2** – flexible wall permeameter tests (n = 10)
  - Gradients 2 to 7 times greater than the highest instantaneous upward hydraulic gradient measured in the Study Area
- Tested for NAPL movement and porous media physical properties

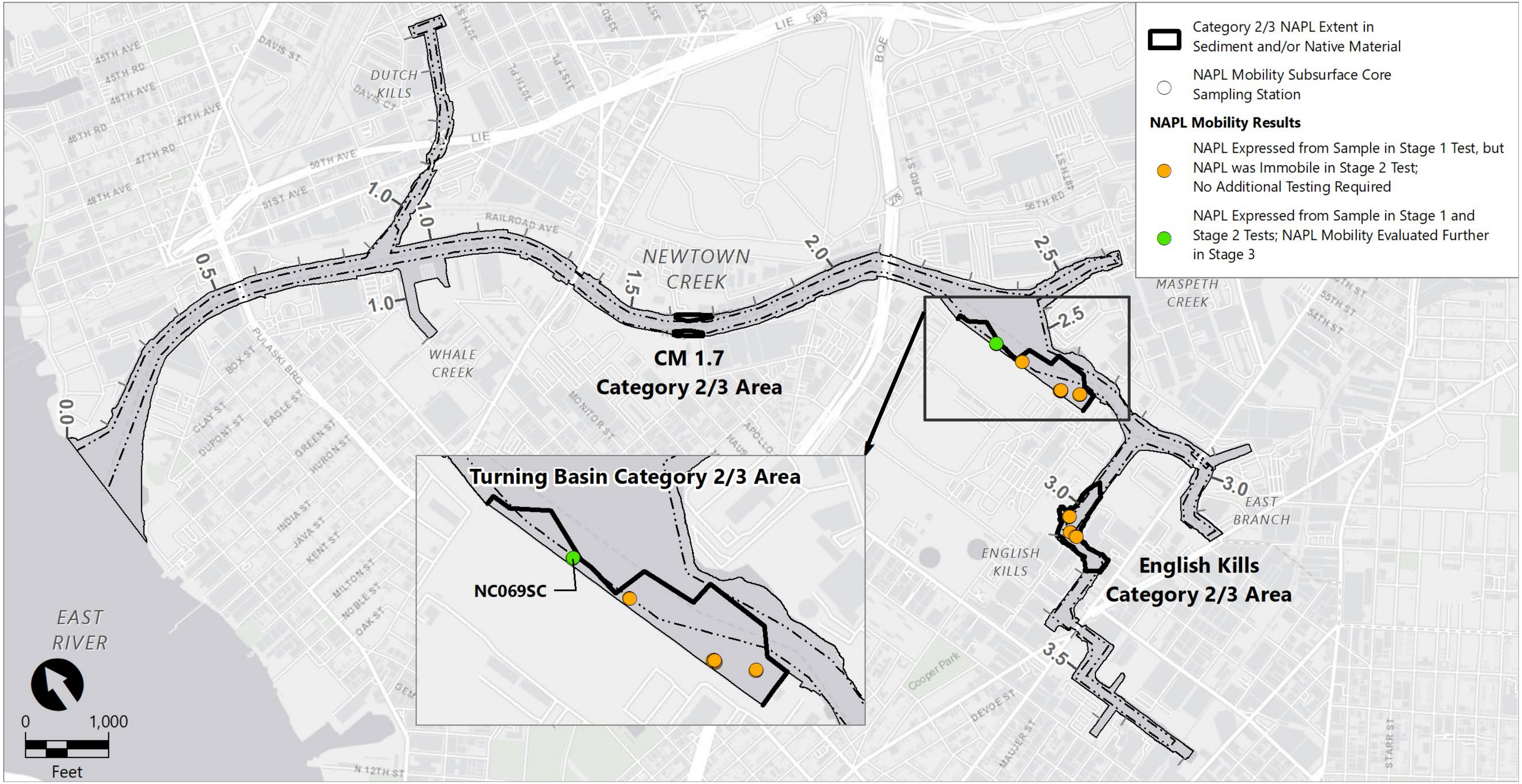
NAPL Mobility Core Sample Locations (n = 33)



