Appendix A
Breakpoint Analysis

NAPL Core Area Determination – Wyckoff/Eagle Harbor Superfund Site Upland Area

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DATE: August 14, 2013

A breakpoint analysis of soil volume requiring treatment was performed along with an examination of the Thiessen polygons to determine the “core” area of NAPL-impacted soils in the upland area at the Wyckoff/Eagle Harbor Superfund Site. This area is intended to represent the area where aggressive remedial technologies would be considered in the Feasibility Study.

Thiessen Polygons

A Thiessen polygon map was created using the “Create Thiessen Polygons” tool in Spatial Analyst in ArcGIS to visualize the Thiessen polygons represented by the TarGOST locations, as described in the *2013 Wyckoff Upland NAPL Field Investigation Technical Memorandum* (CH2M HILL, 2013). The area contained within each Thiessen polygon was then calculated using ArcGIS. Additionally, the depths to the aquitard in each polygon were used to calculate the soil volumes in each polygon, and the length of impacted soil at each TarGOST location was used to calculate the volumes of NAPL-impacted soil within each polygon.

The polygons were divided into three compartments for analysis. Compartment 1 includes all soil between the ground surface and the -5 ft Mean Lower Level Water (MLLW). Compartment 2 includes all soil between -5 ft MLLW and 10 feet above the aquitard. Compartment 3 includes all soil between 10 feet above the aquitard and the bottom of the boring. These compartments are shown in Figure 1.

The data analysis used to determine the extent of NAPL impact in each polygon consisted of summing the total thickness of the TarGOST response above the 10 percent RE threshold in the boring, regardless of thickness of the response. CH2M HILL’s understands that the MVS work being conducted by Sundance also uses the entire TarGOST data set exceeding the 10 percent RE threshold, but the data is then krieged using a 6-inch grid spacing.

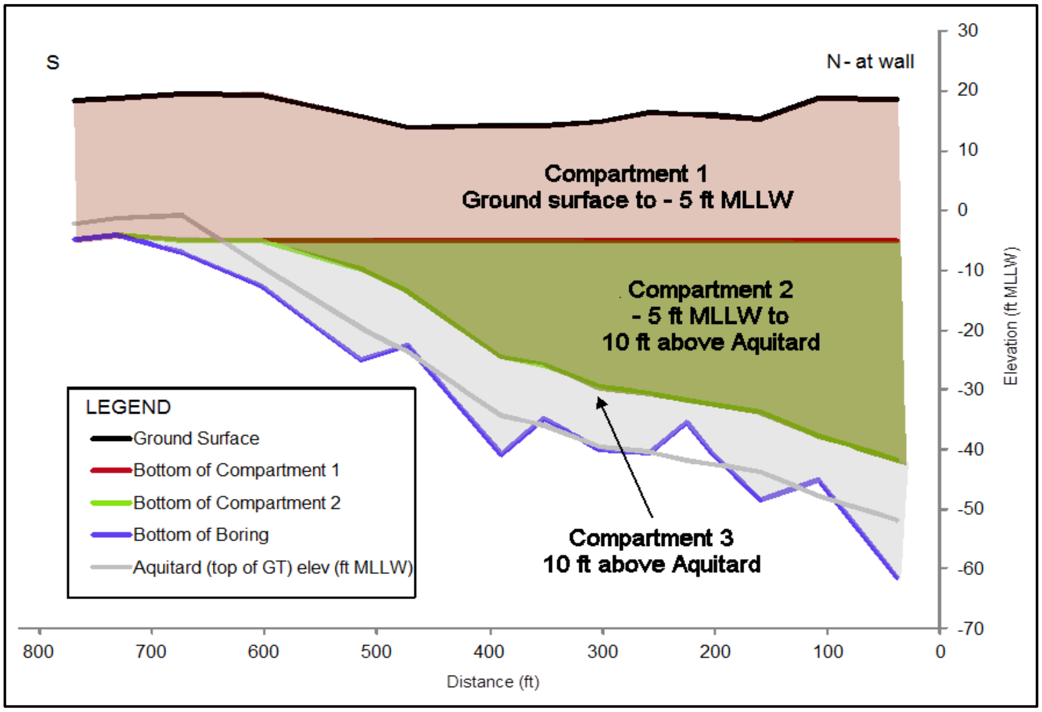


Figure 1. Soil Compartments

Soil Treatment Break-Point Analysis

The process described in this section has been used in Feasibility Studies where the “maximum extent practicable” was used as a remediation objective. For soil impacts, the mass of soil contaminants were estimated versus the volume of soil removed. By identifying the break points in the curve, the “maximum extent practicable” volume was identified. This analysis extends this concept to the “NAPL impacted volume” and the “total soil volume” estimated for the site. By identifying where the total soil volume increases at a higher rate than the impacted volume, a core NAPL target area can be identified.

Because the NAPL impacts in Compartment 1 are higher and more spatially distributed than in Compartments 2 and 3, the data was analyzed using Compartment 1 data alone and a second dataset comprised of compartments 2 and 3 data combined.

Compartment 2 and 3 Analysis

The NAPL-impacted volume and total volume of each compartment were summed, and the resulting total volumes were sorted by largest to smallest percent impacted soil volume. The cumulative NAPL-impacted volume was plotted versus the cumulative total volume (Figure 2), and a breakpoint was evident around 20,000 CY of NAPL-impacted soil and approximately 35,000 CY total soil volume; a ratio of 56 percent.

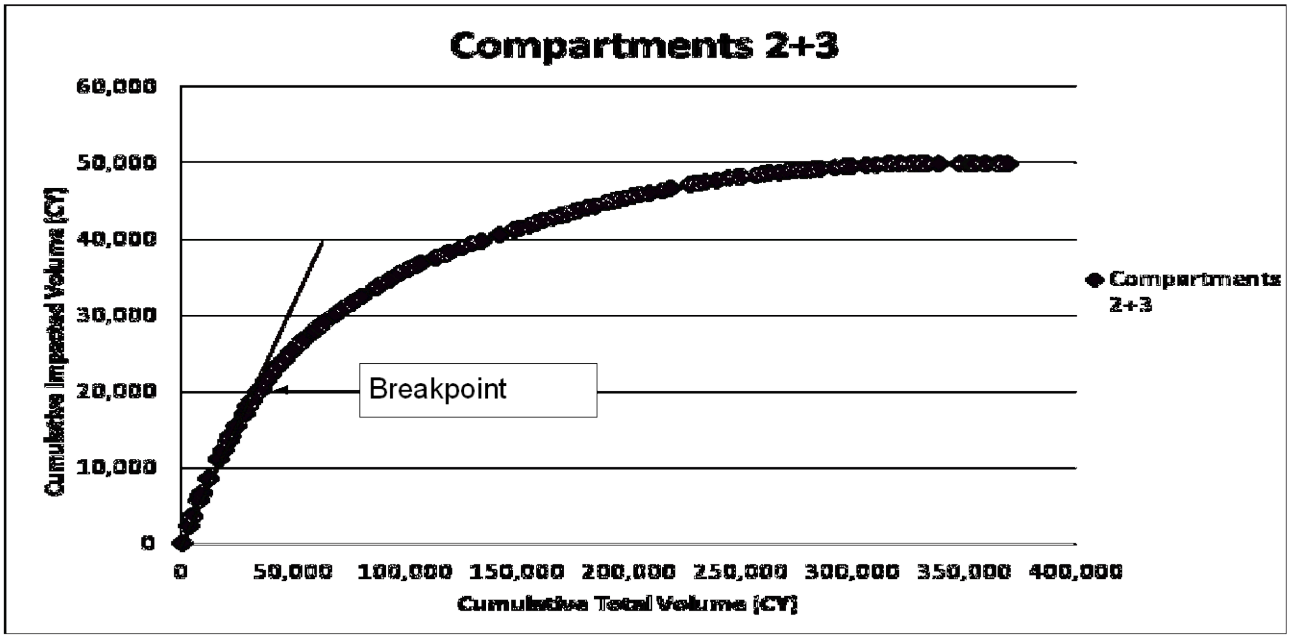


Figure 2. NAPL-Impacted Soil Volume versus Total Soil Volume for Compartments 2 and 3

After this breakpoint, the additional total volume of soil that must be treated increases at a much greater rate than the additional volume of NAPL-impacted soil that is being treated for each step-wise increase. This is illustrated by the incremental change above the breakpoint. To include an additional 10,000 CY affected volume, target volume increases to 68,000 CY with an overall ratio of (30,000/68,000) of 44 percent. The incremental increase of the additional 10,000 CY affected volume/33,000 incremental target volume is only 30 percent compared to 56 percent at the breakpoint. When the polygons falling below the Compartments 2/3 Breakpoint were plotted on a plan view of the site, the result was three discontinuous areas, two of which were separated by a single row of polygons that did not fall below the breakpoint. However, the area between these two sets of polygons that did fall below the breakpoint was so small that those three additional polygons were also included to create one large area for treatment. These additional polygons were called the Compartment 2/3 Breakpoint Connectors. This area added an additional 4,750 CY of NAPL-impacted soil and approximately 13,500 CY total soil volume; a ratio of 35 percent.

Compartment 1 Analysis

The same process was used for Compartment 1, except only the Compartment 1 data was used.

Figure 3 presents the results of the Compartment 1 analysis. Review of this figure did not identify a clear breakpoint as was evident for the Compartment 2+3 analysis. An initial breakpoint was identified at 20,000 CY affected volume, and approximately 40,000 CY total volume, but is not a distinct breakpoint. In addition, since impacts in Compartment 1 are shallow compared to compartment 2/3, additional treatment technologies are potentially viable for this compartment. Therefore, additional incremental steps in the affected volume of 10,000 CY each were included in this analysis.

To include an additional 10,000 CY affected volume, the target volume increases to 70,000 CY with an overall ratio of (30,000/70,000) of 43 percent. The incremental increase of the additional 10,000 CY affected volume/30,000 incremental target volume is only 33 percent compared to 56 percent at the breakpoint.

To include an additional 20,000 CY affected volume, the target volume increases to 110,500 CY with an overall ratio of (40,000/110,500) of 36 percent. The incremental increase of the additional 20,000 CY affected volume/70,500 incremental target volume is only 28 percent compared to 56 percent at the breakpoint.

To include an additional 30,000 CY affected volume, the target volume increases to 172,700 CY with an overall ratio of (50,000/172,700) of 29 percent. The incremental increase of the additional 30,000 CY affected volume/132,700 incremental target volume is only 23 percent compared to 56 percent at the breakpoint.

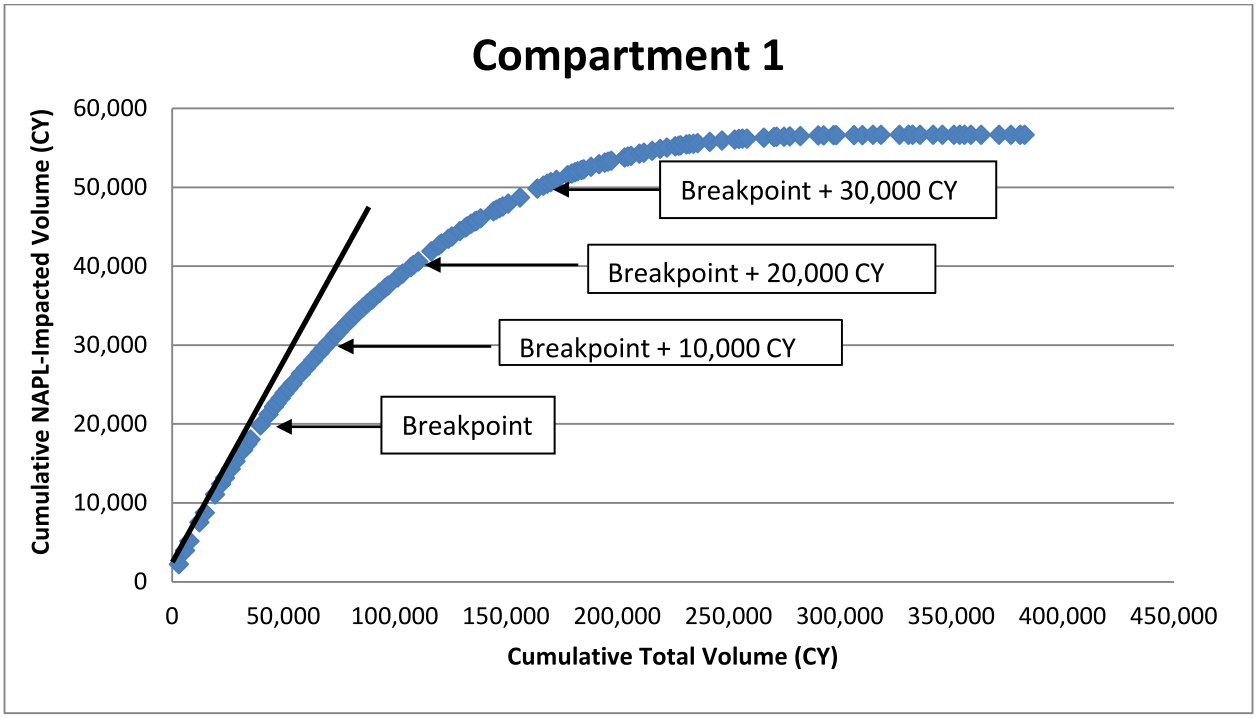
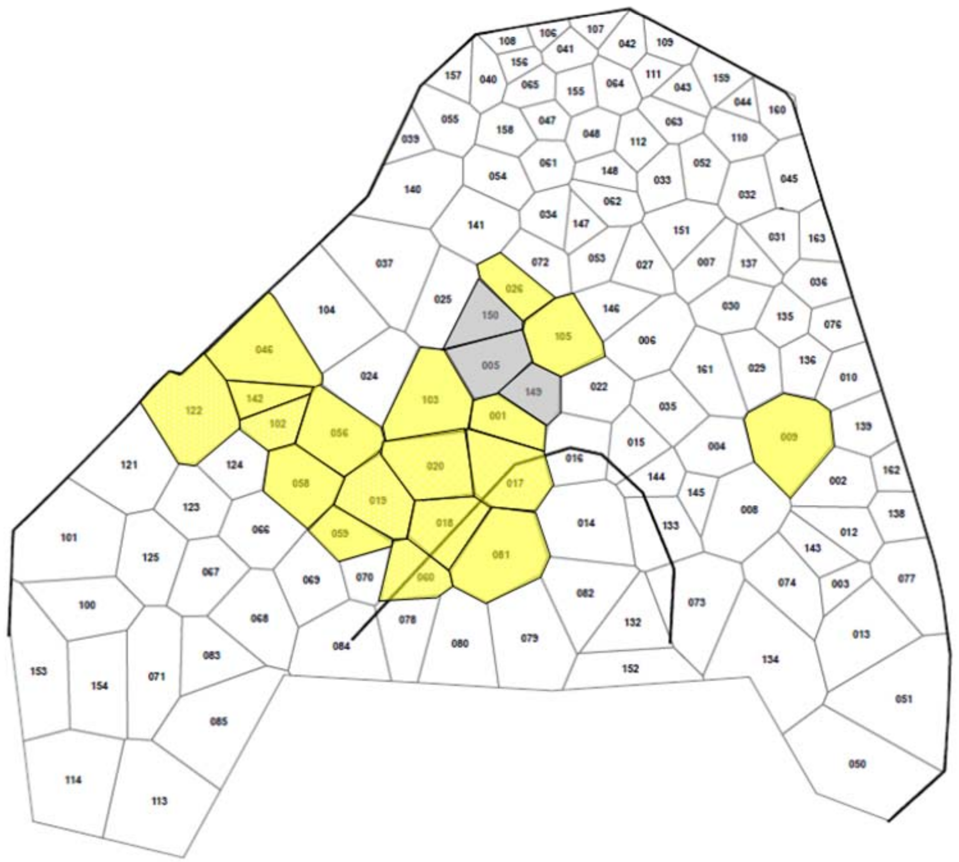


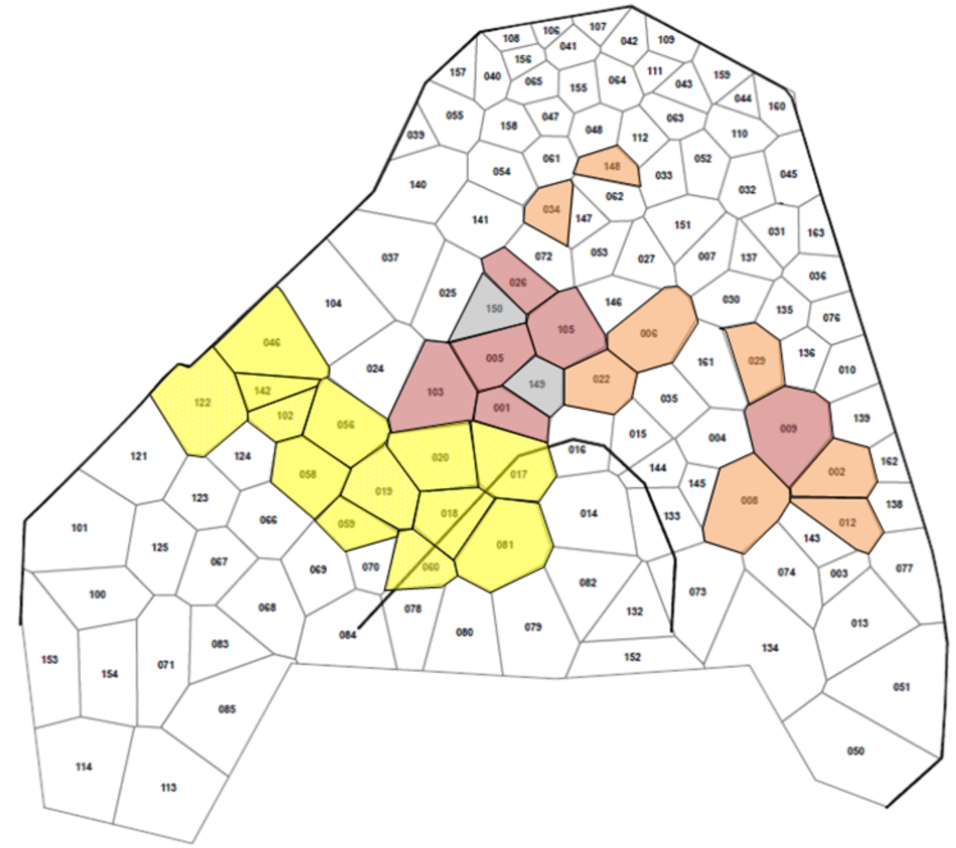
Figure 3. NAPL-Impacted Soil Volume versus Total Soil Volume for Compartment 1

Core Area Determination

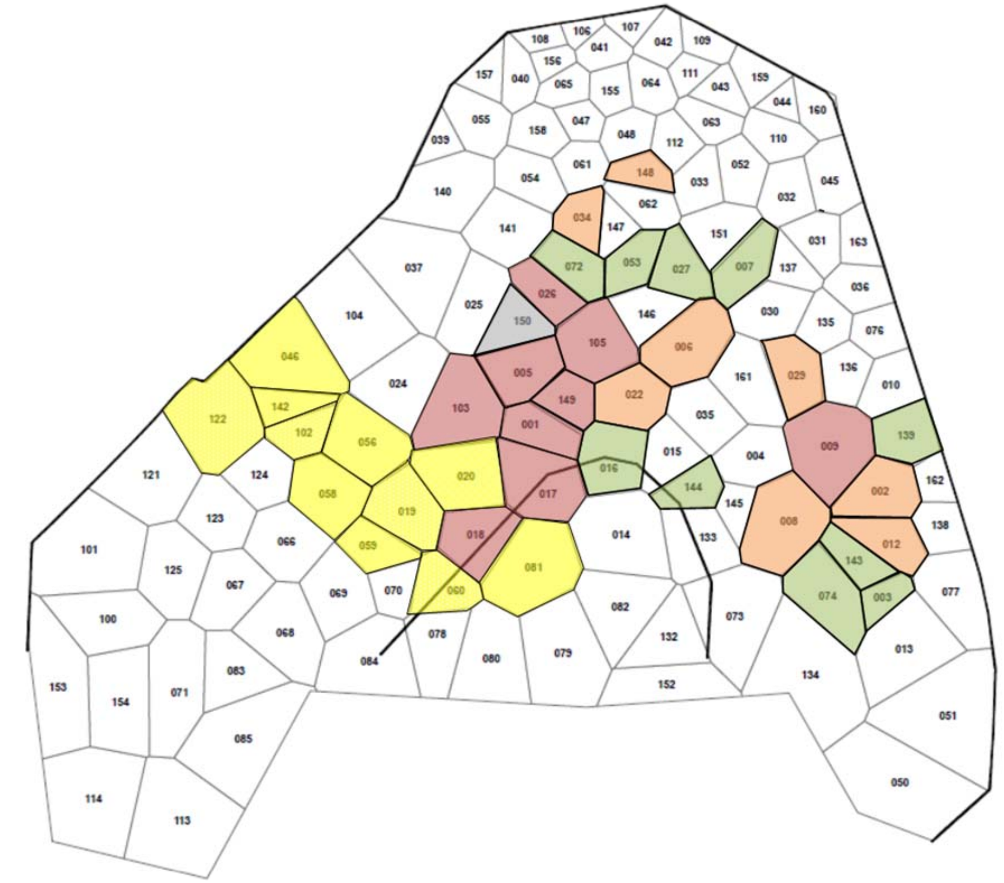
The Thiessen polygons in the data set below the breakpoints and below the additional incremental increases in the Compartment 1 analysis were highlighted on the Thiessen polygon map and are presented on Figure 4. Table 1 presents a breakdown of the NAPL impacted volume and total volume for these areas, as well as a comparison to the overall NAPL impacted volume and total volume for all Thiessen polygons inside the Upland Area. The volumes included for the Compartment 2/3 Breakpoint area and the Compartment 2/3 Connectors area include the volumes of Compartments 1, 2, and 3, since Compartment 1 in these areas would also be treated while treating Compartments 2 and 3. The volumes reported for the Compartment 1 areas include only the Compartment 1 volumes in those areas. The reported Compartment 1 total volumes below are slightly less than the Compartment 1 volumes laid out in the Compartment 1 analysis section above. The Compartment 1 volumes for polygons within the Compartment 1 Breakpoint that are also within the Compartment 2/3 Breakpoint were already included in the Compartments 2/3 volumes in the table from the previous Compartment 2/3 analysis, and are not reported again under the Compartment 1 volumes. This includes Compartment 1 volumes from the following polygons: 2013T-002, 2013T-006, 2013T-008, 2013T-012, 2013T-022, 2013T-029, 2013T-034, and 2013T-148.