Stage 1 Test Results



Stage 2 Test Results



Summary of Stages 1 and 2 Testing Results

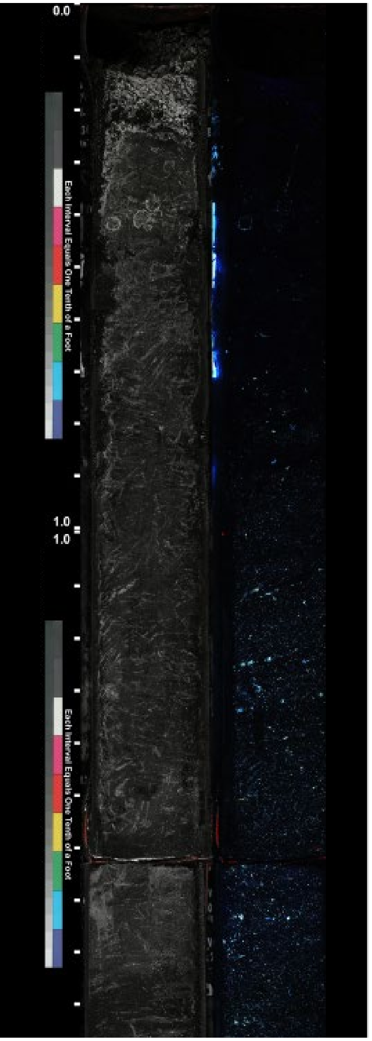
- At all NAPL mobility test sample locations and depths except one, NAPL was immobile at the pore scale
- At one NAPL mobility test sample location and depth (NC069SC), NAPL was mobile at the pore scale **under laboratory test conditions**
  - NAPL movement potential **under reasonably expected field conditions** evaluated further in Stage 3

Stage 3 Evaluation

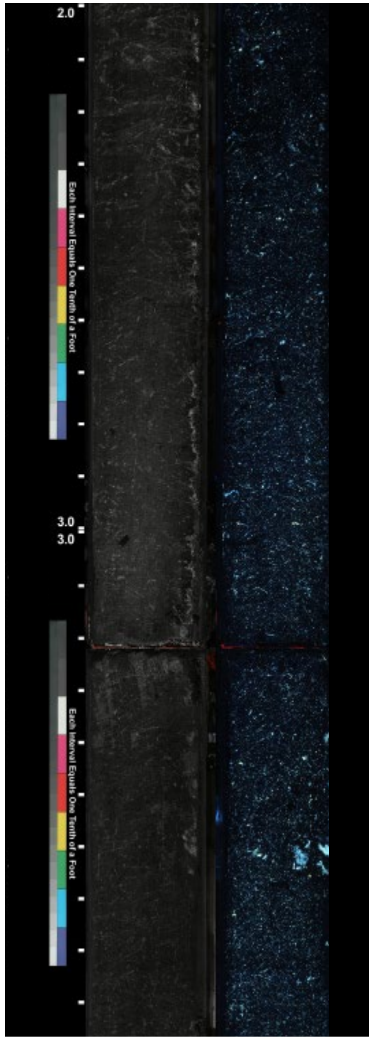
- Evaluated potential for NAPL to migrate under field conditions
- Three lines of evidence (LOEs)
  - Qualitative Stage 3 evaluation
    - **LOE No. 1**: Detailed review of NC069SC core photographs
  - Quantitative Stage 3 NAPL mobility calculations
    - **LOE No. 2**: NAPL effective hydraulic conductivity
    - **LOE No. 3**: Continuous NAPL thickness required to exceed pore entry pressure and move upward (used NC069SC data from remedial investigation and NAPL physical properties from literature)

LOE No. 1: NC069 Core Photo Observations (0 to10 ft)