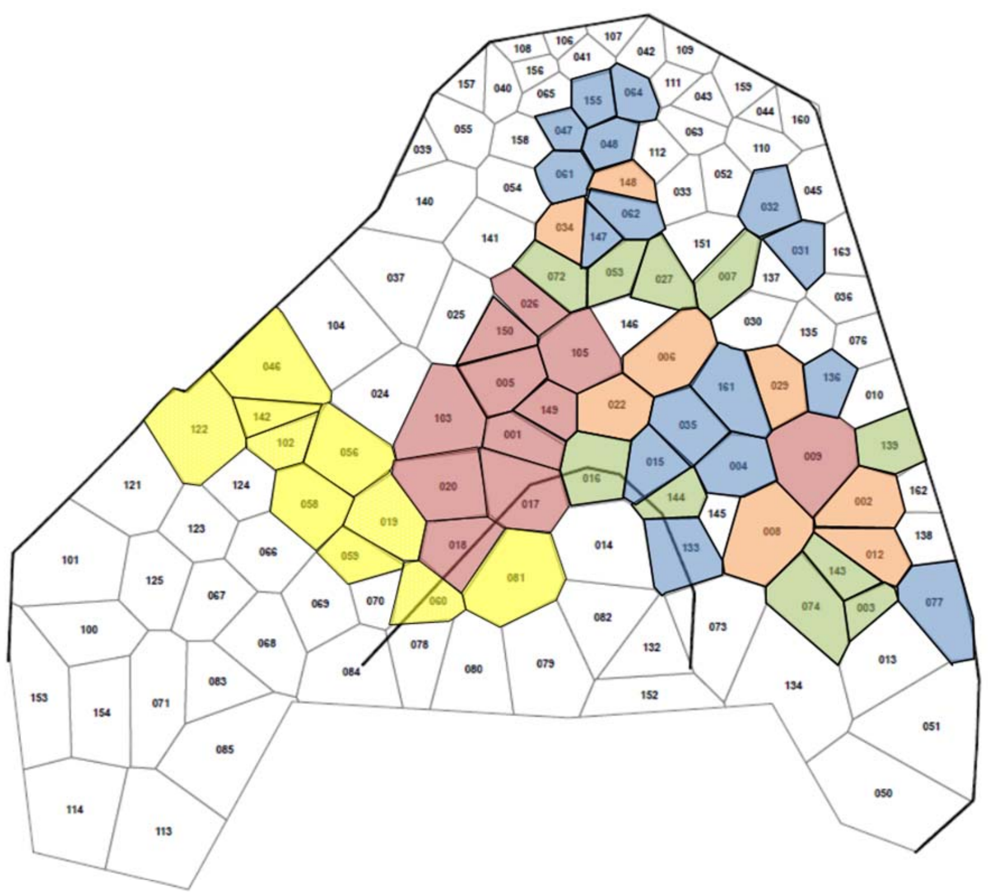
Compartment 2/3 Breakpoint –
40,081 CY Impacted Volume; 108,347 CY Total Volume



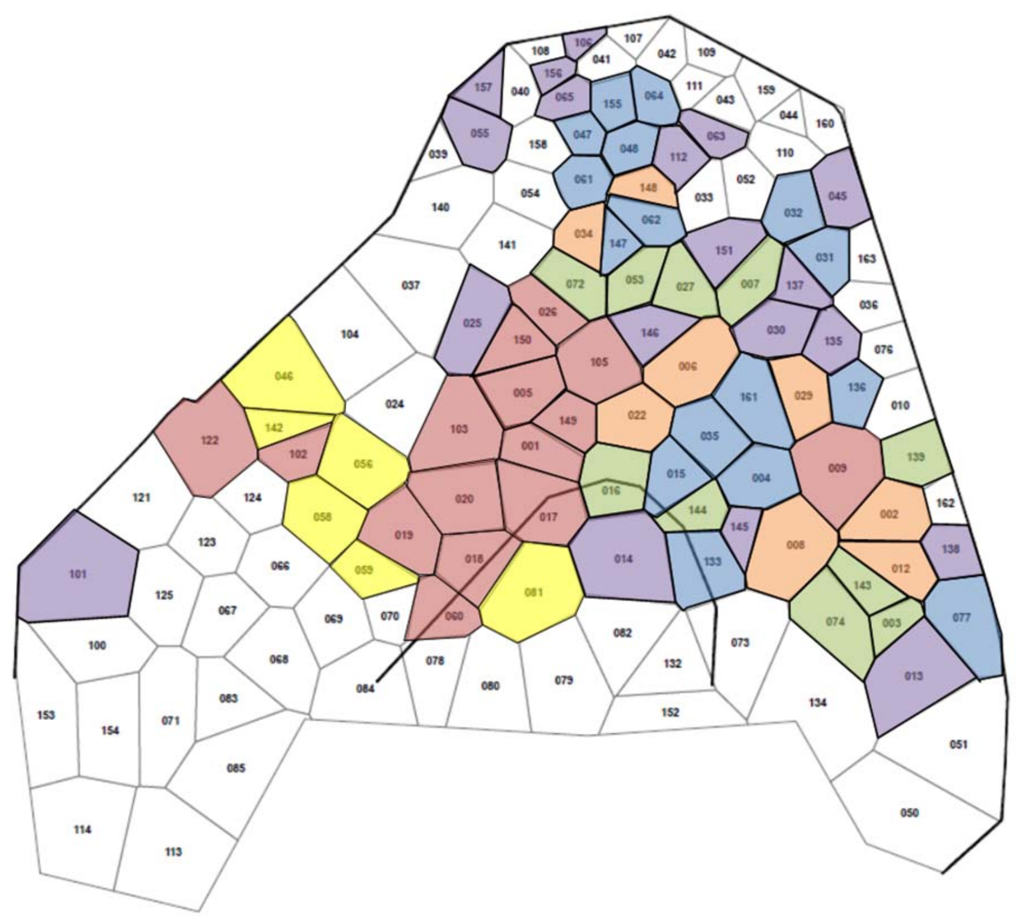
Compartment 2/3 and 1 Breakpoint –
49,304 CY Impacted Volume; 129,345 CY Total Volume



Compartment 2/3 and 1 Breakpoint + 10,000 CY Affected Volume –
56,836 CY Impacted Volume; 151,080 CY Total Volume



Compartment 2/3 and 1 Breakpoint + 20,000 CY Affected Volume –
65,7664 CY Impacted Volume; 185,692 CY Total Volume



Compartment 2/3 and 1 Breakpoint + 30,000 CY Affected Volume –
73,803 CY Impacted Volume; 234,458 CY Total Volume

Compartment 2/3 Breakpoint
Compartment 2/3 Connectors
Compartment 1 Breakpoint
Overlap Areas
Compartment 1 Plus 10,000 CY
Compartment 1 Plus 20,000 CY
Compartment 1 Plus 30,000 CY

Figure 4
Polygon Areas at Identified Breakpoints

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TABLE 1
Core Area Statistics

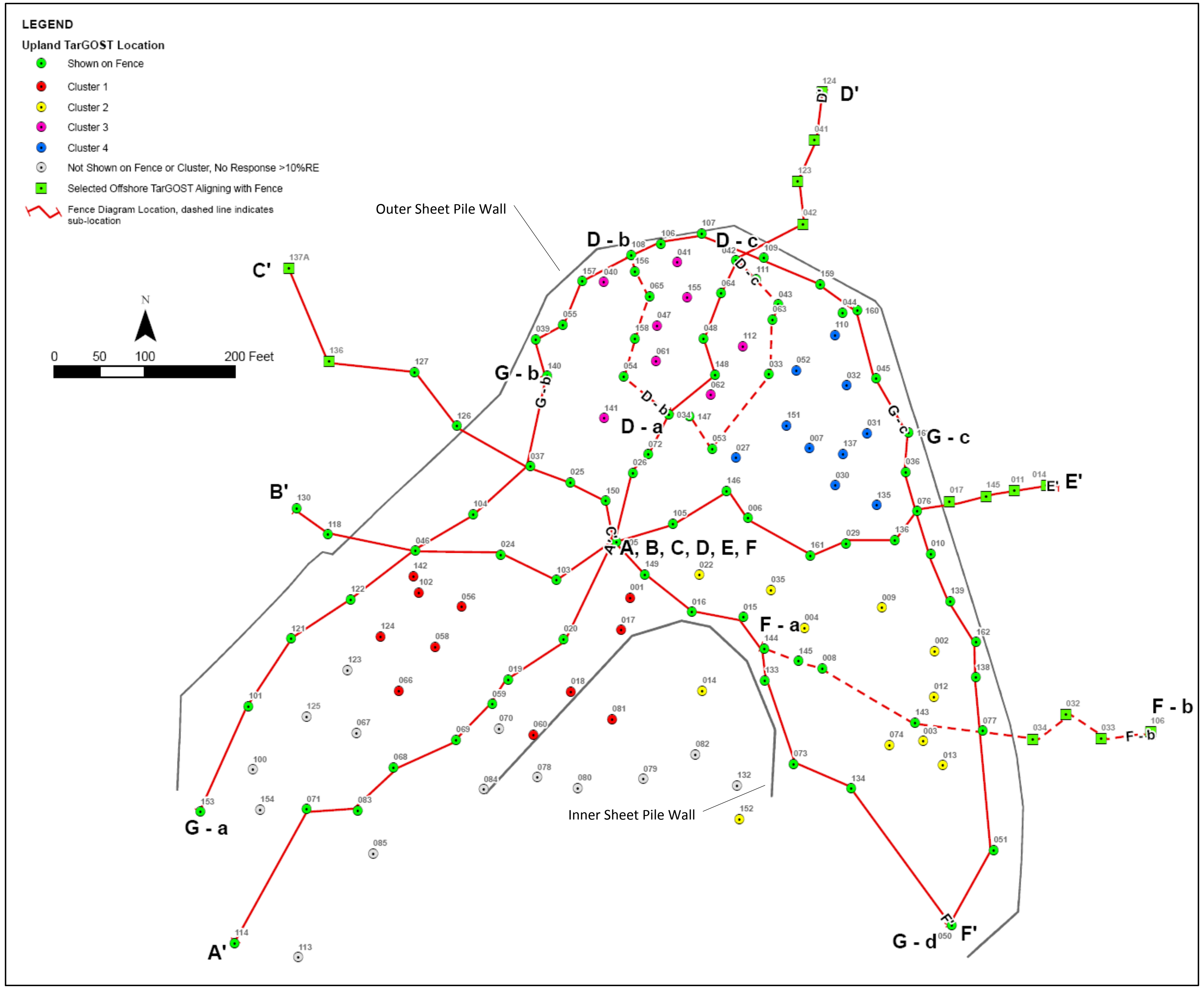
Core Area	NAPL-Impacted Volume (CY)	Total Volume (CY)	Breakpoint % Total Volume Captured	Overall % Total Volume Captured
Compartments 2/3 Breakpoint	35,331	94,847	37%	33%
Compartment 2/3 Connectors	4,750	13,500	35%	38%
Compartment 1 Breakpoint*	9,223	20,998	44%	47%
Compartment 1 Plus 10,000 CY	7,532	21,735	35%	54%
Compartment 1 Plus 20,000 CY	8,828	34,612	26%	62%
Compartment 1 Plus 30,000 CY	8,139	48,766	17%	70%
Total of Above Areas	73,803	234,458		
Total of all Areas	105,995	750,420		

References

CH2M HILL. 2013. *2013 Wyckoff Upland NAPL Field Investigation Technical Memorandum*. Prepared for U.S.. Environmental Protection Agency. June.

Appendix B
Target Zone Fence Diagrams and Cluster Diagrams

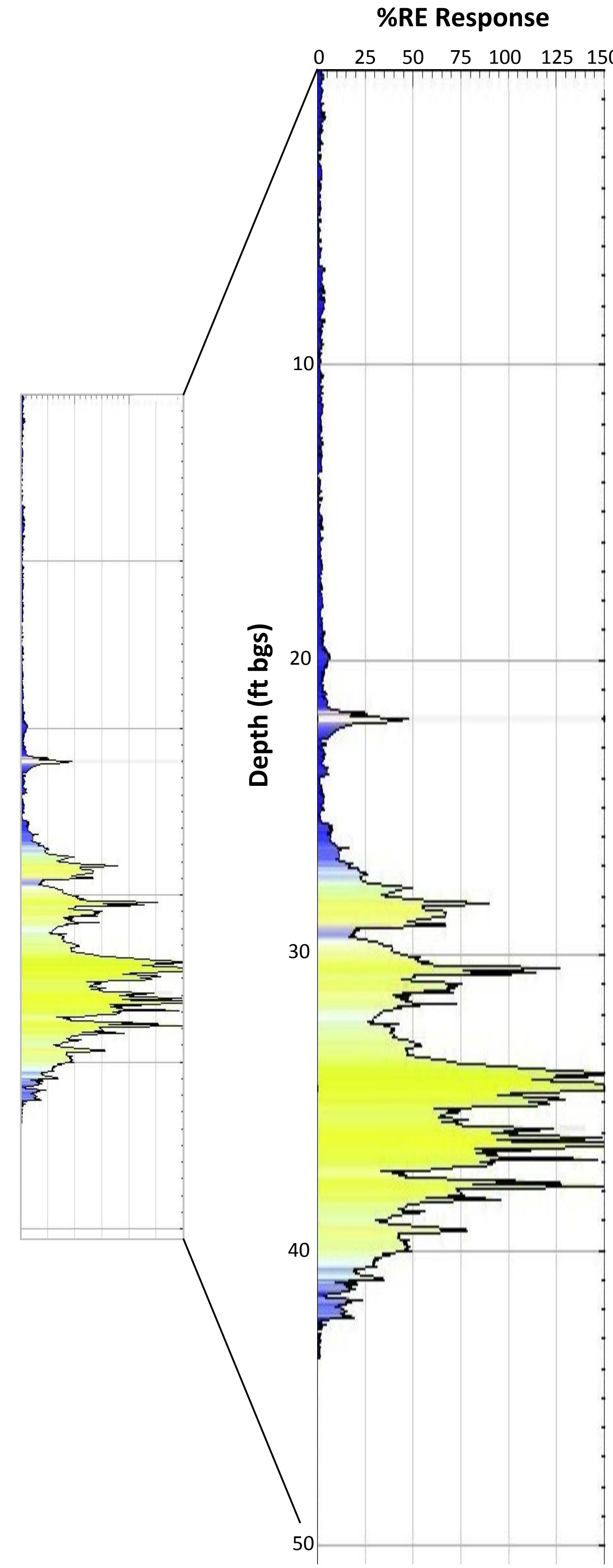
Overview Plan View Map



Fence diagrams A through F radiate out from a TarGOST location central to the site (2013T-005). Fence diagram G (a through c) parallels the sheet pile wall on the upland portion of the site.

Dashed sub-fence diagrams are intended to follow potential flow paths of NAPL to the sheet pile wall.

TarGOST falling between fence diagram lines with responses >10%RE were grouped into Cluster diagrams. Cluster diagram groupings are shown on the map above.



LEGEND FOR FENCE DIAGRAM ELEMENTS

- Ground surface extracted from GIS
- Approximate Aquitard Depth
- TarGOST Refusal Depth
- Outer Sheet Pile Wall
- Compartment Division Depth
- Proposed Treatment Area Thickness for Base Case Periphery TarGOST Location
- Proposed Treatment Area Thickness for Base Case Core TarGOST Location
- 3' Proposed Treatment Area Thickness
- Glacial till depth indicated by recent boring <20 ft from fence
- Depth to refusal of recent boring <20 ft from fence

Figure B-1

Fence and Cluster Diagram Overview and Legend

Focused Feasibility Study Remedial Action Technology Screening and Preliminary Remedial Action Alternatives

Wyckoff/Eagle Harbor Superfund Site

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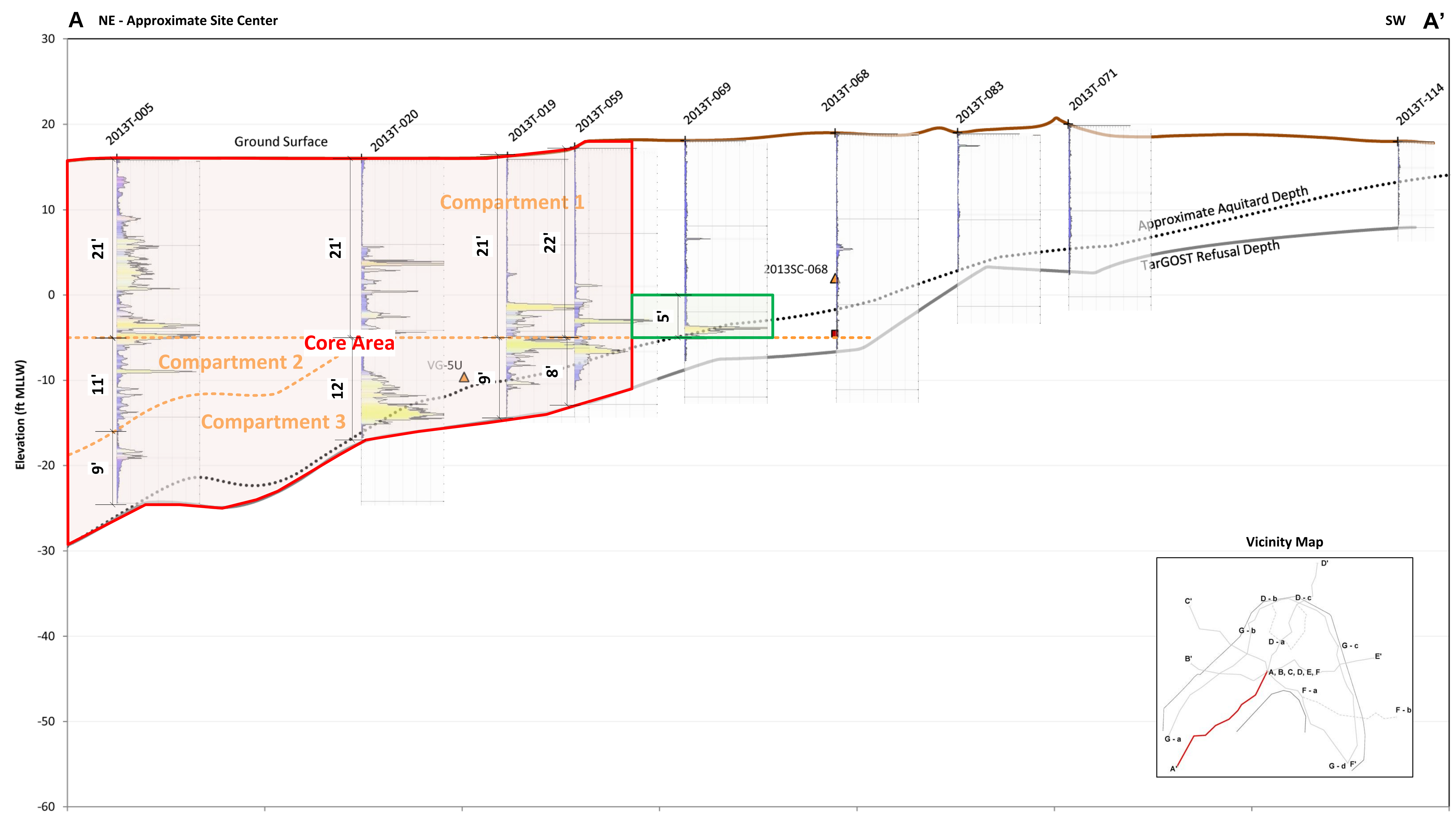

Figure B-2

Fence Diagram A-A' with TarGOST %RE Response

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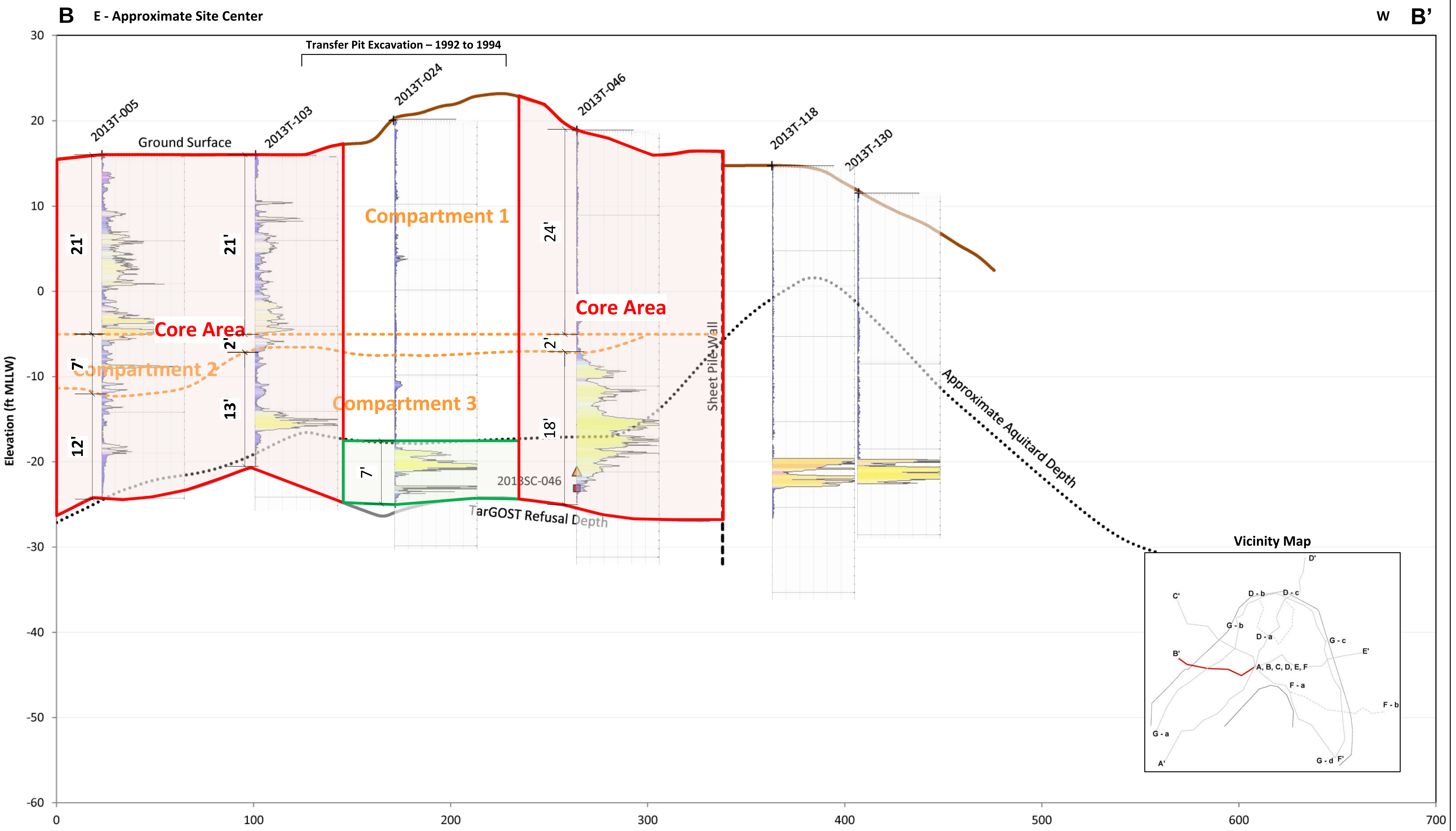

Figure B-3

Fence Diagram B-B' with TarGOST %RE Response

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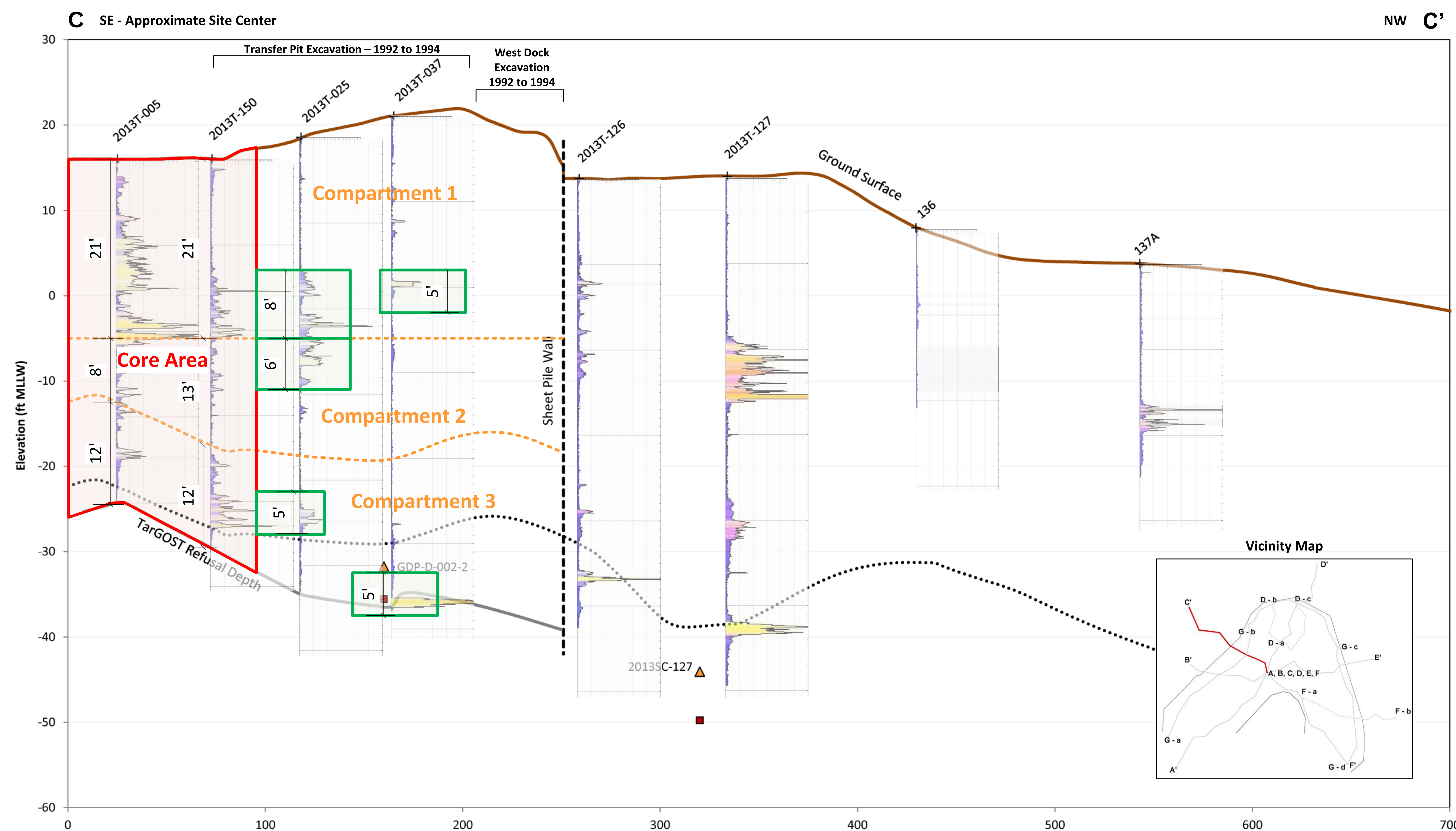

Figure B-4

Fence Diagram C-C' with TarGOST %RE Response

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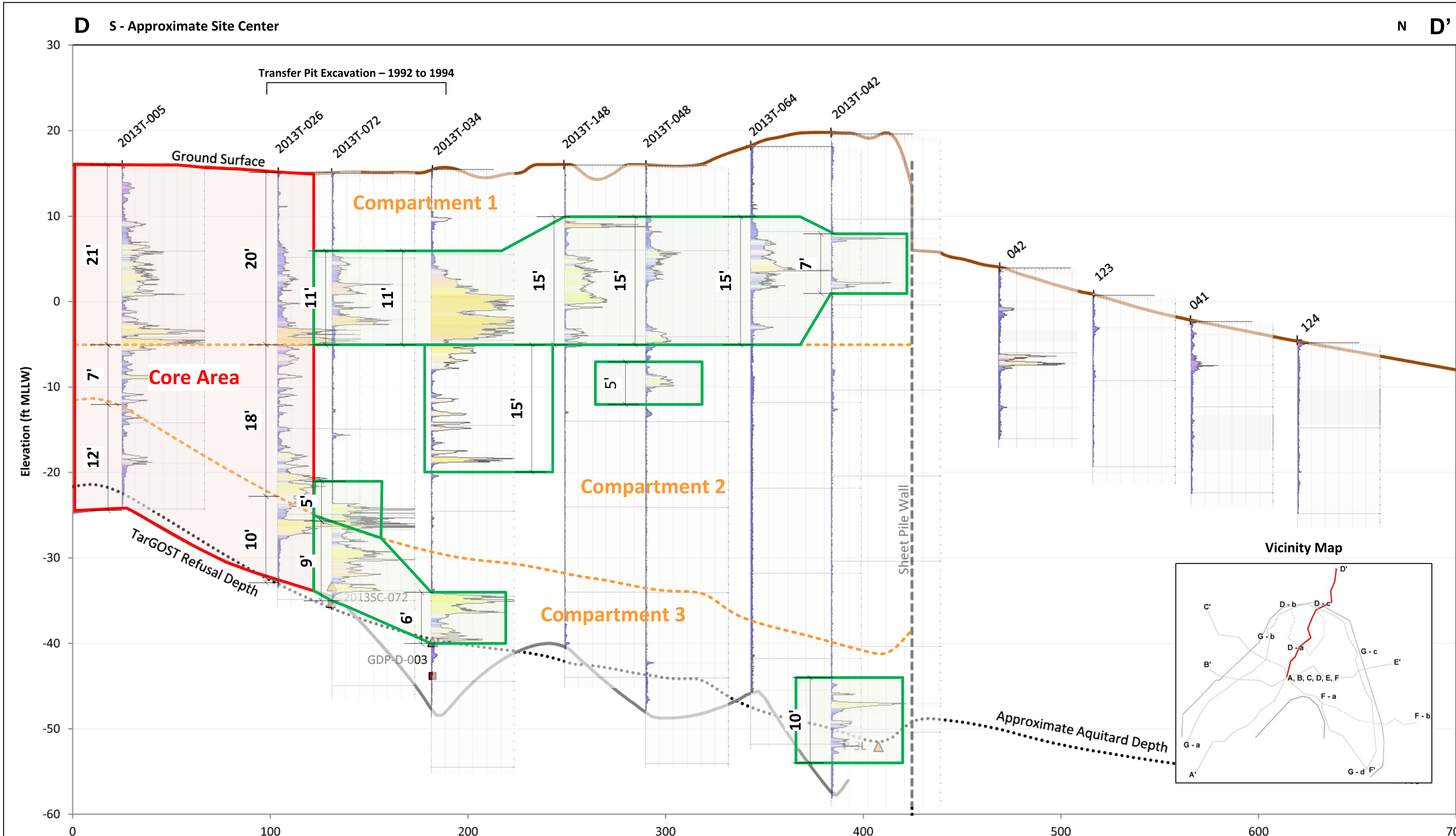

Figure B-5

Fence Diagram D-D' with TarGOST %RE Response

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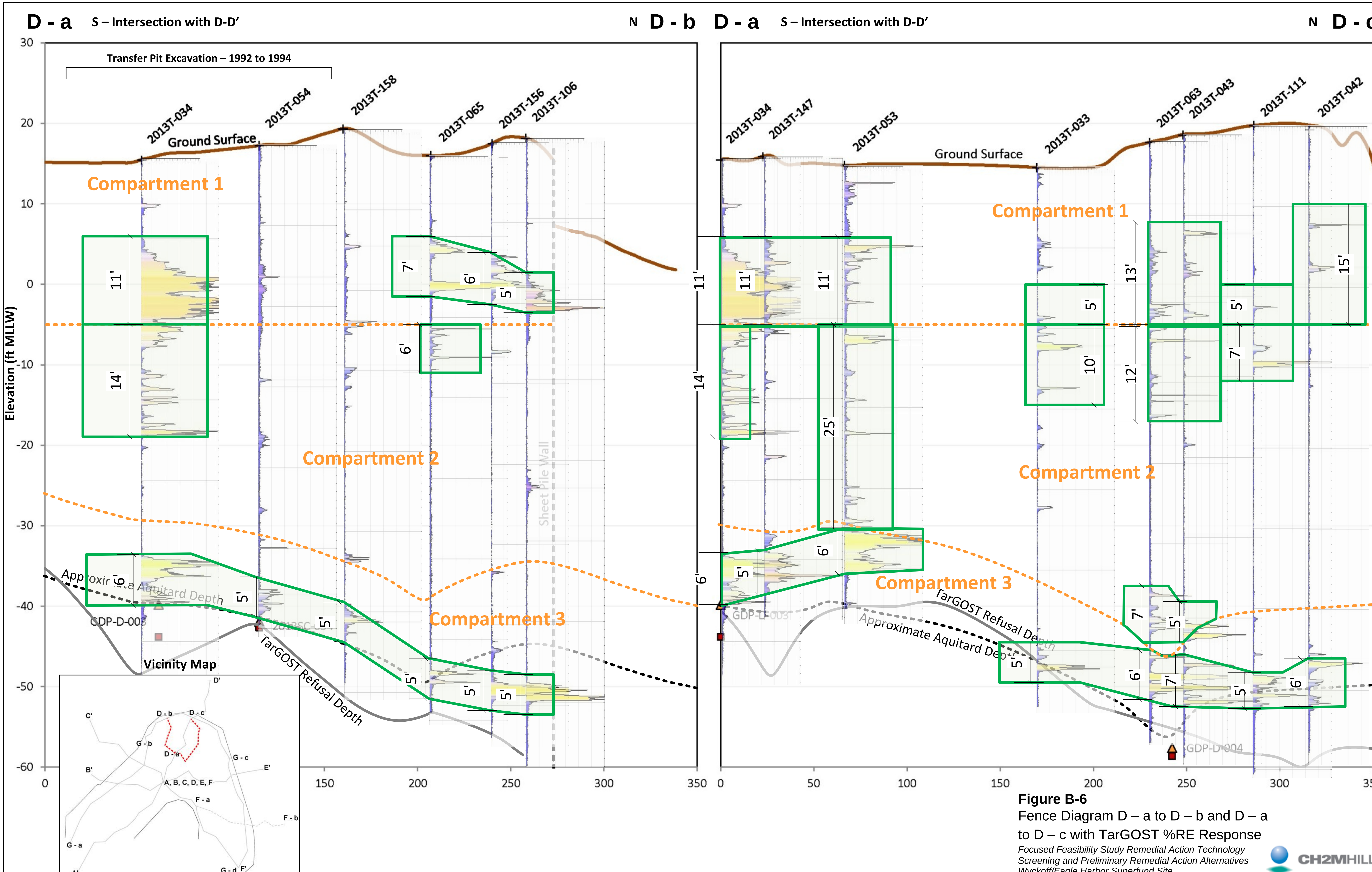

Figure B-6

Fence Diagram D – a to D – b and D – a to D – c with TarGOST %RE Response

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Wyckoff/Eagle Harbor Superfund Site

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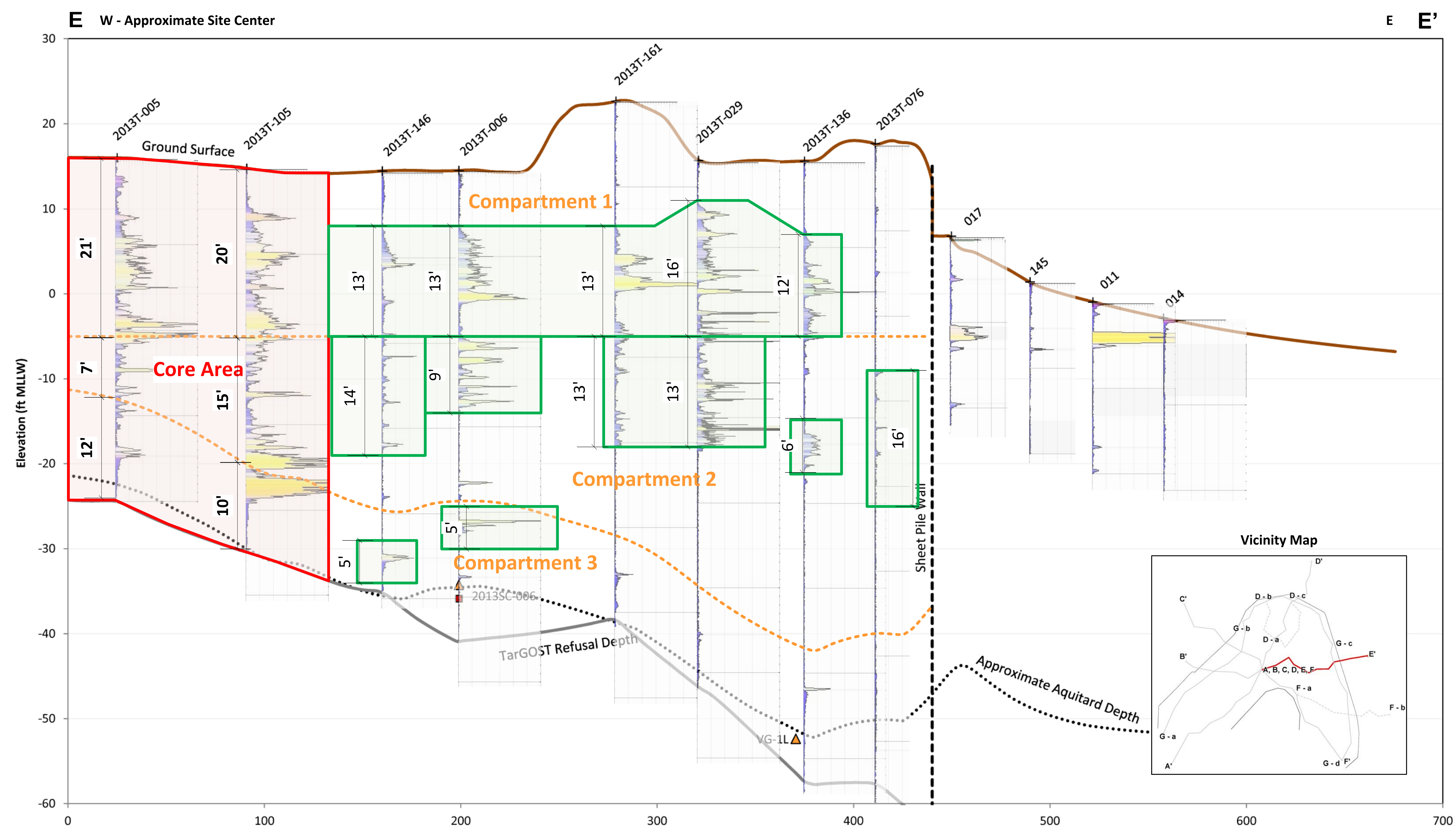

Figure B-7

Fence Diagram E-E' with TarGOST %RE Response

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Wyckoff/Eagle Harbor Superfund Site

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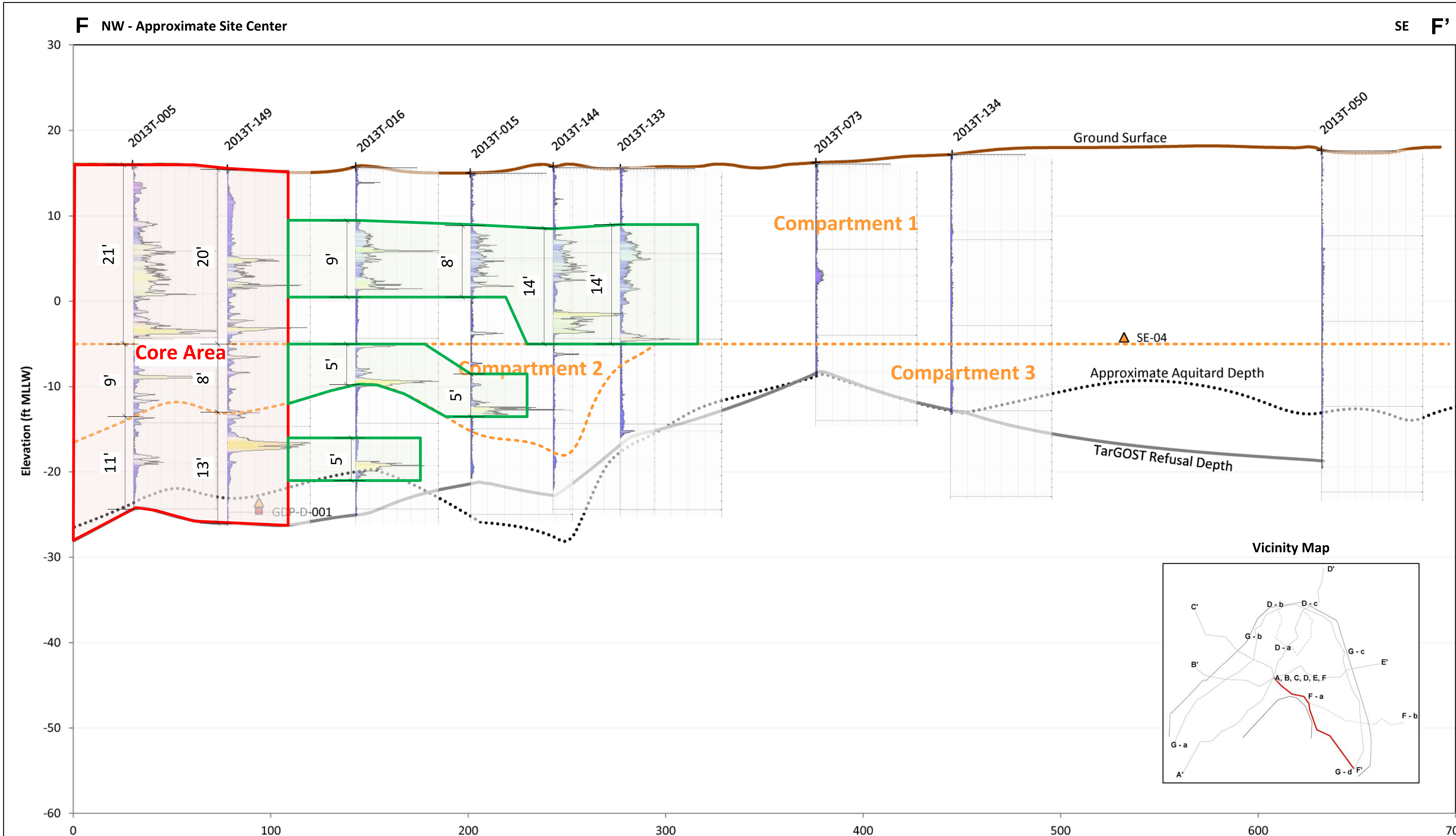

Figure B-8

Fence Diagram F-F' with TarGOST %RE Response

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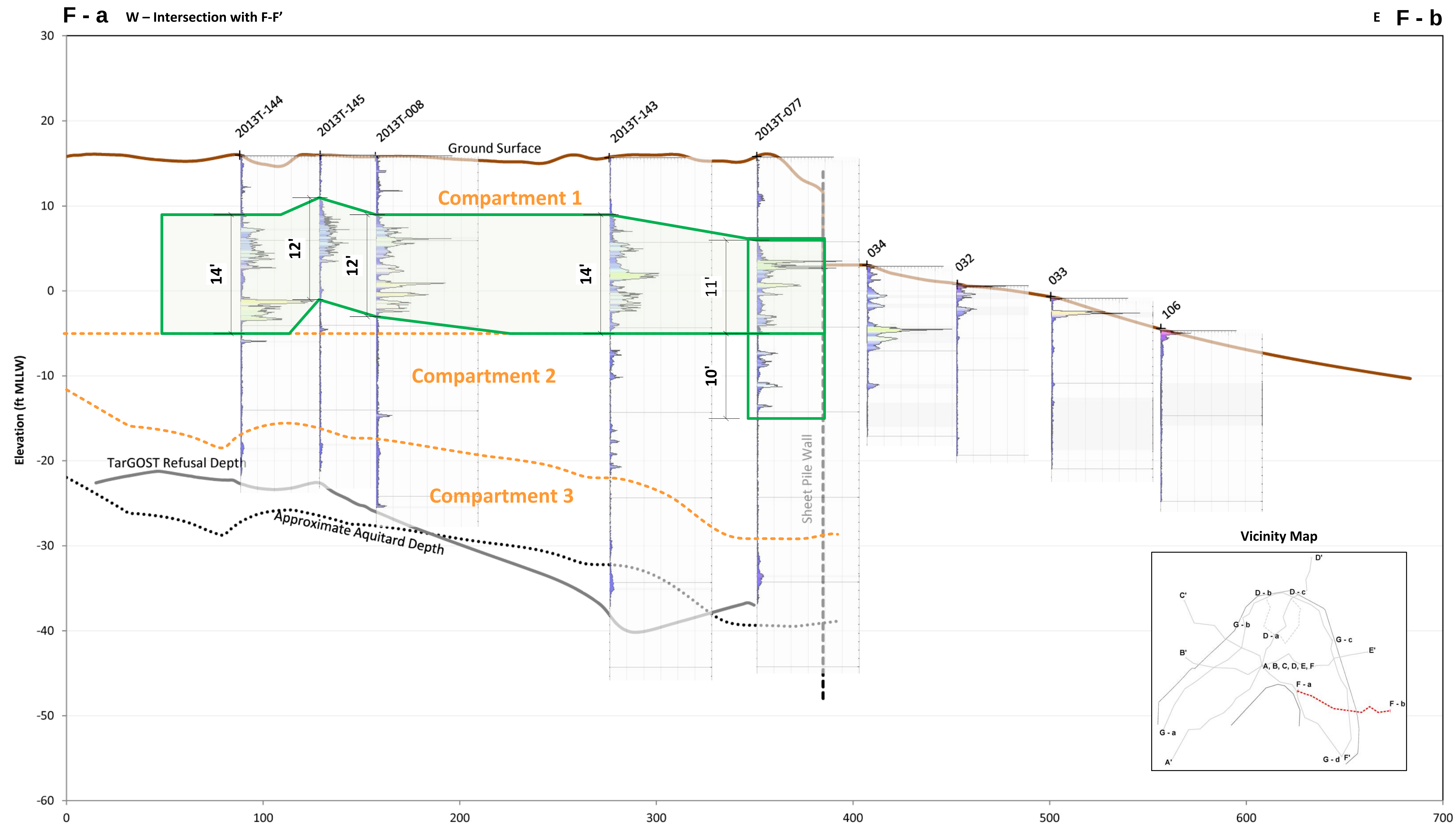

Figure B-9

Fence Diagram F - a to F - b with TarGOST %RE Response

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Wyckoff/Eagle Harbor Superfund Site

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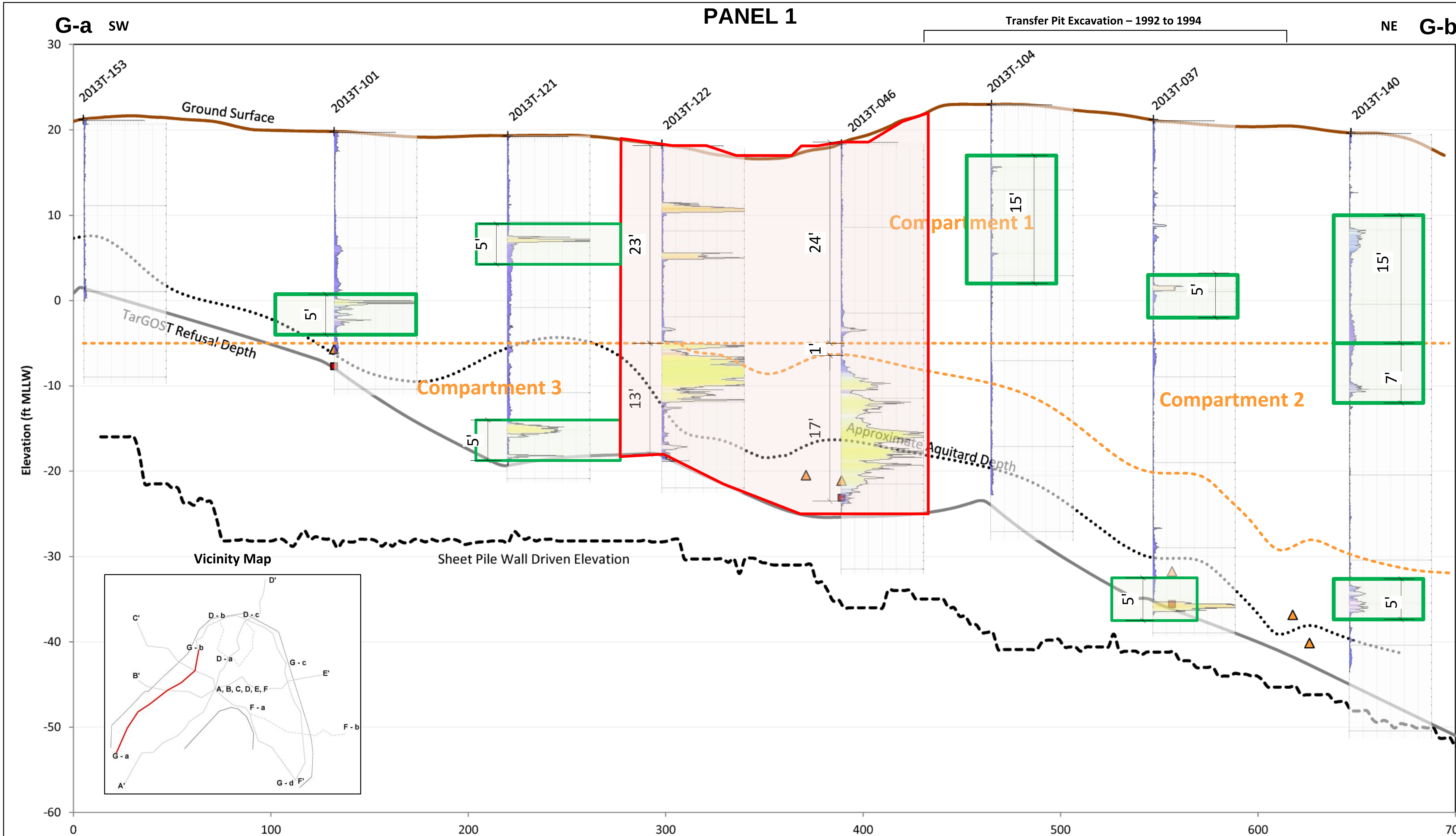

Figure B-10 (Panels 1 – 3)