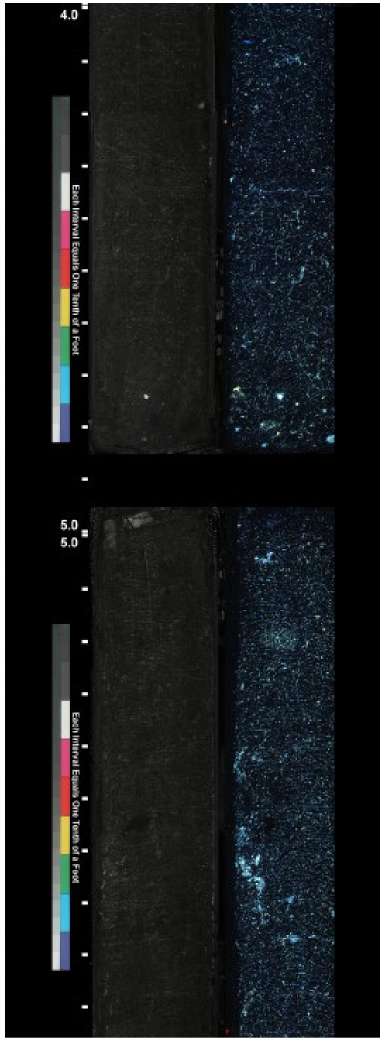
0 to 2 feet



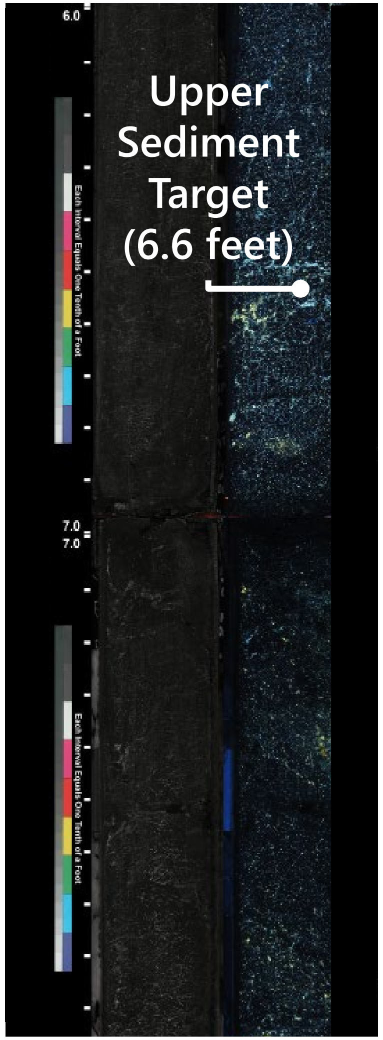
2 to 4 feet



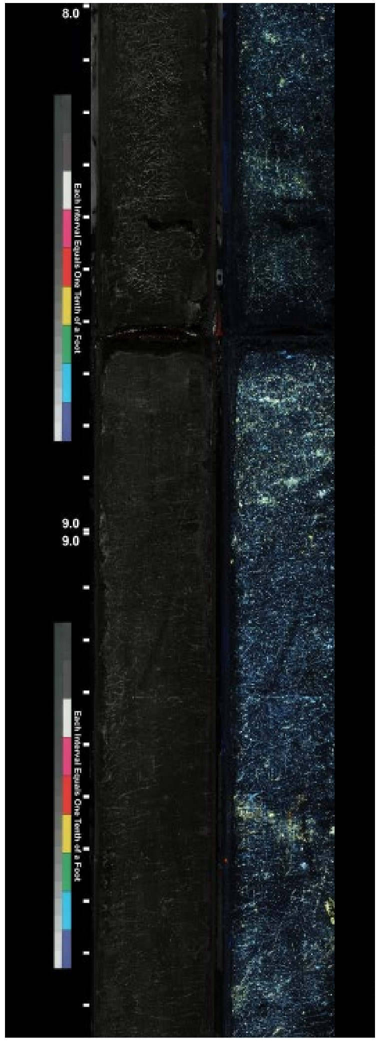
4 to 6 feet



6 to 8 feet



8 to 10 feet



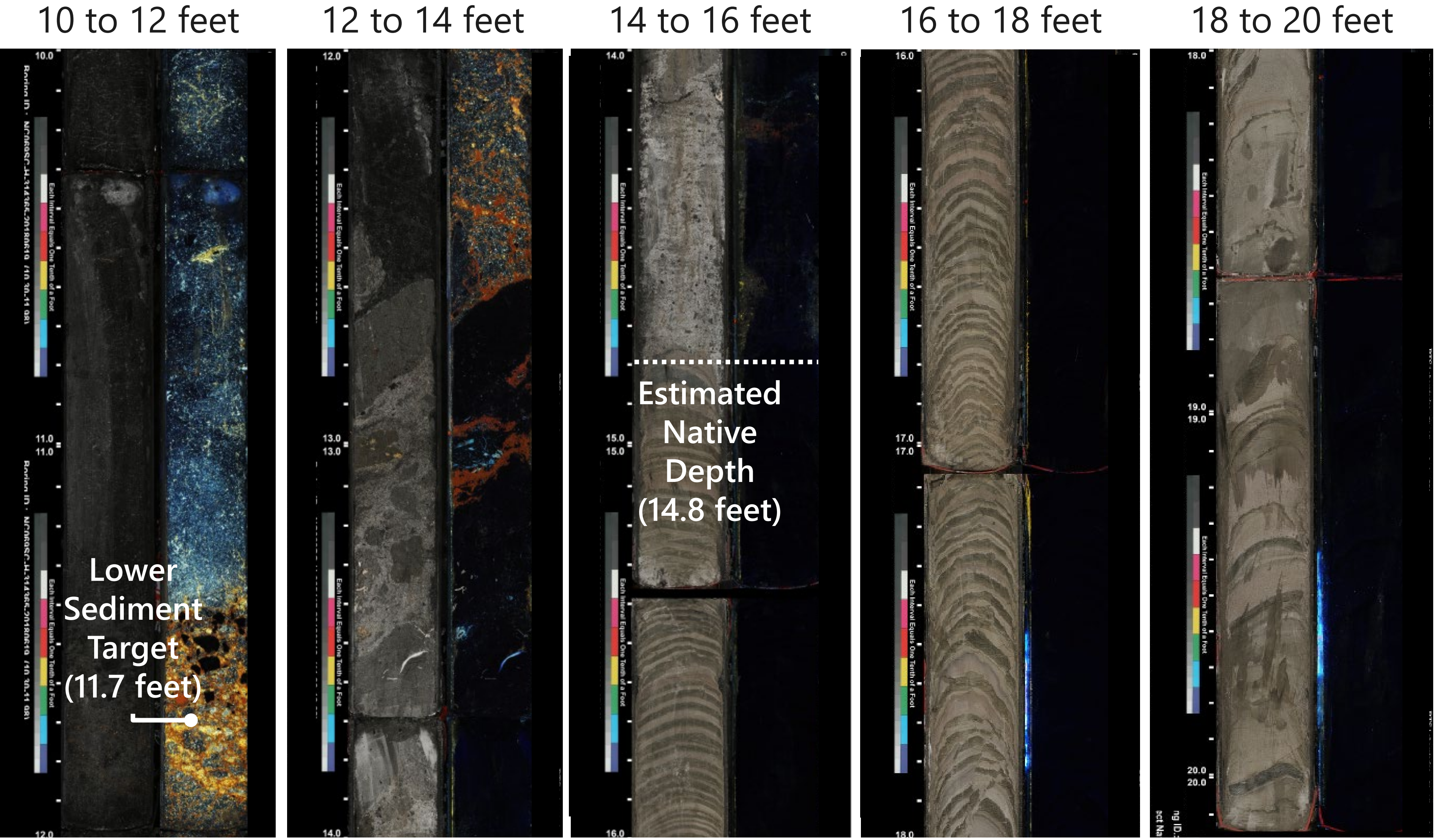
Upper sediment test sample taken from collocated unfrozen core

- NAPL saturation: 6.2%
- Stage 1 result: NAPL immobile

Relatively little NAPL in top 10 feet of sediment

Dispersed, discrete fluorescent specks in a non-fluorescing matrix

LOE No. 1: NC069 Core Photo Observations (10 to 20 ft)



Lower sediment test samples taken from collocated unfrozen core

Stage 1

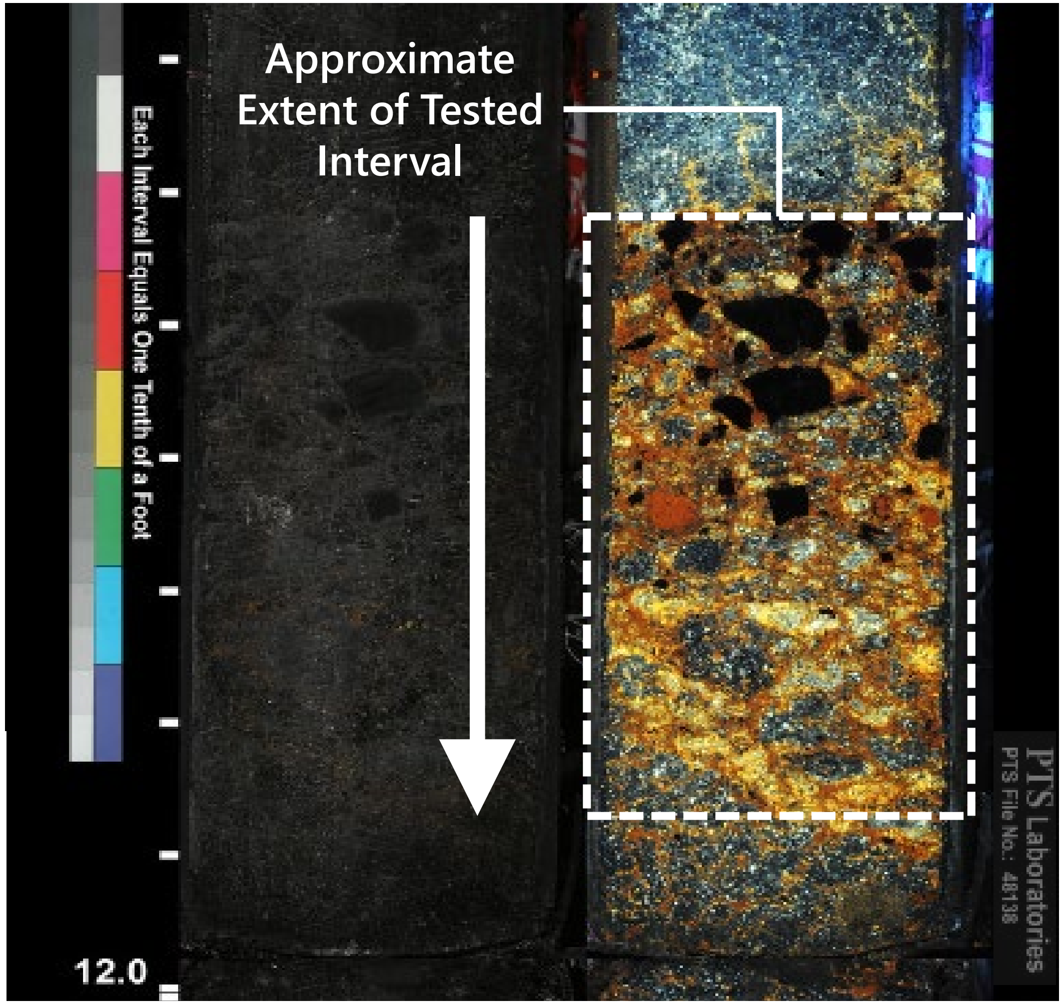
- NAPL saturation: 20.8%
- Result: NAPL mobile under test condition

Stage 2

- NAPL saturation: 26.1%
- Result: NAPL mobile under test condition

LOE No. 1: NC069SC Core Photo Observations

- Ultraviolet fluorescence intensity increases in the **downward** direction
- NAPL saturation increases in the **downward** direction
- Net vertical gradient is downward (i.e., the NAPL is a DNAPL)
- Upward NAPL movement unlikely



LOE No. 2: NAPL Effective Hydraulic Conductivity (K_n)