Fence Diagram G-a to G-b to G-c to G-d with TarGOST %RE Response

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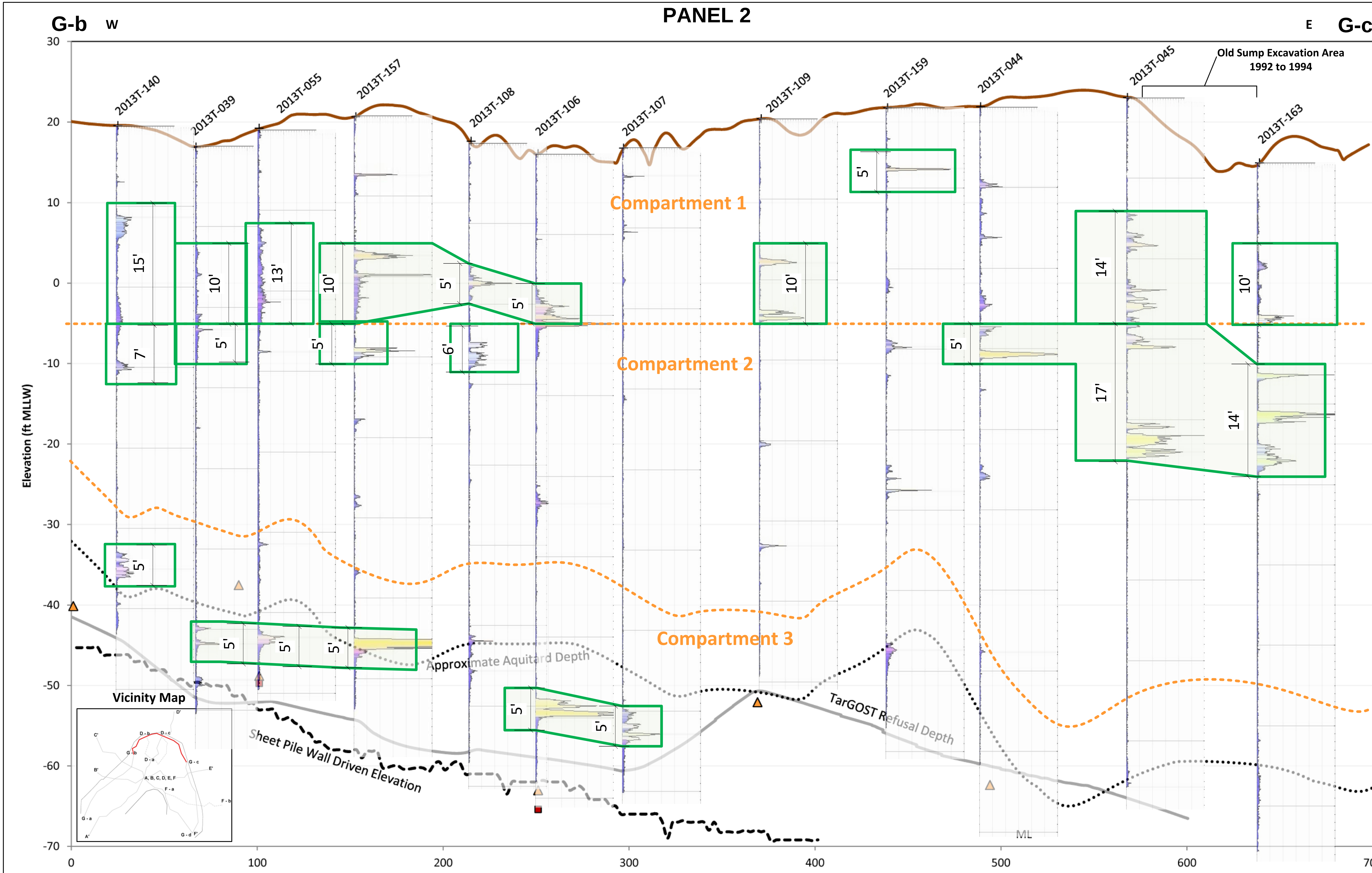
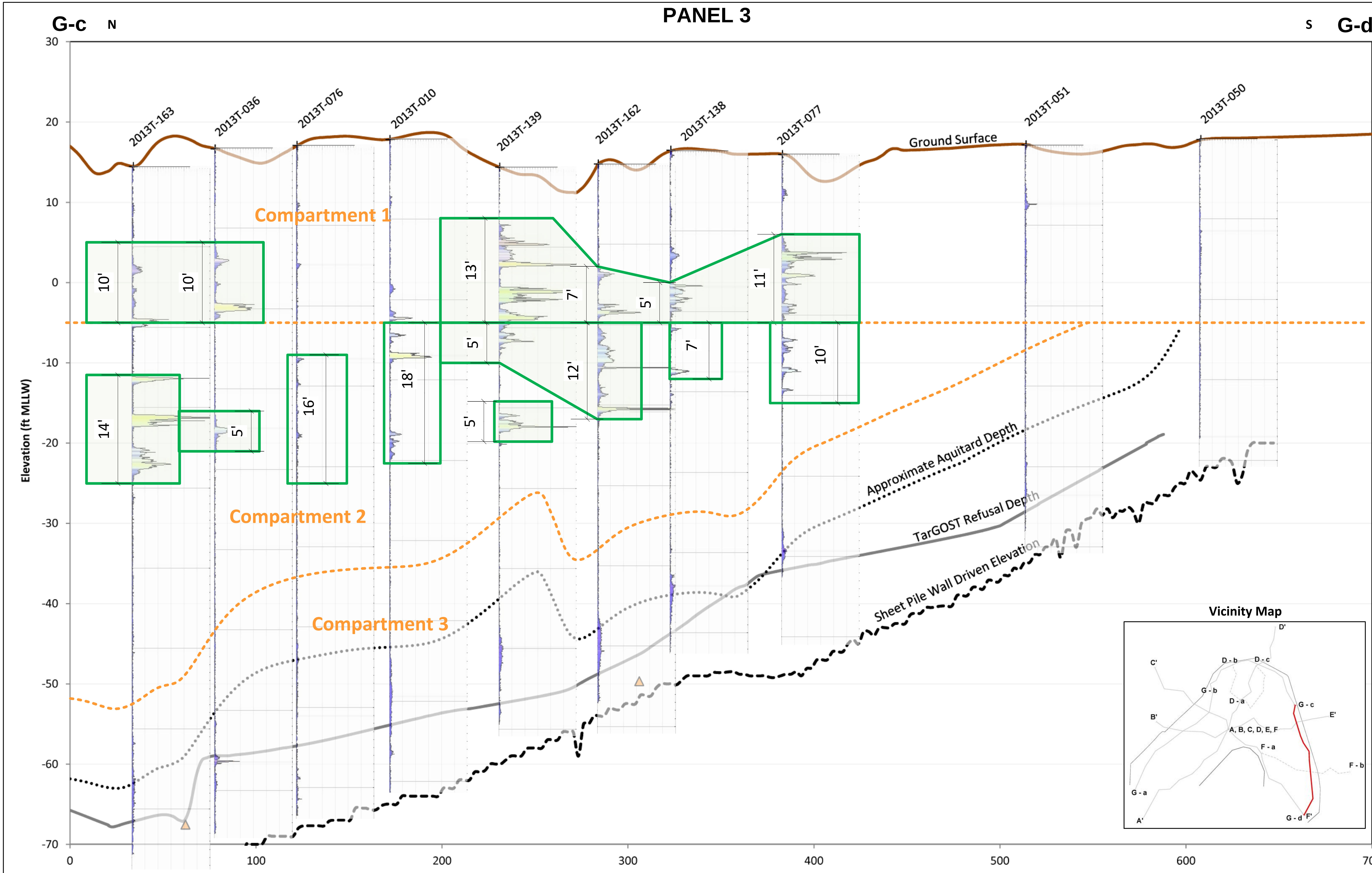
Wyckoff/Eagle Harbor Superfund Site



PANEL 2
G-b
W
E
G-c
Old Sump Excavation Area 1992 to 1994
2013T-140
2013T-039
2013T-055
2013T-157
2013T-108
2013T-106
2013T-107
2013T-109
2013T-159
2013T-044
2013T-045
2013T-163
Compartment 1
Compartment 2
Compartment 3
Approximate Aquitard Depth
TarGOST Refusal Depth
Sheet Pile Wall Driven Elevation
Elevation (ft MLLW)
Vicinity Map
ML



PANEL 3
G-c
N
S
G-d
Elevation (ft MLLW)
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
0
100
200
300
400
500
600
700
2013T-163
2013T-036
2013T-076
2013T-010
2013T-139
2013T-162
2013T-138
2013T-077
2013T-051
2013T-050
Ground Surface
Compartment 1
Compartment 2
Compartment 3
10'
10'
14'
5'
16'
18'
13'
5'
7'
12'
5'
5'
7'
11'
10'
Approximate Aquitard Depth
TarGOST Refusal Depth
Sheet Pile Wall Driven Elevation
Vicinity Map
D'
C'
D - b
D - c
G - b
D - a
G - c
E'
B'
A, B, C, D, E, F
F - a
F - b
G - a
A'
G - d
F'

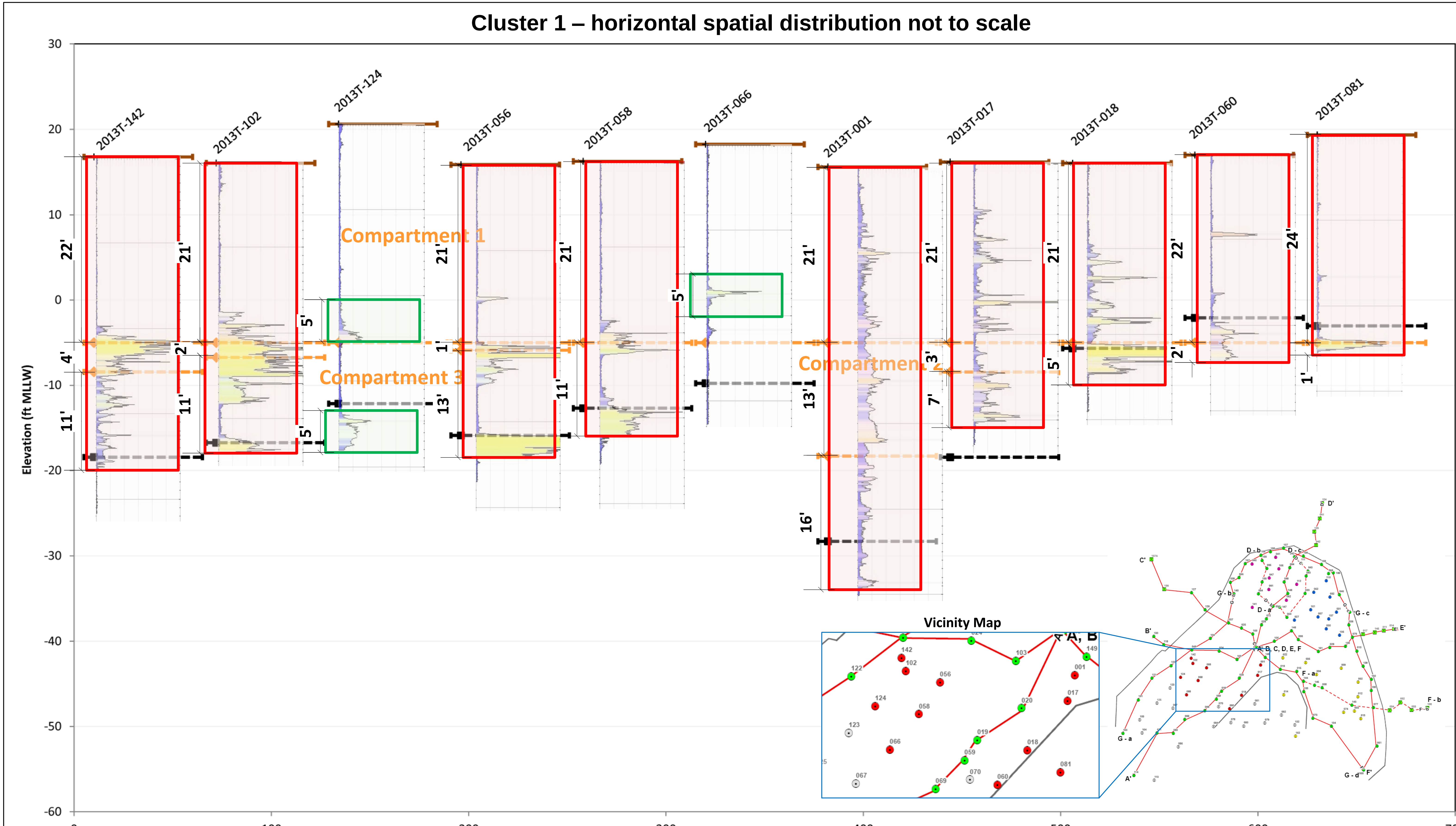


Figure B-11

Cluster 1 with TarGOST %RE Response

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Wyckoff/Eagle Harbor Superfund Site

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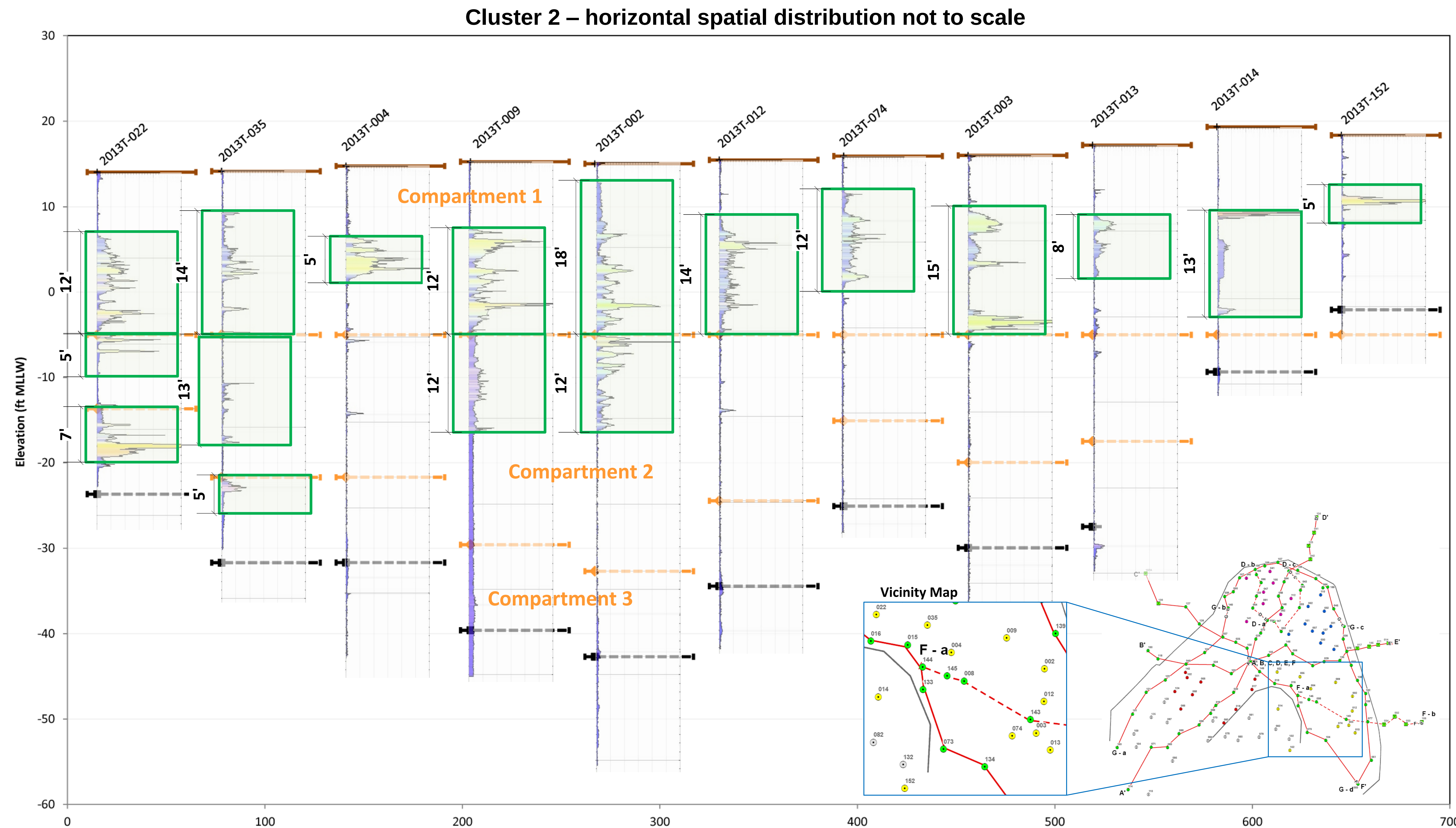

Figure B-12

Cluster 2 with TarGOST %RE Response

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Wyckoff/Eagle Harbor Superfund Site

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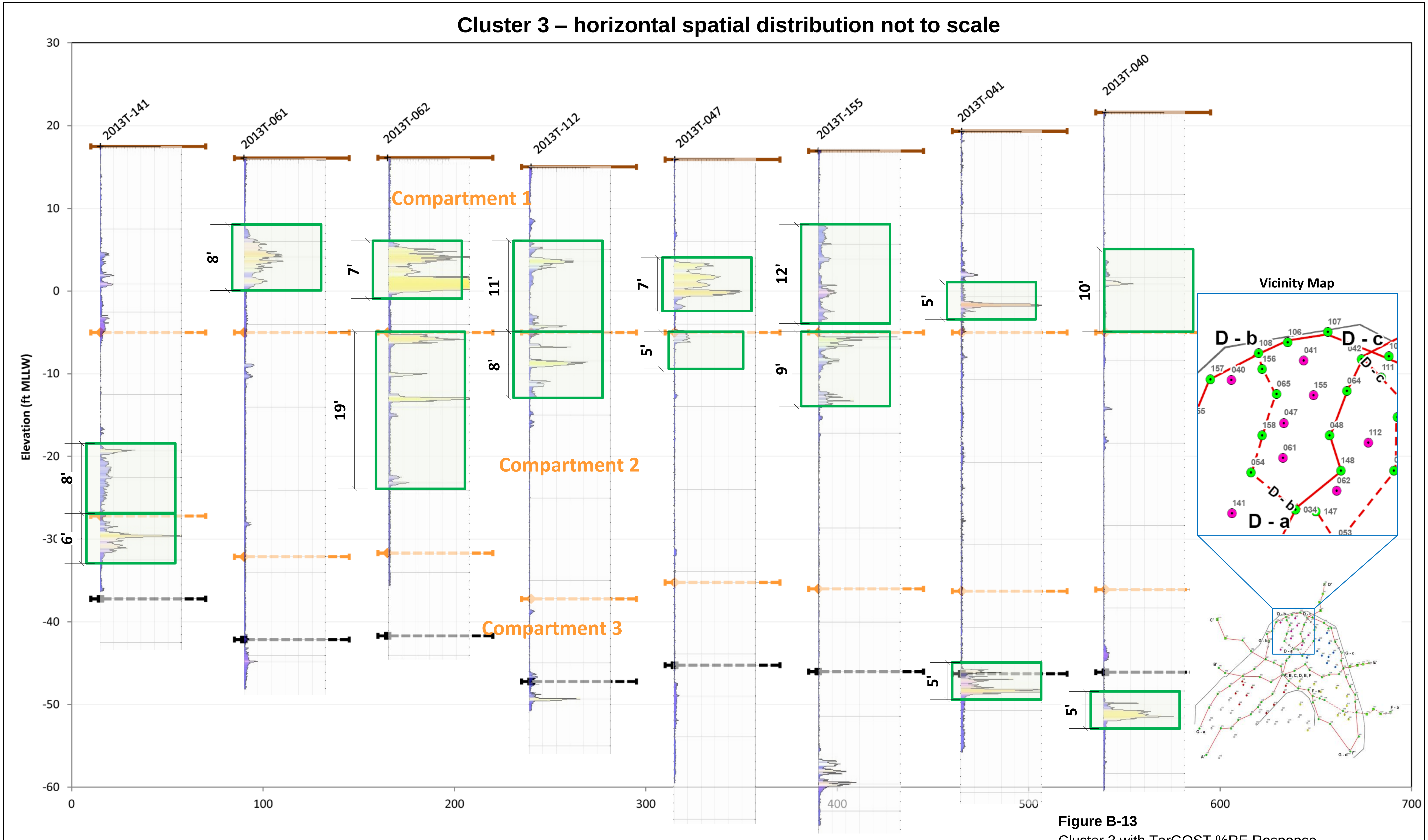

Figure B-13

Cluster 3 with TarGOST %RE Response

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Cluster 4 – horizontal spatial distribution not to scale

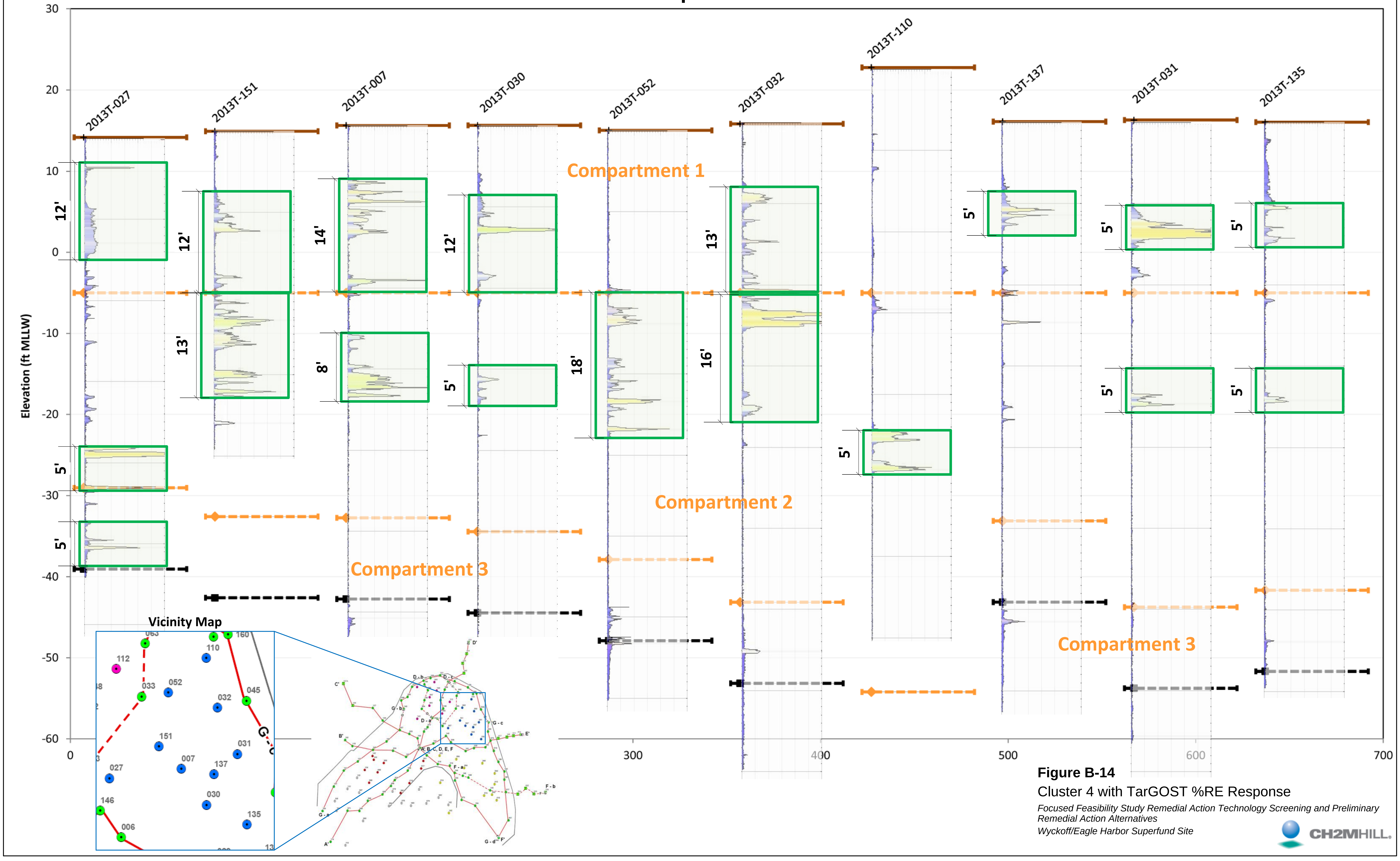

Figure B-14

Cluster 4 with TarGOST %RE Response

Focused Feasibility Study Remedial Action Technology Screening and Preliminary Remedial Action Alternatives

Wyckoff/Eagle Harbor Superfund Site

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Appendix C
Soil and Groundwater OU Remedial Technology Screening Results

TABLE C-1
Soil and Groundwater OU Remedial Technology Screening
Former Process Area, Soil and Groundwater OUs
Wyckoff/Eagle Harbor Superfund Site, Bainbridge Island, Washington

General Response Actions	Remedial Technology	Target Zone, Media, and COCs	Process Options	Description	Effectiveness (Target Zone and RAOs, Impacts to HHE during Construction, Reliability)	Implementability (Technical and Administrative)	Relative Cost	Screening Comment
No Action	No Action	Not Applicable	No action	NAPL in soil and groundwater is left untreated.	**Poor.** Not effective, because no active measures are taken to remove, treat, and/or immobilize NAPL.	**Poor.** While technically implementable, no action does not address CERCLA threshold criteria and principal threats, and therefore, No Action can't be selected under CERCLA.	**None.**	**Retained** per the NCP.
Access Restrictions	Fencing	All Zones Soil/Groundwater NAPL/All COCs	Cyclone perimeter fence	Exposure pathway controlled with engineering measures.	**Poor to Moderate.** Generally effective for protecting human health, but must be maintained over time. May not eliminate entry (trespass) or remedial action worker exposure. Does not contribute to NAPL mobility and thickness reduction.	**Good.** A fence currently encloses the Former Process Area.	**Low.**	**Retained.** Fencing is a component of the current remedy and is needed, as a component of a broader alternative, until RAOs achieved.
	Institutional Controls		Land use zoning, deed restrictions, restrictive covenants	Exposure pathway controlled with administrative measures.	**Poor to Moderate.** Relies on administrative measures to limit exposure to contaminated soil and groundwater. ICs expected to be effective short term, but uncertainty on long-term effectiveness over periods of 100 years or more exists. Does not contribute to NAPL mobility and thickness reduction.	**Moderate.** Readily implemented using existing EPA (EPA 540-F-00-005) guidance, however, requires land-owner concurrence. Some uncertainty on enforcement tools and responsibility over long term.	**Low.**	**Retained.** ICs are a component of the current remedy and are needed, as a component of a broader alternative, until RAOs achieved.
Containment	Surface Barrier	All Zones Soil NAPL/All COCs	Low permeability asphalt barrier (MATCON)	An impermeable cover (asphalt) is placed over ground surface to provide a direct contact barrier and to deter surface water infiltration away from contaminated soil. Typical asphalt mix is modified to use smaller aggregate, higher binder content, and/or proprietary binder additives.	**Moderate.** Low permeability asphalt covers are effective at reducing direct contact with contaminants and reducing infiltration (1x10-8 cm/sec permeability), but require routine inspection, maintenance (crack repair and sealing), and periodic replacement to maintain long-term effectiveness. Not effective in eliminating lateral COC migration unless coupled with vertical barrier. Does not reduce NAPL thickness. Reduces mobility in vadose zone by minimizing infiltration. Does not reduce mobility in Upper Aquifer.	**Good.** Readily implemented. Low permeability asphalt requires special asphalt mix designs (generally proprietary) and high levels of QA/QC to demonstrate impermeability of the barrier. Asphalt barrier can be a benefit or detriment to future site development depending on intended use. Future use would need to be known and accounted for in remedial design.	**High.** Moderate to high capital and periodic cost with low initial O&M cost. O&M cost rises as asphalt ages, eventually requiring replacement. O&M and periodic costs incurred for an indefinite period of time.	**Not Retained** due to long-term site use considerations, and high O&M and periodic costs.
			Multi-layer impermeable barrier	Contaminated surface soil graded and capped with low permeability materials that may include flexible membrane liner, drainage (gravel), sand/silt/clay, and vegetation or combination thereof.	**Moderate.** Mature technology with demonstrated ability to limit infiltration and direct contact with contaminants. Would need to be coupled with other process options (e.g., sheet pile wall) to address groundwater contamination, and ICs to protect against intrusion. Does not reduce NAPL thickness. Reduces mobility in vadose zone by minimizing infiltration. Does not reduce mobility in	**Moderate.** Readily implemented using standard construction practices. Requires long-term inspection and maintenance (mowing, erosion repair). Future site use may be restricted to ensure barrier integrity is maintained.	**Moderate.** Moderate capital cost, with low annual O&M and periodic costs for an indefinite duration.	**Retained.** Is a component of the current remedy. Also expected to be a component of a broader alternative to support long-term reuse.