- Quantifies NAPL flow based on Darcy's Law

$$K_n = Q_n / (Ai)$$

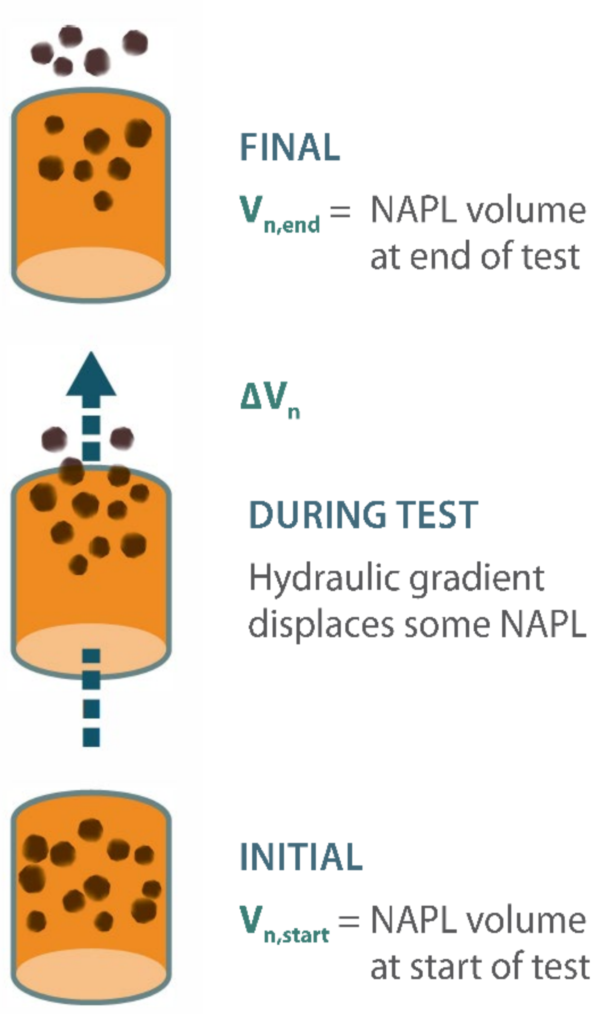
where:

Q_n = average NAPL flow rate (cm^3/s)

A = cross-sectional area for flow (cm^2)

i = lab test hydraulic gradient (unitless)

- Parameters obtained from NAPL mobility test report
- Accounts for soil/sediment pore sizes and NAPL viscosity, saturation, and relative permeability



Source: Gefell et al. (2018)

LOE No. 2: NAPL Effective Hydraulic Conductivity (K_n)

Parameter Description	Parameter Symbol (units)	Stage 1 Test Result	Stage 2 Test Result
Change in NAPL volume	ΔV_n (cm^3)	0.22	0.68
Time	t (s)	36,000	605,000
Average NAPL flow rate	Q_n (cm^3/s)	6.1×10^{-6}	1.1×10^{-6}
Cross-sectional area for flow	A (cm^2)	11	45
Lab test hydraulic gradient	i (unitless)	25	0.5
NAPL effective hydraulic conductivity	**K_n (cm/s)**	**2×10^{-8}**	**5×10^{-8}**
Conclusion: NAPL immobile			

For comparison, typical hydraulic conductivity performance standards for in situ solidification are on the order of 10^{-7} cm/s (ITRC 2011); therefore, $K_n < 10^{-7}$ cm/s is considered immobile.

LOE No. 3: Stable NAPL Thickness

$$h_n = \frac{P_{e(nw)}}{\left(\frac{\rho_w - \rho_n}{\rho_w} + \frac{dh_w}{dz}\right)} \quad (1)$$

$$P_{e(nw)} = 9.6\ (\sigma_{nw}\ /\sigma_{aw})\ (K_w/n)^{-0.403} \quad (2)$$

h_n = maximum stable NAPL thickness (cm^3)

$P_{e(nw)}$ = entry pressure of sediment above NAPL body

ρ_w = water density (g/cm^3)

ρ_n = NAPL density (g/cm^3)

dh_w/dz = vertical hydraulic gradient (dimensionless; positive for upward flow)

σ_{nw} = NAPL-water interfacial tension (dynes/cm)

σ_{aw} = air-water interfacial (surface) tension (dynes/cm)

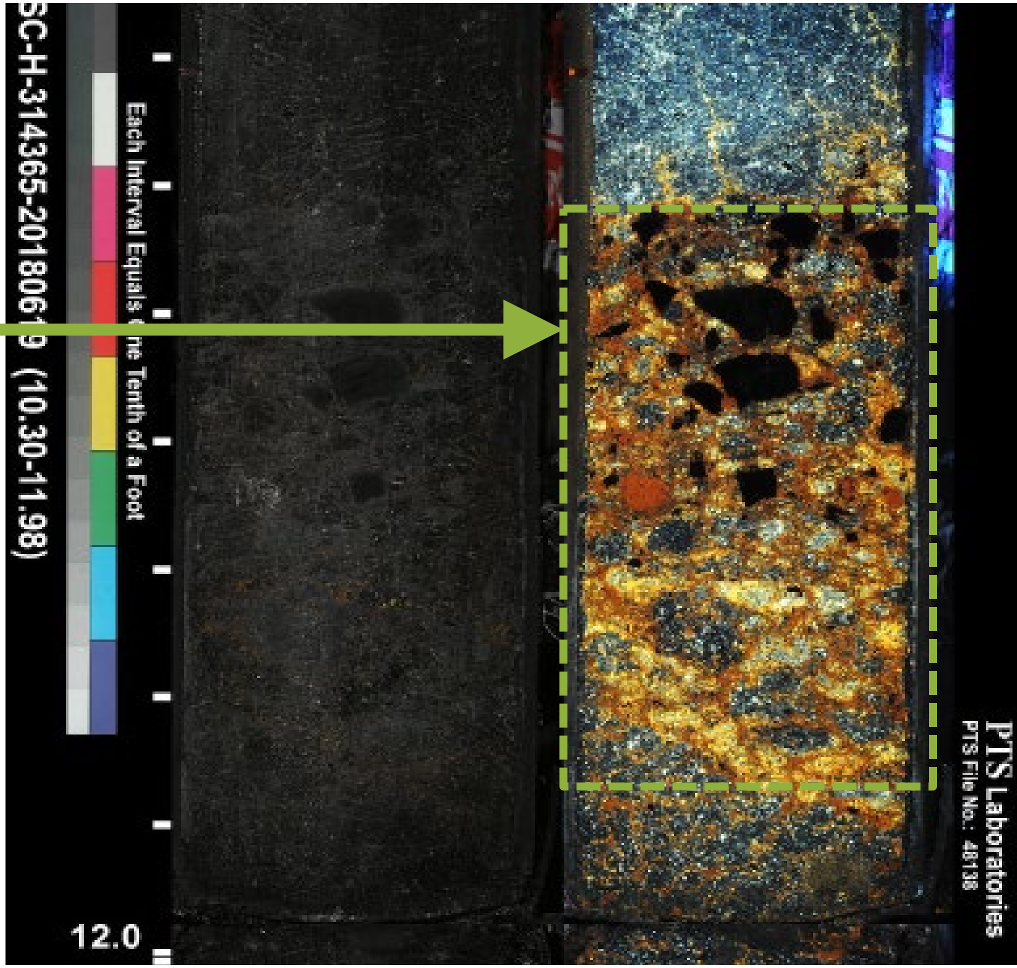
K_w = water-saturated vertical hydraulic conductivity (cm/s)

n = sediment porosity

Sources: Equation 1 based on Payne et al. (2008); Equation 2 from McWhorter and Kueper (1996).

LOE No. 3: Stable NAPL Thickness

- Based on sensitivity analyses, **NAPL thicknesses less than 2.6 to 42 feet are stable** (cannot exceed pore entry pressure)
- Observed NAPL layer thickness is **0.5 foot**
- NAPL in deep sediment at NC069SC cannot exceed pore entry pressure of overlying sediment **(cannot move upward)**



SOLUTION / LESSONS

Summary

- NAPL mobility program designed to evaluate whether migration of NAPL via advection is possible under field conditions
- At all NAPL mobility sampling locations and depths except one (deep sediment at station NC069SC), NAPL was immobile based on Stage 1 and Stage 2 laboratory test results
- Stage 3 evaluations using three LOEs indicated NAPL in deep sediment at station NC069SC immobile under reasonably expected field conditions

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NAPL in sediment and native materials at Newtown Creek Superfund Site is immobile (i.e., cannot migrate via advection)

THANK YOU

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REFERENCES

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