TABLE C-1
Soil and Groundwater OU Remedial Technology Screening
Former Process Area, Soil and Groundwater OUs
Wyckoff/Eagle Harbor Superfund Site, Bainbridge Island, Washington

General Response Actions	Remedial Technology	Target Zone, Media, and COCs	Process Options	Description	Effectiveness (Target Zone and RAOs, Impacts to HHE during Construction, Reliability)	Implementability (Technical and Administrative)	Relative Cost	Screening Comment
					Upper Aquifer.			
			Evapotranspiration (ET) barrier	An engineered soil and native vegetation cover placed over contaminated soil to increase ET rates, and decrease surface water infiltration.	**Moderate.** Most effective in arid climates, but with appropriate design and vegetation selection, can be applied in wetter climates. Barrier layer thickness, soil gradation, vegetation, grading, and drainage, if carefully designed, can effectively limit infiltration beneath the cap. Not effective in eliminating horizontal migration of contaminants unless implemented in conjunction with vertical barrier (e.g., slurry wall). Differential settlement can compromise barrier effectiveness. Does not reduce NAPL thickness. Reduces mobility in vadose zone by minimizing infiltration. Does not reduce mobility in Upper Aquifer.	**Moderate to Good.** Easily implementable with standard construction equipment and materials. May not require mowing (depending on vegetation type), but would still require periodic inspection and repair of any erosion. Long-term maintenance required and future site uses are limited by need to protect barrier integrity. Administrative acceptance may be a barrier to implementation.	**Low to Moderate.** Very low capital and inspection and maintenance costs (does not require mowing). O&M costs incurred for an extended period of time.	**Retained** as a component of a broader alternative.
Containment (Continued)	Subsurface Barrier	All Zones Groundwater NAPL/All COCs	Physical containment wall (e.g., sheet pile, slurry wall) with interior fluids pumping	Vertical wall generally keyed into low permeability natural geologic unit to fully or partially enclose an NAPL source area. Often coupled with fluid pumping inside the containment wall to maintain an inward/upward hydraulic gradient.	**Moderate.** Well suited to site conditions. Effective at minimizing horizontal NAPL and dissolved-phase contaminant migration. Low level pumping necessary to maintain inward/upward hydraulic gradient to offset surface, upland, and Lower Aquifer recharge. Does not provide timely reductions in NAPL thickness. Reduces horizontal mobility in the Upper Aquifer, but less effective at reducing vertical mobility.	**Good.** Readily implemented with conventional construction equipment. Higher level of QA/QC required to confirm that a contiguous barrier is achieved and joint sealer is properly installed. Requires shoreline protection system to guard against corrosion. Effectiveness may decrease over time without this system. Requires periodic replacement (est. at 50 years).	**Moderate to High.** Moderate capital cost due to barrier length. High annual O&M cost for interior fluids pumping, treatment, and discharge. High periodic costs for replacement of various components.	**Retained.** Component of the current remedy. However, must be coupled with other technologies, as a component of a broader alternative, to achieve Performance Objectives and RAOs. Not retained as a stand-alone technology.
	Hydraulic Containment	All Zones Groundwater NAPL/PAHs/PCP	Groundwater extraction, treatment, and discharge	Vertical extraction wells placed throughout the Wyckoff Site to control dissolved-phase plume migration and discharge to surface water.	**Poor to Moderate.** Effective for minimizing dissolved-phase contaminant migration; however, tidal influences and Lower Aquifer hydraulic communication and routine/non-routine O&M downtime may allow some contaminant discharge to Lower Aquifer and surface water. Unlikely to contain vertical and horizontal NAPL migration. Does not provide timely reductions in NAPL thickness.	**Moderate.** All of the process options for this technology are already in place. Requires ongoing O&M operator presence, resource commitment, and vendor support network for transportation and residuals disposal. Dioxin and sulfide in recovered NAPL pose additional implementation challenges.	**Moderate to High.** Low capital cost because infrastructure already in place. High annual O&M and periodic costs based on current information.	**Retained.** Is a component of the current remedy, and expected to be short-term component of a broader alternative. Not retained as a stand-alone alternative.

TABLE C-1
Soil and Groundwater OU Remedial Technology Screening
Former Process Area, Soil and Groundwater OUs
Wyckoff/Eagle Harbor Superfund Site, Bainbridge Island, Washington

General Response Actions	Remedial Technology	Target Zone, Media, and COCs	Process Options	Description	Effectiveness (Target Zone and RAOs, Impacts to HHE during Construction, Reliability)	Implementability (Technical and Administrative)	Relative Cost	Screening Comment
Removal	Shallow Excavation (< 15 ft)	All Zones Debris/Soil/Upper Aquifer Solids NAPL/All COCs	Standard excavation equipment/methods Benching/sloping/shoring Dewatering Stockpiles/Run-off and Run-on controls Air monitoring	Excavation using trackhoe(s). Excavated soil direct loaded for offsite treatment and disposal or stockpiled for onsite treatment and reuse. Shoring potentially needed for depths below 4 ft. Dewatering for excavation below the water table (5 to 7 ft) also requires treatment, and offsite discharge. Air monitoring (worker and perimeter) for fugitive emissions associated with large excavation footprints or excavations in highly concentrated areas.	**Good.** Highly effective because contaminants are permanently removed from excavation zone. Reduces NAPL mobility and thickness.	**Moderate to Good.** Readily implemented to depths of 5 to 7 ft using conventional equipment with limited benching/sloping required. At depths greater than 5 to 7 ft (below water table), implementation challenges grow due to shoring and dewatering additions.	**Moderate** (not including ex situ treatment or disposal costs).	**Retained.**
	Deep Excavation (> 15 ft)	All Zones Soil/Upper Aquifer Solids NAPL/All COCs	Long-reach excavation equipment/methods Benching/sloping/shoring Dewatering Stockpiles/Run-off and Run-on controls Air monitoring		**Poor to Moderate.** Effectiveness decreases at greater depths because there is increased potential for residual contamination to be left behind due to inaccessibility (material against sheet pile wall or material in shoring setback-non excavation zone). Reduces NAPL mobility and thickness. However, due to depth of contamination present at the Wyckoff Site, unlikely that all NAPL down to top of Aquitard can be removed.	**Poor to Moderate.** Shoring and dewatering complexity increases with depth. May have to be implemented using grid approach to better manage shoring and dewatering volumes. Poses significant hazards to remedial action workers.	**Moderate to High.** Costs increase in proportion to excavation depth.	**Retained.** Although no complete direct contact exposure pathway for contaminated media present at depths below 15 ft exists, this material poses a sediment and surface water quality threat through the leaching and transport pathway.
	Extraction	All Zones Groundwater NAPL/All COCs	Fluids pumping from horizontal and vertical wells. Can be coupled with treated water injection, and injection amendments.	Similar to the current groundwater extraction and treatment system. Includes aggressive optimization and potential enhancements to accelerate NAPL and dissolved-phase mass removal.	**Poor to Moderate.** NAPL characteristics are less favorable for recovery via direct pumping, but mass reductions can be achieved over extended time periods. Decreases NAPL mobility and thickness.	**Moderate.** All of the process options for this technology are already in place. Requires ongoing O&M operator presence, resource commitment, and vendor support network for transportation and residuals disposal. Dioxin and sulfide in recovered NAPL pose additional implementation challenges.	**High.** Low capital cost because infrastructure already in place. High annual O&M and high periodic costs based on current information.	**Retained.** Experience with this technology at other wood treater sites indicates this technology, as a stand-alone alternative, would be unable to achieve the Performance Objectives and RAOs established for the Wyckoff Site in reasonable timeframe. However, this technology will likely be needed to support targeted DNAPL recovery, dewatering, and as a polishing step.
			Enhanced solubilization (water flushing/surfactant)	Potable/treated water amended with agent and injected to enhance flushing of NAPL and sorbed PAHs from the Upper Aquifer for extraction and ex situ treatment.	**Poor to Moderate.** Direct contact required. Heterogeneity controls agent distribution in the subsurface. Any heterogeneity lessens effectiveness. Poor injection control can also mobilize NAPL to less accessible areas. More effective for LPAHs and less effective for HPAHs. Temporary short-term increase in NAPL mobility provides long-term reductions in mobility and thickness.	**Moderate.** Can be implemented using existing site infrastructure supplemented with additional wells or infiltration trenches.	**Moderate.** Injection wells and trenches have low capital and O&M costs. Chemical costs will be high due to volume and duration of injection required.	**Not Retained** due to heterogeneity in Upper Aquifer matrix.

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General Response Actions	Remedial Technology	Target Zone, Media, and COCs	Process Options	Description	Effectiveness (Target Zone and RAOs, Impacts to HHE during Construction, Reliability)	Implementability (Technical and Administrative)	Relative Cost	Screening Comment
Disposal	Onsite RCRA Landfill	All Zones Debris/Soil/Upper Aquifer Solids NAPL/All COCs	Standard transportation methods Clean offsite backfill material required	Waste materials are excavated and placed in an onsite landfill constructed with liner, leachate collection, and impermeable cap per regulatory standards.	**Good.** Effective because contaminants are contained in a landfill designed to RCRA standards. Requires long-term monitoring and maintenance to ensure effectiveness.	**Poor.** Site conditions within Former Process Area not compatible with RCRA TSD requirements. Would require identification of location further inland. May limit future site use but design work-arounds possible. Technology used at several Region 6 wood treater sites (Bayou Bonfouca, Conroe Creosote, Hart Creosote, Jasper Creosote Superfund sites). CERCLA AOC policy allows waste materials exceeding LDRs to be disposed onsite.	**Moderate to High.** High capital cost; low O&M cost.	**Not Retained** due to current site conditions and future land use considerations.
	Offsite RCRA TSD	All Zones Debris/Soil/Upper Aquifer Solids NAPL/All COCs	Transport and dispose of waste at offsite RCRA TSD Pretreatment to meet LDRs Clean offsite backfill material required	Waste materials are excavated and transported offsite to a permitted disposal facility. Offsite disposal may require treatment of some or all waste material if subject to LDR.	**Good.** Effective because contaminants are contained in a permitted facility with a high level of monitoring and controls. Pretreatment to meet LDRs required.	**Moderate.** May require pretreatment prior to disposal or obtaining an LDR variance. Obtaining an LDR variance would require a mobility determination. Uncertainty exists on whether such waivers have been granted in Region 10. Potentially requires segregation of dioxin- and non-dioxin-bearing waste.	**High.** Transportation and treatment costs high given the Wyckoff Site's remote location. Rail may be lower cost option. Dioxin-bearing waste may further increase cost. Facility must be in compliance with CERCLA offsite rule.	**Retained** due to limited alternative offsite options.
	Offsite Subtitle D	All Zones Debris/Soil/Upper Aquifer Solids NAPL/All COCs	Transport and dispose of waste at offsite Subtitle D subject to waste acceptance criteria Clean backfill material required	Waste materials are excavated and transported offsite to a permitted disposal facility. Waste subject to receiving facility's acceptance criteria.	**Good.** Effective because contaminants are contained in a permitted facility with a high level of monitoring and controls.	**Moderate.** Applicable for characteristic non-hazardous materials exceeding cleanup levels and listed wastes that have received a no-longer-contained-in determination and require disposal for other technical reasons.	**Moderate to High.** Transportation and treatment costs contingent on facility approved to accept waste. Facility must be in compliance with CERCLA offsite rule.	**Retained** for non-hazardous debris and non-hazardous via characteristic rule material**.**

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General Response Actions	Remedial Technology	Target Zone, Media, and COCs	Process Options	Description	Effectiveness (Target Zone and RAOs, Impacts to HHE during Construction, Reliability)	Implementability (Technical and Administrative)	Relative Cost	Screening Comment
Ex Situ Treatment (assume soil excavated)	Biological Treatment	All Zones Soil/Upper Aquifer Solids NAPL/All COCs	Biopiles/Landfarming	Excavated waste materials are mixed with amendments and placed in a treatment cell with aeration and leachate collection systems. Temperature, moisture, nutrients, oxygen, and pH are controlled to enhance biodegradation of contaminants. Soil is periodically remixed/tilled to promote aeration and stimulate further treatment.	**Poor.** Not effective for HPAHs and dioxin. High concentration wastes may be toxic to microbes, thus limiting effectiveness. Field scale pilot ex situ biological treatment has performed poorly at other wood treater sites (e.g., Hart Creosote and North Cavalcade Superfund sites).	**Poor to Moderate.** Readily implementable using conventional equipment, but may be difficult to implement for very large volumes of contaminated materials due to space limitations. High rainfall amounts at the site will require extensive run-on and run-off controls.	**Moderate.** Moderate capital cost and O&M cost.	**Not Retained** due to ineffectiveness for HPAHs and past performance at other wood treater sites.
			Slurry phase biological	Contaminated materials are mixed with water to form aqueous slurry that is aerated and amended with nutrients, microbes, and pH adjustment. The slurry is mixed to keep solids in suspension and to promote contact between microbes and contaminants. Following treatment, the slurry is dewatered and the treated solids disposed. Water generated from the dewatering and treatment process is recycled into existing treatment process.	**Poor.** More effective for LPAHs and PCP, and less effective for HPAHs and dioxin. Slurry-phase bioremediation of PAHs is generally more effective than solid-phase biological treatment due to more direct contact between contaminants and microbes and ability to control environmental factors (pH, temperature, nutrients).	**Poor to Moderate.** Generally requires less land area than biopiles, but requires more infrastructure. Implementation on a large scale would require treatment of contaminated soil in batches. Large volumes of soil requiring treatment may require long-term operation of a bioreactor to treat all contaminated materials due to time requirement to degrade HPAHs. Also requires screening step to remove debris, gravel, and to break up clayey soils. Soil particles greater than 2 mm are not recommended for slurry phase bioreactors (Sopanaro et al., 2001).	**Moderate.**	**Not retained** due to ineffectiveness for HPAHs and dioxin. Subsurface soil contains fill and marine gravel that would have to be removed through screening. This material would have to be handled using another technology.
	Thermal Treatment	All Zones Soil/Upper Aquifer Solids NAPL/All COCs	Onsite incineration	Waste materials are excavated, and stockpiled onsite prior to treatment in a mobile incinerator unit, which uses high temperatures (typically greater than 1,400 ºF) to destroy organic contaminants. Offgas stream requires air pollution control equipment.	**Good.** Highly effective in destruction of organic contaminants. Requires additional offgas and scrubber water treatment for halogenated contaminants (PCP). Effectiveness is affected by need to do extensive pretreatment, including screening to adjust particle size, chemical treatment to adjust the pH, and dewatering to adjust moisture content (prior to incineration). Used at other wood treater sites in the 1990s.	**Moderate.** Onsite incinerators are required to meet RCRA incinerator regulations (40 CFR Parts 264 and 265, Subpart O). Incinerator performance standards include 99.99% DRE for organic contaminants and 99.9999% DRE for dioxins and furans (EPA-542-R-97-012). Will likely face opposition from local community. Large ash volume would require onsite or offsite disposal. Very high energy (natural gas) operational requirements.	**High.** High capital cost for treatment equipment mobilization/demobilization and operations. Requires ash handling and disposal, which may incur additional capital and O&M costs if managed onsite.	**Not Retained** due to high cost and implementability (public acceptance) concerns.
			Offsite incineration	Waste materials are transported offsite to a permitted treatment facility for incineration prior to offsite landfill disposal.	**Good.** Treatment efficiencies must meet RCRA incinerator regulations (40 CFR Parts 264 and 265, Subpart O) performance standards of 99.99% DRE for organic contaminants and 99.9999% DRE for dioxins and furans (EPA-542-R-97-012). Requires additional offgas and scrubber water treatment for halogenated contaminants. Dedicated offsite treatment facilities can better handle	**Good.** Readily implementable with conventional construction equipment and permitted incineration facilities. Very high energy requirements for treatment. This technology is containment remedy residuals (NAPL and spent GAC media).	**High.** High capital cost for transportation and incineration due to volume of material. No O&M and periodic costs because waste material is removed from the site.	**Retained** for dioxin-contaminated material exceeding land disposal restriction treatment standards.

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General Response Actions	Remedial Technology	Target Zone, Media, and COCs	Process Options	Description	Effectiveness (Target Zone and RAOs, Impacts to HHE during Construction, Reliability)	Implementability (Technical and Administrative)	Relative Cost	Screening Comment
					varying waste materials by blending with other feed streams and utilization of pretreatment steps to maximize treatment efficiency.			
Ex Situ Treatment (assume soil excavated) (Continued)	Thermal Treatment	All Zones Soil/Upper Aquifer Solids NAPL/All COCs	Onsite thermal desorption with onsite reuse	Soil excavated, stockpiled, and screened prior to treatment in a mobile treatment unit. Thermal desorption uses heat and mechanical agitation to volatilize contaminants from soils into a gas stream. The offgas stream is then treated to destroy or remove vapor-phase contaminants. Treated/sterile soil reused to backfill excavation footprints. Top soil cover required to promote future vegetation growth.	**Moderate.** Likely requires offgas treatment because desorption is not a 100% destructive process. Less effective for soils with high silt and clay content (EPA 542-F-96-005). Higher temperature is required for desorption of HPAHs. PCP can lead to formation of dioxins/furans in the stack or air pollution control devices (EPA, 1996). Dioxin treatment uncertain.	**Moderate.** More implementable with granular material; difficult in silt/clayey type soil. Uniform heating of cohesive soils is problematic, and fine particulates can disrupt air emissions equipment (EPA 542-F-96-005) leading to difficulty in meeting air permit requirements. High energy requirement, though lower than incineration. High moisture content increases reaction time and fuel requirements. Equipment poses hazards to remedial action workers. Community acceptance may be low, but not as poor as for onsite incineration. Has been used at other wood treater sites (Central Wood Superfund Site).	**Moderate to High.** Capital cost dependent on volume of material to be treated. No O&M or periodic costs expected.	**Retained**
			Offsite thermal desorption Clean backfill material placement	Soils are excavated and transported offsite for treatment (as described above) at a permitted treatment facility.	**Moderate to High.** Effectiveness is similar to onsite thermal desorption; however, improved treatment performance expected from a permitted/fixed commercial thermal desorption facility.	**Moderate.** Offsite treatment facilities are designed and permitted to handle offgas treatment. High energy requirement, though lower than incineration. Requires offsite transport, which adds transportation risks. Offsite thermal desorption would need to be implemented in conjunction with offsite disposal.	**High.** Cost does not include offsite disposal of treated waste material. Offsite thermal desorption would typically be coupled with offsite disposal, which would increase cost significantly over onsite treatment and disposal.	**Not Retained** due to high cost

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General Response Actions	Remedial Technology	Target Zone, Media, and COCs	Process Options	Description	Effectiveness (Target Zone and RAOs, Impacts to HHE during Construction, Reliability)	Implementability (Technical and Administrative)	Relative Cost	Screening Comment
In Situ Treatment	MNA	All Zones Soil/Groundwater NAPL < 1 ft thickness/ PAHs/PCP	Non-degradation (dispersion, dilution, sorption) Degradation (abiotic and biotic)	Contaminants attenuate over time through natural physical, chemical, and biological processes.	**Poor to Moderate.** HPAHs are relatively stable and not amenable to degradation processes; however, these characteristics render them relatively immobile. LPAHs, and PCP are amenable to degradation through biotic processes under aerobic conditions. Provides nominal contribution to achievement of Performance Objectives and RAOs.	**Moderate.** Implementable using standard monitoring, testing, and data evaluation methods but may be more difficult to prove specific processes and attenuation rates, especially for HPAHs. Limited hazards to remedial action workers and community.	**Moderate.** Long attenuation timeframe will require extended monitoring duration.	**Retained** as a component of a broader alternative.
		All Zones Soil – Dioxin Groundwater NAPL > 1 ft thickness			**Poor.** Dioxin toxicity and volume not reduced; dioxin has low mobility under typical environmental conditions. Mobile NAPL toxicity, mobility, and volume not reduced. Does not contribute significantly to achievement of Performance Objectives and RAOs.	**Poor.** Not implementable due to poor effectiveness.	**Moderate High.** Undefined attenuation timeframe will likely require extended monitoring period.	**Not Retained** due to poor effectiveness.
	Thermal Treatment	All Zones Soil Upper Aquifer Solids Groundwater NAPL/All COCs	Electrical resistance heating Debris removal Vapor recovery Offgas/condensate treatment	Electrical current is passed through electrodes spaced approximately 15 to 20 ft apart. The electrical resistance of the formation creates heat, which vaporizes water, creating steam and volatilizing VOC and SVOC contaminants. Volatilized contaminants captured by a vapor extraction system and treated ex situ.	**Moderate to High.** Effective for VOCs and LPAH in permeable soil. Less effective for HPAH/dioxin compounds. Requires capture and treatment of offgas/condensate containing contaminants for destruction or transfer to another medium for disposal. Reduces NAPL mobility and thickness.	**Poor to Moderate.** Removal of debris improves implementability. Typically, requires a minimum treatment thickness of 10 ft. Energy requirements greater for sites with higher fraction of HPAHs/dioxins. Complex energy, treatment, and supporting infrastructure requirements. Uncertainty on energy source and availability. Electrical generation and distribution equipment can pose hazards to remedial action workers.	**High.** DNAPL source zone treatment costs range from $32 to $300 per cubic yard (McDade et al., 2005).	**Not Retained.** Steam identified as preferred process option for thermal treatment.
			In situ Thermal Destruction (NAPL smoldering - STAR technology) Debris removal Offgas/condensate treatment	Contaminants are used as a fuel source for in situ combustion to destroy NAPL. A heating element is inserted into the treatment zone to heat the NAPL to between 200 and 400 °C, and then air is injected to ignite the NAPL. The heat released through combustion preheats NAPL in adjacent areas. With the continued injection of air, combustion may become self-sustaining and the heating element can be turned off.	**Unknown.** This is an emerging remediation technology with little field-scale data available to sufficiently evaluate the technology's effectiveness. Vendor information suggests treatment efficiencies in the range of 95 to 99% (http://star.siremlab.com/overview.php).	**Poor.** The implementability of this technology is difficult to assess. Based on vendor information, the technology has been demonstrated at the pilot-scale, but full-scale field implementation information is not yet available. Requires a bench-scale and pilot-scale test prior to implementation at estimated cost of $350,000 to $450,000.	**Moderate to High.** No definitive cost information due to lack of full-scale projects. Vendor reports that costs for full-scale implementation are projected to be around $80 per cubic yard.	**Not Retained.** Technology not proven at large enough scale for application at the Wyckoff Site.
			Steam generation and injection Debris removal	Steam is injected into vadose zone and Upper Aquifer through injection wells to vaporize VOCs/SVOCs for recovery via vapor extraction and ex situ treatment.	**Moderate to High.** Effective for removal of VOCs and SVOCs. Used effectively at similar sites.	**Poor to Moderate.** High energy and complex infrastructure requirements. Uncertainty on energy source and availability.	**High.** Capital Cost range from $100-$300 per cubic yard (Clu-in.org).	**Retained** due to effectiveness in reducing NAPL mobility and thickness.

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			Vapor recovery Offgas/condensate treatment		Reduces NAPL mobility and thickness.	Steam generation and handling equipment can pose hazards to remedial action workers, while noise may be objectionable to community.		
In Situ Treatment (Continued)	Physical Treatment	All Zones Soil Upper Aquifer Solids Groundwater NAPL/All COCs	Solidification/stabilization Debris removal Pre-excavation	Injection and mixing of solidifying reagents with the soil to form a monolithic, low-permeability, solid mass with high structural integrity. The resulting matrix reduces the mobility and solubility of contaminants originally present in the soil. Reagents may include Portland cement, fly ash, blast furnace slag, and organic sorbents, such as GAC, Zeolite, and organophilic clay.	**Moderate to Good.** Effectiveness depends on stabilization reagent's ability to demonstrate reduction in leaching of organic contaminants. Sorbents can be added to enhance immobilization of organic contaminants. Process yields a solidified stable mass with high structural strength and low leaching potential. Also results in an increase in overall volume of contaminated media (swell). Increased pH from stabilization increases solubility of naphthalene, which can bleed from the monolith. Technology used at North Cavalcade and Texarkana Superfund (former creosote - wood treater) sites. Decreases NAPL mobility. Not expected to decrease NAPL thickness,	**Moderate to Good.** Large mixing augers (5 to 10 ft diameter) or jet injection equipment used to blend and homogenize reagents with soil. Specialty mixing equipment (augers) can be impeded at sites with debris or coarse granular material (cobbles). Implementation difficulty increases with depth. Large equipment can pose hazards to remedial action workers, while noise may be objectionable to community.	**Moderate.** A majority of cost is capital cost; low O&M cost. Cost increases if swell material is disposed offsite, particularly if pre-treatment required to meet LDRs.	**Retained** based on ability to immobilize NAPL and experience at other sites.
		Periphery Areas Groundwater Dissolved COCs	Funnel and Gate	This is a passive treatment technology that would be deployed following active treatment phase. Consists of a perimeter collection system that routes contaminated groundwater through a treatment media. Depending on media selected and contaminant loading (flux), periodic rejuvenation or change out likely required. For Wyckoff site, may be able to use natural flow gradients and tidal action in lieu of pumps.	**Moderate.** Treatment portion of this technology highly effective, but will require O&M to maintain effectiveness. Some uncertainty on effectiveness of collection system due to unknown vertical contaminant distribution at end of active treatment phase.	**Poor to Moderate.** Technology not as well developed for thick aquifers. More difficult to implement if treatment across the Upper Aquifer's full saturated thickness required.	**Low to High.** Cost will vary depending on length, depth and system flow rate, and treatment media changeout and disposal requirements.	**Retained** in the event some localized groundwater treatment is required following active treatment phase.
	Chemical Treatment	All Zones Upper Aquifer Solids Groundwater Residual NAPL/All COCs	ISCO	Liquid reagents injected to form strong oxidants that chemically destroy contaminants. Generally requires multiple injections.	**Moderate to Good.** Proven technology at multiple sites. High oxidant demand for NAPL and PAHs. Less full-scale wood treater sites.	**Poor to Moderate.** Implementable using array of injection points and trailer/skid-mounted equipment. Uniform distribution of reagents in heterogeneous soil is necessary and represents the primary challenge associated with this and other direct contact treatment technologies. Depending on reagent chosen, may pose increased hazard to remedial action workers.	**Moderate to High** capital cost due to extensive infrastructure and chemical volume requirements. Low O&M costs if treatment objectives are met quickly without need for repeat injections.	**Retained.** Will be incorporated as polishing step within a broader alternative for use in addressing immobile NAPL or areas with limited NAPL thickness.
	Biological Treatment	All Zones Groundwater	Biosparging Enhanced aerobic	Air injection into an array of horizontal or vertical wells to stimulate aerobic biodegradation and volatilization of	**Moderate.** Technology more favorable for LPAHs.	**Good.** Technology design and equipment well developed; lots of experience.	**Low to Moderate** capital and O&M costs depending on size	**Retained** as a polishing component within broader

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General Response Actions	Remedial Technology	Target Zone, Media, and COCs	Process Options	Description	Effectiveness (Target Zone and RAOs, Impacts to HHE during Construction, Reliability)	Implementability (Technical and Administrative)	Relative Cost	Screening Comment
				residual NAPL and dissolved-phase contaminants.			of injection array.	based alternative.

Sources: EPA, 1995, 1996; McDade et al., 2005.

ºC = degrees centigrade
ºF = degrees Fahrenheit
AOC = Area of concern
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
CFR = Code of Federal Regulations
cm/sec = centimeter(s) per second
COC = contaminant of concern
DNAPL = dense non-aqueous phase liquid
DRE = destruction and removal efficiency
Ecology = Washington State Department of Ecology
e.g. = for example
EPA = U.S. Environmental Protection Agency
ET = evapotranspiration
ft = feet; foot
GAC = granular-activated carbon
HHE = human health and the environment
HPAH = high molecular weight PAHs
IC = institutional control
ISCO = in situ chemical oxidation
LDR = land disposal restrictions
LPAH = low molecular weight PAHs
mm = millimeter(s)
MNA = monitored natural attenuation
NAPL = non-aqueous phase liquid
NCP = National Contingency Plan
O&M = operations and maintenance
PAH = polycyclic aromatic hydrocarbons
PCP = pentachlorophenol
QA/QC = quality assurance/quality control
RAO = remedial action objective
RCRA = Resource Conservation and Recovery Act
SVOC = semivolatile organic compound
VOC – volatile organic compound

Appendix D
Common Element Descriptions

APPENDIX D

Common Element Descriptions

Many of the alternatives described in Section 5 of the TM, and Appendices E through H, have one or more common elements (Table 5-1) including several of the key technologies inherent in each alternative name. The following subsections briefly describe the key technologies and common elements comprising each alternative. Most of the information presented in Appendix D is similar to that described in Section 5.1 of the TM.

D1. Access Improvements

Some of the equipment used for the remedial actions are large-scale equipment that will require access improvements in order to deliver the equipment to the Wyckoff Site. The current site access is adequate for small trucks and trailers, but it will not accommodate large semi-trucks and will not be adequate for delivery of larger equipment to the site via roadways. For previous site work, heavy equipment was delivered to the site using a barge. Use of barges to deliver large-scale equipment is included as a common element for remedial action alternatives that will utilize large-scale equipment.

The beach area south of the south end of the sheet pile wall could be used as the delivery point for heavy equipment. The subsurface of the beach in this area was assessed by a geotechnical engineer and found to be suitable to support heavy equipment, which would be offloaded from a barge onto the beach and driven to the Former Process Area. Some temporary access improvements would be required to keep the barge stationary during equipment offloading. A temporary dock and offloading ramp is also included as a common element.

Equipment that could be delivered by barge includes the drill rig and silo for Alternative 4, In Situ Solidification/Stabilization (ISS), and equipment that would be used to install sheet piling around the Core Area for Alternatives 6 and 7 (thermal). Sheet piling is required for the thermal alternatives for dewatering prior to the start of thermal treatment. All other equipment could be delivered by semi-truck.

Semi-truck access to the Wyckoff Site will also require improvements to the existing road or the construction of a new road. The existing road has curves that are too sharp for large semi-trucks to navigate and the 15 percent grade is too steep for trucks to maintain traction. A new road for semi-truck access is also included as a common element.

D2. Demolition, Decontamination, Transport, and Disposal

Previous demolition conducted at the Wyckoff Site has been primarily for aboveground equipment and facilities. Most of the equipment foundations, building foundations, and other belowground concrete structures (primarily sumps) were not removed. In addition to concrete foundations and structures, other buried utilities and debris have not been removed. Buried utilities may include process pipes, storm drains, and electrical conduit. Other buried debris is known to exist onsite, such as the wing wall, and given the long history of the Site, other areas where debris may have been buried in the past could also exist. The concrete structures, buried utilities, and debris must be demolished because it may be contaminated or it may obstruct treatment remedies (such as ISS drilling).

For the alternatives evaluation, it was assumed that all of the concrete and buried utilities would be demolished. Currently, this material has a FO32/FO34 waste designation. However, the U.S. Environmental Protection Agency (EPA) has the authority to give the material a “contained out” determination, which would designate the material as a non-hazardous waste that can be beneficially reused onsite or disposed of in a Class D landfill. In order to be given a contained out determination, concrete and utilities must be cleaned using standard methods generally used for cleaning hazardous materials. For concrete, cleaning includes removing surface contaminants using steam and/or pressure washing plus removal of the concrete surface layer (approximately one-quarter inch), which is assumed to have been contaminated by hazardous product soaking into the concrete. For pipes and conduit, cleaning consists of cutting the material to provide access to the interior surface and steam and or pressure washing to remove surface contaminants. During preparation of the FFS, medium temperature thermal desorption and solidification/stabilization will be evaluated to assess the feasibility of using this technology to supplement or enhance the effectiveness of steam/pressure washing methods.

The estimated area of concrete foundations and structures is 2.5 acres. The majority of this area is composed of two foundations, the creosote facility transfer table foundation (1.0 acre) and the groundwater treatment system foundation (0.4 acre). The thickness of each foundation was conservatively estimated to be 2 to 3 feet based on the known previous use of the foundations. Total estimated volume of concrete is 13,000 cubic yards (CY). Minimal information is known regarding the quantity of buried utilities and other debris. For the alternatives evaluation, it was conservatively assumed that the volume of buried utilities and other demolition debris will be 10 percent of the total concrete volume, or 1,300 CY.

For the alternatives evaluation, EPA has agreed that it is reasonable to assume one-half of the concrete and buried utilities and debris can be cleaned to allow the material to be left onsite or disposed in a Class D landfill. The remaining material is assumed to be hazardous waste that can be disposed in a hazardous waste landfill. Therefore, 6,500 CY of concrete will be cleaned and either left onsite or disposed in a Class D landfill. Concrete that is broken into rock-sized material is suitable for use as fill material at the Site, and the cost of using the clean concrete onsite as fill material is less than offsite disposal. Therefore, for the alternatives evaluation, it was assumed that clean concrete will remain onsite as fill material. Buried utilities and other debris, however, are generally not suitable for fill material. Therefore, it was assumed that cleaned utilities and other debris will be disposed offsite in a Class D landfill.

A summary of the estimated volumes and anticipated disposal routes for demolition materials is shown in Table D-1.

TABLE D-1
Demolition Material Volumes and Disposal – Alternatives 3 to 6
Former Process Area, Soil and Groundwater OUs
Wyckoff/Eagle Harbor Superfund Site, Bainbridge Island, Washington

Material	Volume (CY)	Disposal Destination
Cleaned concrete	6,500	Onsite fill material
Concrete that cannot be cleaned	6,500	Hazardous waste landfill
Cleaned utilities and debris	650	Class D landfill
Utilities and debris that cannot be cleaned	650	Hazardous waste landfill

CY = cubic yards

D3. Groundwater Extraction and Treatment

In addition to providing treatment of groundwater produced by containment or dewatering, the existing groundwater treatment plant (GWTP) will also treat groundwater that is produced by thermal treatment.

After the work described for Alternatives 3 through 6 is completed, the GWTP likely will continue to be maintained and potentially operated, as necessary, for up to 10 years. Any remaining contamination present after 10 years of operation would be addressed by passive groundwater treatment (see Section 5.1.11) and MNA (see Section 5.1.12). For Alternative 2 – Containment, the GWTP would operated for a longer timeframe to be determined in the FFS.

For Alternatives 3, 4, and 6, existing groundwater wells might need to be removed as part of the remedial action. Therefore, for these alternatives, new groundwater wells might have to be installed.

D4. Enhanced NAPL Recovery

Where nonaqueous phase liquid (NAPL) is pooled along the water table (light NAPL [LNAPL]) or on low permeability layers (dense NAPL [DNAPL]), inducing NAPL to flow to wells is an effective means of achieving significant contaminant mass reduction, which in turn increases the effectiveness of other treatment technologies. Under this common element, enhanced NAPL recovery would be performed by increasing the horizontal hydraulic gradient across the area where mobile NAPL occurs. The mobile NAPL area is defined by the area where a Tar-specific Green Optical Screening Tool or (TarGOST®) response greater than 50 percent reference emitter (RE) was observed. Gradient control across this area would be achieved through a coordinated injection and total fluids pumping strategy. The boundaries of the enhanced NAPL recovery treatment area will be refined during remedial design to align with other elements of the selected remedy.

Based on the 140 gallons per minute (gpm) maximum design capacity of the GWTP, it is assumed that 10 new injection wells and 15 new recovery wells would be installed in the mobile NAPL treatment area. Each new recovery well would be fitted with a top filling (LNAPL) or bottom filling (DNAPL) total fluids pump. Pumped fluids would be conveyed to the GWTP were the NAPL would be separated and transferred to a storage tank for offsite treatment, or if possible, the recovered NAPL could be used as a fuel supplement under Alternatives 3, 5 and 6. A portion of the treated water from the GWTP would be pumped to the injection wells. For the purposes of the FFS, it is assumed enhanced NAPL recovery would be performed for up to 5 years.

D5. Dewatering, Treatment and Discharge

Dewatering is included as a common element for Alternatives 3 through 6. The dewatering system design will be developed to utilize the available capacity of the existing GWTP, which has a design capacity of 140 gpm, with modifications to the existing plant control systems. During the period between October and April, the GWTP would treat groundwater from the containment wells at an average flow rate of 60 gpm. Therefore, during this period, the GWTP's available capacity would be 80 gpm. This common element also includes modification of the existing outfall structure to allow for higher discharge rates and pumped discharge versus the current outfall which only allows for gravity discharge.

D6. Soil Excavation

Because some buried utilities and debris may not be detectable using aboveground instrumentation such as metal detectors, it is assumed that most areas of the Wyckoff Site will need to be processed for demolition by excavating the area to a depth of 4 feet. In addition to soil excavation as part of demolition, soil will also be excavated to prepare areas for in situ treatment (Alternatives 4, 5, and 6) or to feed contaminated soil to ex situ treatment (Alternative 3). Table D-2 summarizes excavation requirements and depths associated with preparing areas for in situ treatment or for ex situ treatment.

Since soil excavation for demolition only requires a 4-foot excavation depth, while soil excavated for in situ or ex situ treatment alternatives requires 4 feet or more of excavation depth, soil excavation as needed for the in situ or ex situ treatment alternatives will be the controlling factor in determining soil excavation requirements.

TABLE D-2
Excavation Depths
Former Process Area, Soil and Groundwater OUs
Wyckoff/Eagle Harbor Superfund Site, Bainbridge Island, Washington

Alternative	Description	Excavation Depth (ft)
Alternative 3 – MTTD	Soil from the Core Area and shallow areas in the east and north areas is excavated and treated by the MTTD process. All the soil from the Core Area is treated. Approximately half the soil in the east and north areas is assumed to be uncontaminated and will not need treatment.	25 to 35
Alternative 4 – ISS	Prior to starting ISS, an excavated area will be prepared to contain swell volume generated during treatment. The Core Area and areas containing LNAPL on the north and east sides of the Site will be treated with ISS.	7
Alternatives 5 and 6 – Thermal Enhanced Extraction	A cap above the area receiving steam is required to prevent steam from venting to the surface. The best approach for the cap construction is to excavate contaminated soil and replace it with gravel, a geomembrane, and clean soil backfill.	4

ft = feet
ISS = in situ solidification/stabilization
LNAPL = light non-aqueous phase liquid
MTTD = medium temperature thermal desorber

Currently, soil onsite is designated as a FO32/FO34 waste. EPA has the authority to designate a portion of the soil using a “contained out determination,” which would reclassify the soil as a non-hazardous waste that could be left onsite or disposed of in a Class D landfill. Two potential mechanisms may allow a contained out determination as follows:

1. If existing data obtained from in situ soil sampling shows the upper layer of soil to be non-hazardous (i.e., all contaminant concentrations are below hazardous waste criteria) and in situ treatment is designed to treat all hazardous soil below the surface layer, then the upper layer of soil could be given a contained out determination. All areas except for the Core Area could potentially be in this category.
2. If soil is excavated, stockpiled, sampled, and analyzed for hazardous constituents, and found to have no contaminant concentrations above hazardous waste criteria, then the soil could be given a contained out determination. Any of the excavated soil could potentially be in this category.

Table D-3 shows a breakdown of expected soil handling by alternative and treatment areas.

TABLE D-3
Excavated Soil Volumes
Former Process Area, Soil And Groundwater OUs
Wyckoff/Eagle Harbor Superfund Site, Bainbridge Island, Washington

Alternative	Target Zone	Size (Acres)	Excavated Volume (cubic yards)	Soil Handling[a]
Alternative 2 - Containment	No soil excavation performed			
Alternative 3 – Excavation, Thermal Desorption, and ISCO Alternative 6 – Excavation, Thermal Desorption, and Thermal Enhanced Extraction	Core	1.8	87,100 (based on average 30-foot depth)	Stockpile, sample, and test; assume 50 percent is designated clean and used as fill onsite; assume 50 percent is treated by MTTD process and then used as fill onsite.
	North and East Shallow (LNAPL)	2.4	116,000 (based on average 30-foot depth)	Stockpile, sample and test; assume 50 percent is designated clean and used as fill onsite; assume 50 percent is treated by MTTD process and then used as fill onsite.
	Demolition Only	5.8	37,400	Assume designated as “contained out” by existing data. Excavate and stockpile next to trench; backfill after demolition material is removed.
Alternative 4 – In Situ Solidification/Stabilization	Core	1.8	20,300	Stockpile, sample and test; assume 50 percent is designated clean and used as fill onsite; assume 50 percent is treated in ex situ cell and reused onsite
	North and East Shallow (LNAPL)	2.4	27,100	If designated as “contained out” by existing data, stockpile and use as fill onsite. If “contained out” determination not obtained, treat in ex situ cell and reuse onsite.
	Demolition Only	5.8	37,400	Assume designated as “contained out” by existing data. Excavate and stockpile next to trench; backfill after demolition material is removed.
Alternatives 5 – Thermal Enhanced Extraction and ISCO	Core	1.8	11,600	Stockpile, sample and test; assume 50 percent is designated clean and used as fill onsite; assume 50 percent is disposed in hazardous waste landfill.
	Periphery Noncore	7.2	46,500	Assume designated as “contained out” by existing data. Excavate and stockpile next to trench; backfill after demolition material is removed.

[a] For the purposes of this FFS, it is assumed that hazardous material generated during implementation of Alternatives 3, 4, and 6 can be treated and a “contained out” determination obtained thus allowing onsite reuse. Alternative 5 technologies cannot handle ex situ soil and debris treatment; therefore, hazardous material transported to offsite Subtitle C facility.

MTTD = medium temperature thermal desorber
ISCO = in situ chemical oxidation
LNAPL = light non-aqueous phase liquid

D7. Propane System Details

Alternatives 3, 5, and 6 will require a fuel source to power the rotary kiln (Alternative 3) or the steam boiler (Alternatives 5 and 6). No natural gas is available near the Wyckoff Site and it was assumed that constructing a natural supply line would not be cost effective compared to using propane, which could be delivered to the Site using tanker trucks. The total estimated propane consumption for Alternative 3 is approximately 3 million gallons. For Alternatives 5 and 6, the total estimated propane consumption is approximately 1.3 million gallons. Estimated rates of consumption assuming 24/7 operation are 9,600 gallons per day for Alternative 3 and 3,000 gallons per day for Alternatives 5 and 6. At these rates, daily propane deliveries of one or more trucks would be required.

Suburban Propane, who supplies most of the propane on Bainbridge Island, was contacted to discuss a temporary propane storage and vaporization system. Based on the quantity of propane that would be consumed, they stated that Suburban Propane would supply an 18,000-gallon storage tank and a vaporizer system free-of-charge. This equipment would be placed on a concrete foundation.

D8. In Situ Chemical Oxidation

In general, in situ chemical oxidation (ISCO) is an aqueous phase reaction, thus the NAPL must dissolve into water to react with the oxidant, although some evidence exists supporting oxidation at the NAPL surface. The most suitable oxidants for polycyclic aromatic hydrocarbons (PAHs_ are hydrogen peroxide, sodium persulfate, and permanganate (Forsey, 2004).

Hydrogen peroxide is a stronger oxidant than persulfate and permanganate; however, persulfate and permanganate remain active much longer in the subsurface, allowing more time for distribution and reaction with contaminants present in low permeability soils such as silts and clays. Persulfate is not compatible with the Former Process Area sheet pile wall and, therefore, is not considered further in this TM. Numerous methods are available to catalyze hydrogen peroxide to increase its oxidizing strength. Aqueous iron, heat, and ozone are examples. NAPL mass and architecture determine whether chemical oxidation is applied initially or after the application of other NAPL treatment technologies.

Application of ISCO technologies for NAPL remediation are relatively straightforward. Under theoretically ideal conditions, the stoichiometric reaction between the oxidant and dissolved contaminant yields the mass of oxidant required for treatment if initial estimates of NAPL mass and composition are known. The stoichiometric requirement on a mass basis for destruction of naphthalene by the most common oxidants is provided in Table 5-2. Naphthalene accounts for the largest mole fraction for the NAPL present at the Wyckoff Site and ISCO treatment for the remaining fraction is expected to respond similarly to that of naphthalene.

Beyond the mass of contaminant, native organic material present in aquifer solids also reacts with the oxidant. This background oxidant demand must also be met in addition to the NAPL requirement. Background oxidant demand is determined by performing total oxidant demand (TOD) tests in the laboratory with soil samples collected from the site (Haselow et al., 2003). Hydrogen peroxide is generally considered to have a low TOD requirement and an initial TOD estimate can assume a zero value. A recent laboratory study (Liao et al., 2011) reports typical TOD values for various soil types ranging from 7 to 50 grams permanganate per kilogram (kg) of soil with higher values needed for increasing clay content. The TOD values for hydrogen peroxide and permanganate were used to develop initial estimates of oxidant mass required for this common element.

Both hydrogen peroxide and permanganate are delivered to the subsurface by injection through direct push technology or through installed vertical wells. The compatibility of these oxidants with injection through direct push wells facilitates their use for targeted applications (i.e., higher doses in more contaminated locations and vice versa).The oxidant and method of subsurface delivery under this common element will vary depending on the target zone being treated. Specific information is provided in the alternative descriptions presented in Sections 5.2 through 5.7.

D9. Enhanced Aerobic Biodegradation

This common element injects oxygen into the subsurface to accelerate in situ biodegradation of sparse NAPL and dissolved contaminants. The oxygen is delivered via low-level air injection (biosparging), ozone, or an oxygen-release compound. For this common element, biosparging is assumed.

Based on the makeup of creosote at the Wyckoff Site, naphthalene is a suitable surrogate to represent the hydrocarbon mixture for degradation. The overall stoichiometry for aerobic biodegradation of naphthalene results in 1 cubic yard of soil, containing 1 gallon of creosote (4.15 kg), being treated for each 53 kg, or 1,530 standard cubic feet of air injected. This estimate provides an initial basis for the minimum cumulative mass of air required for the design of a biosparging system.

The air injection rate in the biosparging system will be estimated from the anticipated half-lives of contaminants in the groundwater and the partitioning of oxygen from air into the groundwater. For naphthalene, observed half-lives under ambient conditions range from 1 to 250 days. For bioventing in the vadose zone, the half-life of naphthalene ranges from 16 to 48 days. The number of air injection points will be determined from pilot testing performed during remedial design. For the FFS, a 20-standard-cubic-foot-per-minute flow rate and 30-foot-radius of influence are assumed.

D10. Surface Cover/Sheet Pile Wall

The planned final end use of the Wyckoff Site is a park with open areas. To reduce surface water infiltration at the Site and to prevent exposure to potential, low-level residual contaminants, a surface cover with an impervious bottom liner is included as a common element for Alternative 2 and Alternatives 3 to 6. Stormwater would be collected and discharged to surface water using best management practices typical of vegetated areas. Several cover designs are possible for the Former Process Area, including variations on a multilayer cover or some form of evapotranspiration (ET) cover. Both would allow for a range of recreational uses.

This common element also includes maintenance of the outer sheet pile wall until remedial action objectives (RAOs) are achieved. Maintenance activities include the following:

- Installation of a shoreline protection system to protect the above grade portion of the sheet pile wall against corrosion and physical damage. The shoreline protection system consists of installing a shallow secondary wall, constructed of corrosion resistant material, to a depth of up to 30 feet. This activity would be performed for Alternative 2 and potentially Alternatives 3 through 6, if deemed necessary during remedial design.
- Joint sealing. This consists of impregnating the existing sheet pile wall joints with a sealant material to reduce or eliminate groundwater and NAPL seepage. This activity applies to Alternative 2 and potentially Alternatives 3 through 6, if deemed necessary during remedial design.
- Periodic replacement of the sheet pile wall. This activity consists of replacing the outer sheet pile wall every 50 years. This activity only applies to Alternative 2, which has an operations and maintenance timeframe greater than 30 years.

D11. Passive Groundwater Treatment

This common element is proposed as an optional technology to supplement enhanced aerobic bioremediation (EAB) if deemed necessary based on EAB performance monitoring results. It consists of three main components: a collection system, a treatment media, such as granular-activated carbon or other reactive media housed in a treatment vessel, and a pipe that conveys the treated water to the outfall described in Section 5.1.5. The passive treatment system collects Upper Aquifer contaminated groundwater, removes dissolved phase contaminants of concern (COCs), and discharges the treated groundwater. This common element controls contaminant flux through the sheet pile wall, thereby protecting water quality in the intertidal area where groundwater upwells to surface water. The design concept utilizes the hydraulic head difference that occurs due to tidal fluctuations to provide passive groundwater treatment. The design concept minimizes the need for electricity, pumps, and other features common in active treatment systems. The system treats and discharges contaminated groundwater during periods when there is a significant head difference across the sheet pile wall allows groundwater flow through the treatment system to occur.

D12. Monitored Natural Attenuation

Monitored Natural Attenuation (MNA) relies on natural degradation and nondegradation processes to decrease contaminant concentrations. When relying on natural attenuation processes for site remediation, EPA prefers processes that degrade or destroy contaminants (OSWER Directive 9200.4-17P, *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites*, EPA, 1999). The key degradation processes for dissolved-phase creosote constituents at the Wyckoff Site include aerobic and anaerobic biodegradation. The key nondegradation processes include dispersion and groundwater-surface water mixing.

Under this common element, a network of Upper Aquifer and Lower Aquifer monitoring wells and intertidal aquifer tubes would be maintained and sampled semiannually for the first 2 years, and annually thereafter, for semivolatile organic compounds to track contaminant concentrations and to develop information on attenuation rates. Periodic sampling (once every 5 years) for geochemical indicator parameters, stable isotope probing, and phospholipid fatty acids would be performed to develop evidence on specific attenuation processes. It is assumed that sampling would be conducted from 10 Upper Aquifer, 5 Lower Aquifer, and 5 multilevel intertidal aquifer tubes.

D13. Access Controls

For all remedial alternatives (except Alternative 1 – No Action), site fencing would remain until the Site can be converted to a public area. Institutional controls (ICs) to ensure that the Upper Aquifer groundwater within the Former Process Area remains unused would be implemented. ICs restricting site use to reduce direct exposure to soil would also be instituted.

D15. 5-Year Reviews

The National Contingency Plan (NCP), under 40 CFR 300.430(f)(4) (ii), requires that periodic reviews be conducted if a remedial action is selected that results in hazardous substances, pollutants, or contaminants remaining at the site above levels that allow for unlimited use and unrestricted exposure. These reviews are conducted no less often than every 5 years after the selected remedial action is initiated. Three 5-year reviews have been performed to date, with the third 5-year review completed in 2012. This common element provides for continuation of the 5-year reviews until the contaminants are no longer present at unrestricted use/unrestricted exposure levels. For the purposes of this FFS, it is assumed that the cost for 5-year reviews would be incurred under each alternative.

Appendix E
Alternative 3 Description

APPENDIX E

Alternative 3 Description

Under this alternative, the Core Area, North Shallow (light non-aqueous phase liquid [LNAPL]), and East Shallow (LNAPL) target zones would be excavated, treated ex situ in a medium temperature thermal desorber (MTTD), and the treated soil returned to the excavation as clean fill. In the smaller, less-contaminated Other Periphery target zone, enhanced aerobic biodegradation (EAB) would be the treatment technology applied. In the North Deep (dense non-aqueous phase liquid [DNAPL]) target zone, in situ chemical oxidation (ISCO) using injection of permanganate as the oxidant would be applied. It is assumed that multiple applications of the oxidant would be needed to achieve the remedial action objectives (RAOs) for source reduction. Optimized extraction of mobile DNAPL, using a network of existing and newly installed recovery wells, would precede oxidant injection under the enhanced NAPL recovery common element to reduce the mass of oxidant required for treatment. In the Other Periphery target zone, ISCO using catalyzed hydrogen peroxide as the oxidant would be applied using direct push technology for injections rather than fixed wells. EAB would be applied as a polishing technology in areas with persistent contamination.

In addition to the above key alternative components, this alternative includes an array of common elements as shown in Table 5-1 of the *Wyckoff/Eagle Harbor Soil and Groundwater Operable Units Focused Feasibility Study - Remedial Technology Screening and Preliminary Remedial Action Alternatives Technical Memorandum* (TM).

E1. Remedial Approach by Target Zone

The following subsections provide additional information on the technologies and their associated process options that would be used under Alternative 3 to treat the five identified target zones. A description of the common elements associated with this alternative (see Table 5-1) is provided in Appendix D, Common Element Descriptions, of this TM.

E1.1 Core Area, North Shallow (LNAPL), and East Shallow (LNAPL)

In the Core Area, the target interval for excavation and ex situ treatment via MTTD includes the ground surface down to the top of the Aquitard. In the North Shallow (LNAPL) and East Shallow (LNAPL) target zones, the excavations would extend to a maximum depth of 35 feet below ground surface (bgs). Excavation and MTTD would be implemented as follows:

1. Hydraulically isolate the Core Area by installing sheet pile walls, structural shoring walls, or similar.
2. Initiate dewatering in the isolated zone using existing and newly installed pumping wells.
    a. Route extracted water to the existing Groundwater Treatment Plant (GWTP).
3. Simultaneous with Step 2, install surface components of the ex situ soil treatment system.
    a. Mobilize and place a propane-fired MTTD unit and associated fuel tank.
    b. Prepare staging areas.
4. Initiate excavation and debris removal from the surface as described in Section 5.1, Common Elements, of the TM.
    a. Supplement dewatering with sumps and pumps internal to the excavation.
    b. Operate pressure relief wells in the Lower Aquifer to minimize uplift pressures acting on the Aquitard, if needed.
5. Perform excavation and treatment throughout the Core Area.

a. Soil will be excavated sequentially in several cells to reduce dewatering rates and to allow room for stockpiling before and after treatment.

b. Cells may be separated by temporary sheet pile walls with internal bracing.

c. Soil will be screened for contamination during excavation. Clean soil will be segregated, tested, and left untreated.

d. Contaminated soil will be processed in the MTTD unit by heating to approximately 1,100 degrees Fahrenheit.

e. Treated and clean soil will be stockpiled and moisture-adjusted prior to use as backfill.

f. Backfilled areas will be pre-loaded (temporarily overburdened with several feet of additional soil) to compact replaced soils.

6. At the completion of the Core Area excavation, treatment, and backfilling, move site activities to the North Shallow (LNAPL) and East Shallow (LNAPL) target zones.
7. Excavate the North Shallow (LNAPL) and East Shallow (LNAPL) target zones, which would also require dewatering. Dewatering would be performed in successive areas of excavation (excavation cells) using a series of existing and newly installed pumping wells, temporary sheet pile installations (with internal bracing), and sumps and pumps internal to the excavation.
8. Perform excavation, treatment, and backfilling, as described above in Step 5, across the North Shallow (LNAPL) and East Shallow (LNAPL) target zones.
9. At the completion of all excavation, treatment, and backfilling, remove all temporary isolation and shoring devices.
10. Site restoration would include installation of a surface cover as described in Section 5.1, Common Elements, of this TM.

E1.2 North Deep (DNAPL)

In the North Deep (DNAPL) target zone, treatment would be performed with ISCO using permanganate as the chemical oxidant. Permanganate was selected because of the depth below the water table where DNAPL occurs, its effectiveness for polycyclic aromatic hydrocarbon (PAH) destruction, the persistence of its oxidizing power, and its relative ease of injection through fixed wells. The primary drawback to permanganate in this application is its negative impact on subsequent aerobic biological degradation processes and a potential lag phase for re-establishing suitable conditions for EAB. It is assumed that ISCO would be deployed during three separate treatment events, with each treatment event (phase) targeting a progressively smaller area and requiring a smaller volume of oxidant.

ISCO would be implemented in the following steps:

1. Collect representative soil and groundwater samples from the target zone above and at the interface of the Aquitard at various locations. Sample collection would coincide with the installation of fixed vertical DNAPL recovery wells screened just above and across the interface between the Upper Aquifer and the Aquitard. This drilling effort would also include the installation of performance monitoring wells screened in the middle of the Upper Aquifer, which would be later reused as biosparge points or amendment injection wells for a post-ISCO EAB polishing treatment step.
2. Perform site-specific, bench-scale testing of oxidant dosage in both the Upper Aquifer and Aquitard materials collected as representative soil and groundwater samples in Step 1.

3. Perform pilot tests of candidate permanganate doses and injection rates, determine the radius of influence for fixed well injection, assess persistence of the permanganate, and evaluate treatment effectiveness and residual groundwater quality impacts.
4. Evaluate bench and pilot test results to develop a field protocol for oxidant injection and monitoring.
5. Install wells for injection of the oxidant and monitoring of results. These installations would also include wells screened in the middle of the Upper Aquifer for biosparging and performance monitoring.
6. Pump existing and newly constructed wells for DNAPL recovery and continue until DNAPL recovery rates approach an asymptotic level. Extracted groundwater and DNAPL would be pumped to the GWTP.
7. Mobilize equipment (e.g., mixing tanks and injection pumps) to the site, establish a chemical storage and staging area, and receive initial shipments of oxidant.
8. Initiate oxidant injection through the fixed wells and move progressively across the target zone. Monitor groundwater quality ahead of the injection front to assess radius of influence and contaminant contact.
9. At the completion of the initial injections, which is expected to occur after about 6 months, monitor PAH concentration trends over time (6 to 12 months) to assess effectiveness, to measure for presence of residual oxidant, and to asses other groundwater conditions such as reduced effective permeability from precipitated manganese dioxide.
10. Evaluate collected data and assess the need to install additional injection wells. Assume a 10 percent increase to the number of injection and monitoring wells.
11. After the installation of new wells, initiate a second round of oxidant injection that is assumed to equal approximately 50 percent of the initial mass of permanganate injected.
12. At the completion of the second round of injection, which is expected to occur after about 3 months, monitor PAH concentration trends over time (6 to 12 months) in treated areas to assess effectiveness, residual oxidant, and other groundwater conditions including reduced effective permeability from precipitated manganese dioxide.
13. Evaluate collected data and assess the need to install additional injection wells. Assume a 5 percent increase to the number of injection and monitoring wells.
14. After the installation of new wells, initiate a third round of oxidant injection that is assumed to equal approximately 25 percent of the initial mass of permanganate injected.
15. Evaluate collected data and assess groundwater conditions and the need for more aggressive intervention in select areas to attain remedial goals.
16. Plugging and abandonment of all wells and site restoration to include installation of a surface cover as described in Section 5.1, Common Elements, of this TM.

E1.3 Other Periphery Areas

The primary treatment technology for this target zone is ISCO, although a small, shallow area would be excavated and treated with MTTD with the option described in Section E1.1. The oxidant selected for this target zone is catalyzed hydrogen peroxide. Ozone can catalyze peroxide and also enhances biodegradation by releasing molecular oxygen. Hence, the catalyst is expected to be ozone, as the subsequent release of oxygen will also promote biodegradation. The catalyzed hydrogen peroxide would be injected through direct push technology. Details of ISCO with hydrogen peroxide are described with Alternative 6 (see Appendix G, Sections G1.2 and G2.2, of this TM).

E2. Design Criteria and Basis for Approach

The following subsections present the design criteria and design basis for each of the key Alternative 3 components.

E2.1 MTTD Treatment

The design basis for the MTTD treatment is based primarily upon the practical throughput rate for treating contaminated soil of 20 tons per hour. Other general design parameters include:

- MTTD Soil Treatment Throughput = 20 tons/hour (hr) (15 cubic yards [CY]/hr)
- Auxiliary Fuel = Propane @ 15 to 25 gallons per ton of soil treated
- MTTD Equipment Layout Area = 75 feet x 100 feet
- Total Area for Soil Staging, Processing, and Storage = 50,000 square feet
- Excavator Operation Time = 10 hr/day x 5 days/wk = 50 hrs/week (wk)
- MTTD Operation Time = 24 hr/day x 4.3 days/wk = 100 hrs/wk
- Soil Treatment Rate = 1,500 CY/wk

Design parameters and assumptions specific to the Core Area include:

- Sheet pile wall and shoring totaling 1,100 linear feet would be installed for hydraulic isolation.
- The water table can be lowered by 37 feet within four months of pumping at 80 gallons per minute (gpm).
- Drawdown can be maintained with an extraction rate of 36 gpm.
- Total Soil Volume Excavated = 129,000 CY
- Total Soil Volume Treated with MTTD Unit = 87,000 CY (67 percent of excavated soil)
- Duration of MTTD operations in the Core Area is estimated at 14 months.

Design parameters specific to the North Shallow (LNAPL) and East Shallow (LNAPL target zones include:

- Temporary sheet pile walls, dewatering with fixed wells, and pumping internal to the excavation footprint provide stable and dry conditions necessary for excavation.
- The water table can be lowered by 20 feet with two months of pumping at 80 gpm.
- Drawdown can be maintained with an extraction rate of 23 gpm.
- Total Soil Volume Excavated = 134,000 CY
- Total Soil Volume Treated with MTTD Unit = 36,000 CY (27 percent of excavated soil)
- Duration of MTTD operations in the North Shallow (LNAPL) and East Shallow (LNAPL) target zones is estimated at 6 months.

E2.2 ISCO Treatment for North Deep (DNAPL)

The design basis for permanganate-based ISCO application in the North Deep (DNAPL) target zone is based primarily upon three parameters: (1) the estimated oxidant demand associated with the DNAPL mass and other organic material making up the total soil oxidant demand, (2) the number, spacing, and screen intervals of injection wells, and (3) the injection rate for the oxidant solution. The spacing of wells and injection rate of oxidant are a function of injection depth, soil permeability, oxidant persistence, and practical limits on the production and chemical delivery rate.

The assumed design parameters include:

- The stoichiometric requirement on a mass basis for destruction of creosote components by sodium permanganate is estimated to be 18.7 gram per gram of creosote.

- The soil oxidant demand is negligible compared to the DNAPL mass oxidant demand.
- The radius of influence for injection of oxidant over the interval from 55 to 65 feet bgs is 20 feet yielding 28 injection wells over an area of approximately 30,000 square feet.
- The permanganate remains active for several days following injection.
- Permanganate solution can be injected at a concentration of 10 percent by weight.
- Permanganate solution can be injected at a total of 10 gpm (cumulative for multiple well injections).
- Sodium permanganate solution at a concentration of 40 percent by weight can be delivered to the site at a rate of 2,200 gallons per day during each of the three injection phases.

E2.3 ISCO Treatment for Other Periphery Areas

The design basis for hydrogen peroxide-based ISCO application in the Other Periphery Areas is described with Alternative 6 in Appendix G, Section G2.2, of this TM. The assumed design parameters for this alternative include:

- The stoichiometric requirement on a mass basis for destruction of creosote components by hydrogen peroxide is estimated to be 6.4 gram per gram (g per g) of creosote.
- The soil oxidant demand is negligible compared to the contaminant demand.
- The radius of influence for injection of oxidant over the interval from 15 to 25 feet bgs is 8 feet yielding 176 injection points over an area of 31,000 square feet.
- Catalyzed hydrogen peroxide is active for 3 hours.
- Hydrogen peroxide solution can be injected at a concentration of 17.5 percent weight (%wt).
- Hydrogen peroxide solution can be injected at a total of 16 gpm (cumulative for multiple direct push rigs).
- Hydrogen peroxide solution at a concentration of 35 %wt can be delivered to the site at a rate of 8,000 gallons per day in tankers.

E2.4 EAB Treatment for Polishing

The design basis for implementing EAB will vary across the Wyckoff Site and depends upon the following factors:

- Oxygen requirement for aerobic biological degradation based on contaminant mass estimates (e.g., 1,000 standard cubic feet of air per kilogram of contaminant mass).
- Evaluation of radius of influence (i.e., the number and depth of biosparging points required).
- Anticipated air injection rate for soil properties, air distribution patterns, NAPL dissolution rates, and biological degradation rates of individual creosote components.

NAPL dissolution, oxygen distribution and diffusion, and reaction rates combine to slow the process and reduce the efficiency of oxygen utilization, thereby requiring the injection of an excess of oxygen into the subsurface. The air injection rate in the biosparging system will be estimated from the anticipated half-lives of contaminants in the groundwater at the Wyckoff Site and the partitioning of oxygen from air into groundwater. For naphthalene, observed half-lives under ambient conditions range from 1 to 250 days. For bioventing in the vadose zone, the half-life of naphthalene ranges from 16 to 48 days.

E3. Implementation Schedule

Implementing Alternative 3 would take approximately 6 to 10 years from initial design to achievement of remedial goals. The MTTD, ISCO, and EAB alternative components are assumed to occur simultaneously. The duration of EAB is expected to continue from 2 to 4 years beyond the MTTD and ISCO operations as summarized below:

Component	Schedule in Years
Design	0.5
Construction	1 to 2
– Hydraulic Isolation and Dewatering	
– Well Installation for ISCO and EAB	
Operation	
– Core Excavation, Treatment, Backfill	1.5 to 2
– LNAPL Excavation, Treatment, Backfill	0.5 to 1
– ISCO	concurrent
– EAB	2 to 4
Site Restoration	0.5

Appendix F
Alternative 4 Description

APPENDIX F

Alternative 4 Description

Under Alternative 4, in situ solidification/stabilization would be performed in each of the target zones. In addition to this key component, this alternative also includes an array of common elements as shown previously in Table 5-1 of the *Wyckoff/Eagle Harbor Soil and Groundwater Operable Units Focused Feasibility Study - Remedial Technology Screening and Preliminary Remedial Action Alternatives Technical Memorandu*m (TM).

Prior to the initiation of In Situ Solidification/Stabilization (ISS) activities, demolition of subsurface infrastructure would be performed in each target zone's footprint as described in Section 5.1, Common Elements, of the TM. Demolition and debris removal is necessary to eliminate underground obstructions, foundations, piers, pipes, and debris that inhibit soil mixing equipment and reagent distribution.

Soil would also be removed to establish an ISS working platform at a depth of approximately 7 feet below ground surface (bgs). This step would allow for ISS auger treatment to a depth of approximately 60 feet below the original ground surface elevation providing a sump to contain the excess volume, or "swell," that occurs during in-situ soil mixing. This volume expansion is typically 20 to 25 percent of the original treatment volume. The working platform is leveled and stabilized with gravel, and, if necessary, wood crane mats can be placed over the gravel base to create stable working conditions for the ISS equipment.

Extensive dewatering would not be required as all pre-excavation (Common Element) activities would take place above the water table; however, it is expected that some general construction dewatering within the sump footprint would be required. ISS would be performed from an excavated working platform established above the water table. Localized dewatering to remove collected stormwater may be required and run-on controls consisting of berms and trenches would also be used to minimize stormwater entry into the work area. Groundwater modeling would be performed during remedial design to evaluate new groundwater flow patterns around the ISS mass, evaluate mounding that could result in groundwater seeps above grade, and to estimate post ISS groundwater quality conditions.

Following completion of the subsurface infrastructure removal and pre-excavation steps, ISS would be performed using a combination of the following equipment:

- Vertical augers attached to a crane-mounted drilling platform
- Vertical augers advanced using a hydraulic drill rig
- Excavator-mounted horizontal augers such as Lang Tool
- Jet grouting
- Bucket mixing using a hydraulic excavator
- Multiple head deep soil mixing (DSM) or cutter head soil mixing (CSM)

In areas with continuous or near continuous impacts to approximately 60 feet bgs, ISS would be performed using a vertical auger to mechanically mix reagents and non-aqueous phase liquid (NAPL)-contaminated soil from the top to the bottom of the treatment zone. Due to the difficulties in mobilizing large crane-mounted equipment to the Site, it is assumed that mixing would be performed using a hydraulic drilling rig. Reagent for ISS would be mixed onsite in a batch plant.

Geotechnical and treatability testing would be performed during remedial design to establish the exact drilling equipment and auger size, but for the purposes of the Soil and Groundwater Operable Unit (OU) FFS, it assumed that NAPL-contaminated soil present at depths up to 35 feet would be treated using an 8-foot-diameter auger while NAPL-contaminated soil present at depths between 35 and 60 feet would be mixed using a 6-foot-diameter auger.

In the North Deep (DNAPL) target zone, jet grout equipment would be used.

Once ISS is completed, a surface cover would be placed over the site as described in Appendix D, Common Element Descriptions. The surface cover may include supplementary stormwater controls, consistent with future site uses, consisting of collection basins, conveyance pipes, swales and infiltration galleries.

F1. Remedial Approach by Target Zone

The following subsections described how ISS would be implemented in each of the target zones. Table F-1 presents the approximate treatment quantity in each area, including the proposed pre-excavation volume and anticipated swell volumes.

F1.1 Core Area, North Shallow (LNAPL), and East Shallow (LNAPL)

NAPL-contaminated soil in the Core Area generally extends to depths less than 50 feet bgs, and in the two LNAPL target zones to depths between 25 and 45 feet bgs. In these three target zones, a combination of 6-foot and 8-foot-diameter vertical augers would be used to deploy ISS.

F1.2 North Deep (DNAPL)

In this target zone, DNAPL occurs in discrete layers above the top of the Aquitard to depths of up to 76 feet bgs. Jet grouting equipment would be used to deploy ISS.

TABLE F-1
Estimated ISS Treatment Volumes
Former Process Area, Soil and Groundwater OUs
Wyckoff/Eagle Harbor Superfund Site, Bainbridge Island, Washington

ISS Volumes	Pre-Excavation Volume to 7 feet bgs (CY)	ISS Treatment Volume (CY)	Swell Volume (CY)
Core Area	20,000	86,000	17,000
East Shallow Periphery Sub-Area	35,000	120,000	25,000
North Shallow Periphery Sub-Area	6,000	17,000	3,300
North Deep Periphery Sub-Area	11,000	53,000	11,000
North Shallow & Deep Periphery Sub-Area	4,200	17,000	3,300
Other Periphery Sub-Area	9,500	29,000	5,800
Jet Grout Volumes		**Volume (CY)**	**Spoils (CY)**
North Deep Periphery Sub-Area		6,100	2,440
North Shallow & Deep Periphery Sub-Area		1,600	640

CY = cubic yards
ISS = In Situ Solidification/Stabilization

F2. Design Criteria and Basis for Approach

The primary design criteria for ISS include the following:

- Identify the compressive strength for the stabilized material that supports future site reuse.
- Determine the leaching reduction needed to achieve groundwater and surface water protection remedial goals.

- Develop mix design for inner and perimeter columns. The mix design for the perimeter columns is expected to be enriched relative to the inner columns to improve leachability and durability characteristics.

A typical compressive strength of 50 pounds per square inch (psi) with no single point less than 40 psi is assumed for the Soil and Groundwater OU FFS. Compressive strength is an indirect indicator of durability as materials with higher initial compressive strength are typically considered more resistant to aging (Interstate Technology and Regulatory Council [ITRC], 2011).

Leaching is reduced by either a reduction in hydraulic conductivity or by using amendments to absorb organic constituents. The lower hydraulic conductivity of the ISS monolith relative to the surrounding soils forces groundwater around it, thereby reducing the potential for groundwater to come into direct contact with entombed contaminants. Absorbents (activated carbon or oleophilic clay) can reduce leaching by increasing the ability to absorb contaminants over native soils. For the purposes of this FFS, the addition of an adsorbent material is not deemed necessary.

An evaluation of leaching reduction would be performed through treatability testing performed during remedial design to aide in the selection of the most effective reagent mix design. Leachability testing would be conducted on both the untreated NAPL-contaminated soil and the NAPL-contaminated soil treated with various mix designs after a 28-day cure period. The testing would be conducted in accordance with the approaches presented in the *Development of Performance Specifications for Solidification/Stabilization* (ITRC, 2011) using U.S. Environmental Protection Agency (EPA) premethods known as Leaching Environmental Assessment Framework (LEAF). The leaching characteristics of the untreated material will be evaluated using Premethod 1314 or 1316, while the treated material will be evaluated using Premethod 1315 to assess the reduction in leaching after treatment. These tests are not intended as a measure of performance during full-scale ISS, but rather as a tool to identify the most effective mix design and to provide data to model post-ISS groundwater quality conditions outside the target zones.

Because reagents can be a significant cost component of ISS treatment, the representative mix design assumed for the Soil and Groundwater OU FFS consists of up to 10 percent Portland cement and 1 percent bentonite. Although other wood treater Superfund sites have used activated carbon, the leaching reduction was not evaluated using the new LEAF methods, and older methods showed higher leaching than with the new LEAF tests because the material was pulverized prior to testing (ITRC, 2011).

F3. Sequencing

The bench-scale treatability test program would be performed during remedial design to determine the optimum reagents, mix ratios, and addition rates. Existing site geologic information will be evaluated to determine if heterogeneities exist that may require multiple mix designs. Initial treatability testing would focus on developing a range of mix designs that result in successful treatment to achieve the design criteria. Testing would be performed using readily available bulk materials such as Portland cement, blast furnace slag, and bentonite in amounts that have been successful in achieving design/performance criteria at similar wood treater sites where ISS has been deployed. Performance requirements include maximum hydraulic conductivity, minimum unconfined compressive strength, and leaching reduction using LEAF methods to test and evaluate leaching performance of ISS materials. Optimization testing may be performed to better refine the reagent mix design, establish ranges for reagent and water addition ratios, or evaluate the use of other available reagents to improve performance or lower overall remedial costs.

For large-scale projects a field demonstration test is often performed to verify the bench-scale results, evaluate full-scale equipment options and productivity, and identify scale-up considerations. Due to logistical limitations to mobilizing ISS equipment to the Site for a standalone field demonstration test, a demonstration period would occur at the start of full-scale remediation.

Field activities would be sequenced as follows:

1. Mobilization and set-up of ISS rig and reagent batch plant occurs first. Large items such as silos and the ISS rig would be transported to the Site via barge. Smaller items that can be transported without oversize load restrictions would be delivered to the Site overland via track. The batch plant would be set up in a central location to allow for delivery of reagent to the entire treatment area. In general, the batch plant must be located within 1,000 feet of the target zones. Additional grading surface stabilization may be required within the batch plant and bulk material storage area. The batch plant includes pumps, mixers, silos, mixed reagent storage, tool shed, and laydown areas. It is expected the ISS operation would be performed year-round so adequate winterizing of the batch plant would be required.
2. Site controls, erosion and sediment controls, stormwater controls and collection systems, odor and vapor controls systems, temporary facilities, and temporary utilities will be installed. Perimeter air monitoring systems be initiated prior to any invasive activities.
3. Demolition and pre-excavation as described in Common Element Descriptions (Appendix D) completed.
4. Given the size of the site and the volume to be treated, several operations will be performed concurrently.
5. As pre-excavation progresses from north to south across the Site, jet grouting will be initiated in the North Deep (DNAPL) target zone. Prior to full-scale jet grout treatment, a jet grout field demonstration test will be performed to evaluate jet grout characteristics and expected jet grout column size based on the site-specific conditions. Several columns will be created using varying injection pressures, drill stem revolutions per minute, and drill stem withdrawal rate. The columns will be created at a depth that will allow for excavation and observation after curing.
6. As the pre-excavation and Jet grout operations proceed south across the site, ISS mixing will commence. Mixing would be done with 6-foot and 8-foot-diameter augers, depending on required depth of treatment and the difficulty of mixing. ISS columns will be overlapped to treat 100 percent of the NAPL-contaminated soil within the target zone. The first several days will be used to demonstrate that the treatability results are verified and to establish the effectiveness of the selected equipment to mix sufficiently to the target depths. Visual observations, field tests, and quick turnaround laboratory testing will be used to demonstrate achievement of performance requirements.
7. Full-scale ISS operations will commence after completion of the demonstration phase. Quality control during full-scale ISS includes:
    a. Verifying contractor calculations for reagent slurry mixture and for volume of reagents to be added for each ISS column.
    b. Requiring the contractor to complete at least three mixing strokes (a stroke is from top to bottom to top again).
    c. Discrete sampling at different depth intervals to check for consistency of mixing, using color charts, pH, and slump. No unmixed soil should be observed in the sample. This sampling will be done at no less than one time per shift.
    d. Collection of samples for laboratory testing at a frequency of once every 500 CY or once per shift, whichever is less.
8. Stockpiled soil removed during the pre-excavation step will be treated using ex situ solidification/stabilization. A treatment cell(s) would be created using a lined and bermed area. Measured quantities of soil will be transferred from the soil stockpile to the treatment cell and

mixed with reagents. It is assumed that the same reagent mix design used for ISS would be appropriate to treat the pre-excavation soils, although the water ratio may be adjusted for ex situ conditions. This will be evaluated during the initial demonstration period. The soil and reagent mixture would be mixed using a hydraulic excavator and/or excavator equipped with a horizontal blending attachment. When the soil is adequately mixed, it will be transferred to an onsite curing cell. This material can be used for final site grading and contouring, consistent with planned future site use, to create landscape features.

9. At completion of ISS, the contractor will decontaminate equipment, dismantle the ISS auger and jet grout rig and batch plant, and demobilize.
10. Stormwater controls and final landscaping will be completed after ISS demobilization.

F4. Implementation Schedule

Set-up and site preparation activities are estimated to take 4 months. Assuming two ISS auger rigs are operating at the Site, the duration of ISS is expected to be approximately 12 months. Site restoration and mobilization activities are estimated at 3 months.

F5. References

Interstate Technology and Regulatory Council (ITRC). 2011. *Development of Performance Specifications for Solidification/Stabilization*.

Appendix G
Alternative 5 Description

APPENDIX G

Alternative 5 Description

Under Alternative 5, the Core Area and East Shallow (light non-aqueous phase liquid [LNAPL]) target zones are treated using thermal enhanced extraction, while the North Shallow (LNAPL) and North Deep (dense non-aqueous phase liquid [DNAPL]) target zones are treated using in situ chemical oxidation (ISCO), which is preceded by enhanced NAPL recovery. ISCO with hydrogen peroxide as the oxidant is applied in the shallow zones and ISCO with permanganate is applied in the deep zones. Enhanced aerobic biodegradation (EAB) via biosparging is applied in smaller areas of these target zones. The Other Periphery target zone is treated using either thermal enhanced extraction or ISCO. The EAB treatment step occurs after thermal and ISCO treatment as a polishing step for residual contamination that might remain. EAB has synergy with both the thermal treatment and hydrogen peroxide-based ISCO. Air injection for biosparging promotes mixing of dissolved contaminant mass with oxygen and/or oxidant, while the residual heat from thermal operations promotes increased dissolution of residual non-aqueous phase liquid (NAPL) and increased biological degradation rates. The catalyst for the hydrogen peroxide can also be selected to promote the generation of dissolved oxygen (e.g., ozone).

G1. Remedial Approach by Target Zone

The following subsections provide additional information on the technologies and their associated process options that would be used under Alternative 5 to treat the five identified target zones. A description of the common elements that are also a component of this alternative (see Table 5-1) is provided in Section 5.1 of this *Wyckoff/Eagle Harbor Soil and Groundwater Operable Units Focused Feasibility Study - Remedial Technology Screening and Preliminary Remedial Action Alternatives Technical Memorandum* (TM).

G1.1 Core Area and East Shallow (LNAPL)

In the Core Area, the target zone would be divided in half because of infrastructure limitations, with treatment performed sequentially in each half as described in the following steps:

1. Remove subsurface infrastructure and soil to a depth of 4 feet below ground surface (bgs) across the Core Area, as described in Section 5.1, Common Elements, and prepare the area for in situ thermal treatment as follows:
    a. Install engineering controls to protect the Lower Aquifer, if required.
    b. Install a low permeability cap at a depth of 4 feet bgs and cover with clean soil.
    c. Install temporary sheet pile walls to reduce dewatering rates.
2. Install process wells for application of the thermal remedy in the first half of the Core Area target zone.
3. Simultaneous with Step 1, install surface components of the vapor and liquid treatment system.
    a. Place a propane-fired steam generator and associated fuel tank.
    b. Place process equipment for pre-treatment of extracted liquids ahead of the existing Groundwater Treatment Plant (GWTP) (e.g., heat exchangers, NAPL separators, NAPL storage tank)
    c. Place soil vapor extraction system for extraction and treatment of subsurface vapors with a propane-fired thermal oxidizer.

4. Install piping between process equipment and process wells, including heat tracing or equivalent to maintain vapors at an elevated temperature up to the point of ex situ treatment.
5. Install downhole pumps in dewatering wells and connect to process lines.
6. Initiate dewatering to lower the water table and recover mobile NAPL (if present).
7. Dispose of recovered NAPL collected throughout the Wyckoff Site at an offsite disposal facility.
8. Initiate soil vapor extraction.
9. Initiate steam injection and operate as designed with observational improvements.
   a. Estimate 30 days to bring the target zone in the Core Area to steam temperature with a total injection rate of 9,800 pounds per hour (pph).
   b. Assumed treatment intensity of 1,000 pounds (lbs)/cubic yard (CY) yields a treatment duration of 220 days.
10. Cease steam injection and continue liquid and vapor extraction.
11. As NAPL recovery and vapor concentrations subside but soil temperatures remain elevated, initiate air injection to enhance volatilization and to introduce oxygen for EAB.
12. Cease vapor and liquid extraction, allowing the water table to rise; continue biosparging; and monitor biological degradation parameters and groundwater polycyclic aromatic hydrocarbon (PAH) concentrations.
13. Remove and inspect extraction wellhead assemblies and downhole pumps, remove injection wellhead assemblies and replace with wellheads for biosparging injection, disassemble piping (excluding air lines to injection wells) and manifolds, and refurbish all for reuse, as much as practical, in the second half of the Core Area target zone.
14. Initiate the introduction of amendments, as necessary, to optimize aerobic biodegradation of residual contamination by adjusting redox conditions and adding electron donors, acceptors, and nutrients as needed.
15. Repeat application of the thermal treatment in the second half of the Core Area as described above.
16. Assess groundwater conditions and the need for more aggressive intervention in select areas to attain remedial goals.
17. Restore site as described in Section 5.1, Common Elements.

G1.2 North Shallow (LNAPL)

The North Shallow (LNAPL) and East Shallow (LNAPL) target zones would be treated using ISCO. The oxidant selected for these target zones is catalyzed hydrogen peroxide, also known as modified Fenton's reagent when aqueous iron is the catalyst. Numerous other methods are available to catalyze hydrogen peroxide, including heat and ozone. Ozone also enhances biodegradation by releasing molecular oxygen. At some sites, existing soil minerals are sufficient catalysts. Stabilizers are also available to slow reaction rates and modify system pH. Based on the complex chemistry, this process option includes bench-scale treatability tests performed during remedial design, pilot testing performed during remedial design or during the initial phase of remedial action, and contingencies based on field observations. The primary contingency is the assumption of up to three rounds (phases) of injection.

ISCO in the North Shallow (LNAPL) and East Shallow (LNAPL) target zones would be deployed as follows:

1. Collect representative soil and groundwater samples from the capillary fringe and below the water table at various locations in the LNAPL areas during remedial design.

2. Perform site-specific, bench-scale testing of oxidant dosage, catalyst, pH, and stabilizers during remedial design.
3. Perform field-scale pilot tests of candidate methods for catalyzing and optimizing the modified Fenton's process, determining the rate of injection and radius of influence for varying injection strategies, assessing benefits of allowing an exothermic reaction, and evaluating the treatment impact on groundwater concentrations. This testing could be performed during remedial design, potentially resulting in lower overall cost, or during the initial phase of remedial action.
4. Pump existing and additional new recovery wells to remove mobile LNAPL until recovery rates diminish. By removing LNAPL, the oxidant demand per unit volume of soil and overall mass of oxidant required would be significantly reduced. Extracted groundwater and NAPL could be routed to the GWTP and/or the thermal process treatment system.
5. Mobilize direct push rigs and ancillary equipment (e.g., injection rods and injection pumps) to the Wyckoff Site, establish a chemical storage and staging area, and receive initial chemical shipments.
6. Initiate a campaign of oxidant and catalyst injection using direct push rigs that advance across the target zones, in accordance with the remedial design protocol, with injections to depths at least 5 feet below the water table. In select areas, the injections would extend as deep as 15 feet below the water table into Compartment 2. Anticipated oxidant injection rates will require daily deliveries of concentrated hydrogen peroxide.
7. As injections move across each of the target zones, monitor results in treated areas for changes in PAH concentrations and/or other groundwater quality indicators, and biological activity.
8. At the completion of the initial sweep, expected to occur after 18 months, and an evaluation of collected data, initiate a second round of injections that is assumed to encompass approximately 50 percent of the initial target area and volume.
9. In areas outside the second oxidant injection footprint, install biosparging wells and initiate introduction of air and amendments, as necessary, to optimize the biodegradation of residual contamination by adjusting redox conditions and adding electron donors, acceptors, and nutrients as needed.
10. As the second round of injections move across the target area, monitor results in treated ISCO and biosparging areas for changes in PAH concentrations and/or other groundwater quality indicators, and biological activity. Cease biosparging in areas attaining remedial goals.
11. At the completion of the second round, which is expected to require about 10 months, and an evaluation of collected data, initiate a third round of injections that is assumed to encompass approximately 25 percent of the initial target area and volume.
12. In areas outside the third oxidant injection footprint, install additional biosparging wells and continue introduction of air and amendments to optimize biodegradation of residual contamination as necessary to attain remedial goals.
13. At the conclusion of the third round of oxidant injection, implement biosparging as needed across the balance of the target zone to attain remedial goals.
14. Assess groundwater quality conditions and the need for more aggressive intervention in select areas to attain remedial goals.
15. Site restoration common to all remedial alternatives (see Section 5.1, Common Elements).

G1.3 North Deep (DNAPL)

DNAPL in the North Deep (DNAPL) target zone will be treated with ISCO using permanganate as the oxidant. Permanganate was selected because of the depth below the water table, its effectiveness for PAH destruction, the persistence of its oxidizing power, and its relative ease of injection through fixed wells. The primary drawback to permanganate in this application is its negative impact on subsequent biological degradation and a potential lag phase for re-establishing suitable conditions for EAB. This process option includes an assumption of up to three rounds of oxidant injection.

ISCO in this target zone would be implemented in a manner nearly identical to that described in Section E1.2 for Alternative 4.

G1.4 Other Periphery

The primary treatment technology for these target zones is either thermal enhanced extraction or hydrogen peroxide based ISCO, implemented as part of the volumes described in Sections G1.1 and G1.2, respectively, and supplemented with EAB using an array of air and amendment injection points and wells. Biosparging points and wells for amendment injection and monitoring will be installed as needed to provide injection points for air and nutrients to enhance aerobic biodegradation of contaminants throughout the Other Periphery areas.

G2. Design Criteria and Basis for Approach

The following subsections present the design criteria and design basis for each of the key Alternative 5 components. Transportation and disposal of recovered NAPL offsite and the uncertainty of its volume present a large uncertainty in the design of this alternative.

G2.1 Thermal Treatment in the Core and East Shallow (LNAPL) Target Zones

The design basis for the thermal treatment is based primarily upon a specified groundwater extraction and treatment rate available to the thermal process of 80 gpm. Based on this assumption, other design parameters are:

- Sheet pile wall totaling 1,100 linear feet will be installed for hydraulic isolation.
- The water table can be lowered by 35 feet with 6 weeks of pumping at 80 gpm.
- Drawdown can be maintained with an extraction rate of 20 gpm.
- Average steam injection rate = 9,800 pph
- Duration of initial heating phase = 30 days
- 9,800 pph provides sufficient energy to heat 51,000 CY in 30 days.
- Core soil treatment volume for heating = 102,000 CY
- Remediation of the Core Area in two parcels (2 x 51,000 CY)
- Treatment “intensity” of 1,000 lbs of steam per CY
- Parcel treatment time = (1,000 lbs/CY) x (51,000 CY) / (9,800 pph)
- Parcel treatment time = 220 days (approximately 7 months per parcel)

G2.2 ISCO in the North Shallow (LNAPL)

The design basis for hydrogen peroxide-based ISCO application to the LNAPL in the northern area is based primarily upon three parameters: (1) the estimated oxidant demand presented by the LNAPL mass and other organic material making up the total soil oxidant demand; (2) the number, spacing, and vertical interval of injection locations; and (3) the injection rate of oxidant solution. The spacing of points and injection rate of oxidant solution are a function of injection depth, soil permeability, oxidant persistence, number of injection rigs, and practical limits on the production and delivery rate of chemicals, particularly hydrogen peroxide. These design parameters would be determined from bench-scale treatability tests performed during remedial design and pilot testing performed during remedial design or during the initial phase of remedial action.

The assumed design parameters for this process option include:

- The stoichiometric requirement on a mass basis for destruction of creosote components by hydrogen peroxide is estimated to be 6.4 gram per gram (g per g) of creosote.

- The soil oxidant demand is negligible compared to the contaminant demand.
- The radius of influence for injection of oxidant over the interval from 15 to 25 feet bgs is 8 feet yielding 790 injection points over an area of 138,000 square feet.
- Catalyzed hydrogen peroxide is active for 3 hours.
- Hydrogen peroxide solution can be injected at a concentration of 17.5 percent weight (%wt).
- Hydrogen peroxide solution can be injected at a total of 16 gpm (cumulative for multiple direct push rigs).
- Hydrogen peroxide solution at a concentration of 35 %wt can be delivered to the Wyckoff Site at a rate of 8,000 gallons per day in tankers.

G2.3 ISCO in the North Deep (DNAPL)

The design basis for permanganate-based ISCO application to the DNAPL in the northern area is based primarily upon three parameters: (1) the estimated oxidant demand presented by the DNAPL mass and other organic material making up the total soil oxidant demand; (2) the number, spacing, and screen intervals of permanent injection wells; and (3) the injection rate of oxidant solution. The spacing of wells and injection rate of oxidant solution are a function of injection depth, soil permeability, oxidant persistence, and practical limits on the production and delivery rate of chemicals. These design parameters would be determined from bench-scale treatability tests performed during remedial design and pilot testing performed during remedial design.

The assumed design parameters for this process option include:

- The stoichiometric requirement on a mass basis for destruction of creosote components by sodium permanganate is estimated to be 18.7 g per g of creosote.
- The soil oxidant demand is negligible compared to the contaminant demand.
- The radius of influence for injection of oxidant over the interval from 55 to 65 feet bgs is 20 feet yielding 30 injection wells over an area of approximately 32,000 square feet.
- Permanganate is active in the subsurface for 3 to 5 days.
- Permanganate solution can be injected at a concentration of 10 %wt.
- Permanganate solution can be injected at a total of 20 gallons per minute (gpm) (cumulative for multiple well injections).
- Sodium permanganate solution at a concentration of 40 %wt can be delivered to the Wyckoff Site at a rate of 2,200 gallons per day during each of the three injection phases.

G2.4 Other Periphery and Polishing

The Other Periphery target zones are included in either the thermal enhanced extraction or the ISCO injections described above. The design basis for implementing EAB in lesser contaminated target areas and as a polishing step will vary across the Wyckoff Site and depend upon the following factors:

- Oxygen requirement for aerobic biodegradation based on contaminant mass estimates (e.g., 1,000 standard cubic feet of air per kilogram of contaminant mass)
- Evaluation of radius of influence (i.e., the number and depth of biosparging points required)
- Anticipated air injection rate for soil properties, air distribution patterns, NAPL dissolution rates, and biological degradation rates of individual creosote components.

NAPL dissolution, oxygen distribution and diffusion, and reaction rates combine to slow the process and reduce the efficiency of oxygen utilization, thereby requiring the injection of an excess of oxygen into the subsurface. The air injection rate in the biosparging system will be estimated from the anticipated half-lives of contaminants in the groundwater at the Wyckoff Site and the partitioning of oxygen from air into groundwater. For naphthalene, observed half-lives under ambient conditions range from 1 to 250 days. For bioventing in the vadose zone, the half-life of naphthalene ranges from 16 to 48 days.

G3. Sequencing and Schedule

Implementing Alternative 5 will take approximately 7 to 12 years from initial design to site restoration. The thermal, ISCO, and EAB activities are assumed to occur simultaneously, followed by a period of EAB throughout the Wyckoff Site, summarized as follows:

Component	Schedule in Years
Design	1 to 2
Construction	1 to 2
Operation – Thermal, ISCO, and EAB Treatment	2 to 4
Operation – Cool Down and Additional EAB	2 to 3
Site Restoration	1

Appendix H
Alternative 6 Description

APPENDIX H

Alternative 6 Description

Alternative 6 includes the following: 1) excavation and ex situ thermal treatment of non-aqueous phase liquid (NAPL)-contaminated soil in the upper portion (to 35 feet below ground surface [bgs]) of the Core Area; and 2) thermal enhanced extraction in the lower portion of the Core Area, in the North Shallow (light NAPL [LNAPL]), East Shallow (LNAPL), and North Deep (dense NAPL [DNAPL]) target zones. The Other Periphery target zones would be included in the medium temperature thermal desorber (MTTD) option or thermal enhanced extraction option. Enhanced aerobic biodegradation (EAB) would be deployed in lesser contaminated areas of some targets and deployed as a polishing step in the thermally treated zones if necessary.

H1. Remedial Approach by Target Area

The following subsections provide additional information on the technologies and their associated process options that would be used under Alternative 6 to treat the five identified target zones. A description of the common elements that are also a component of this alternative (see Table 5-1) is provided in Section 5.1, Common Elements, and Appendix D, Common Element Descriptions, of this *Wyckoff/Eagle Harbor Soil and Groundwater Operable Units Focused Feasibility Study - Remedial Technology Screening and Preliminary Remedial Action Alternatives Technical Memorandum* (TM).

H1.1 Core Area

In the Core Area, the target interval for excavation and ex situ treatment using MTTD includes the ground surface down to 35 feet bgs. This alternative component would be implemented as follows:

1. Hydraulically isolate the Core Area with sheet pile walls, structural shoring walls, or similar.
2. Initiate dewatering in the isolated zone using existing and newly installed extraction wells.
    a. Route extracted water to the existing Groundwater Treatment Plant (GWTP).
    b. Supplement dewatering with sumps and pumps internal to the excavation.
    c. Operate pressure relief wells in the Lower Aquifer to minimize uplift pressures acting on the Aquitard, if needed.
3. Simultaneous with Step 2, install surface components of the MTTD system.
    a. Mobilize and place a propane-fired MTTD unit and associated fuel tank.
    b. Prepare staging areas.
4. Initiate infrastructure demolition and surface soil excavation as described in Appendix D, Common Elements Descriptions.
5. Perform excavation and treatment across the Core Area down to 35 feet bgs or the Aquitard interface.
    a. Soil will be excavated sequentially in several cells to reduce dewatering rates and to allow room for stockpiling before and after MTTD treatment.
    b. Cells may be separated by additional temporary sheet pile walls with internal bracing.
    c. Soil will be screened for contamination during excavation. Clean soil will be segregated, tested, and left untreated.

   d. Contaminated soil will be processed in the MTTD unit by heating to approximately 1,100 degrees Fahrenheit (°F).

   e. At the bottom of the excavation, if the Aquitard is not encountered, a clay barrier will be installed to act as a confining layer for the deeper aquifer during in situ thermal treatment.

   f. Treated and clean soil will be stockpiled and moisture-adjusted prior to use as backfill.

   g. Backfilled areas will be pre-loaded (temporarily overburdened with several feet of additional soil) to compact replaced soils.

6. Following completion of the excavation, treatment, clay layer installation, and backfilling steps, transition site activities to in situ thermal enhanced extraction in the deeper portion of the Core Area below the newly installed clay barrier down to the Aquitard, as described below in Section H1.3.

7. Restore site surface as described in Section 5.1 and Appendix D, Common Element Descriptions.

H1.2 North Shallow (LNAPL) and East Shallow (LNAPL)

LNAPL in these two target zones will be treated by thermal enhanced extraction employing steam injection and fluid extraction and treatment. Thermal treatment will occur concurrently with excavation and MTTD in the upper portion of the Core Area with the thermal treatment components repurposed for treatment of contamination in the deeper portion of the Core Area.

The LNAPL target zone would be divided in half because of infrastructure limitations, with treatment performed sequentially in each half as described in the following steps:

1. Remove subsurface infrastructure and soil to a depth of 4 feet bgs across the Core Area, as described in Section 5.1, Common Elements, and prepare the area for in situ thermal treatment as follows:
   a. Install engineering controls to protect the Lower Aquifer, if required.
   b. Install a low permeability cap at a depth of 4 feet bgs and cover with clean soil.
   c. Install temporary sheet pile walls to reduce dewatering rates.
2. Install process wells for application of the thermal remedy.
3. Simultaneous with Steps 1, install surface components of the treatment system.
   a. Place a propane-fired steam generator and associated fuel tank.
   b. Place process equipment for pre-treatment of extracted liquids ahead of existing GWTP (e.g., heat exchangers, NAPL separators, NAPL storage tank).
   c. Place soil vapor extraction system for extraction and treatment of subsurface vapors with a propane-fired thermal oxidizer.
4. Install piping between process equipment and process wells.
5. Install downhole pumps in dewatering wells and connect to process lines.
6. Initiate groundwater extraction to lower the water table and recover mobile NAPL.
7. Offsite disposal of recovered NAPL unless recovered NAPL can be processed in the MTTD unit deployed for the Core Area.
8. Initiate soil vapor extraction.
9. Initiate steam injection and operate as designed with observational improvements.
   a. Estimate 35 days to bring the target volume to steam temperature with a total injection rate of 7,200 pph.

   b. Assumed treatment intensity of 1,000 lbs/CY yields a treatment duration of 9 months.

10. Cease steam injection and continue liquid and vapor extraction.
11. As NAPL recovery and vapor concentrations subside but soil temperatures remain elevated, initiate air injection to enhance volatilization and introduce oxygen for EAB.
12. Cease vapor and liquid extraction allowing the water table to rise, continue biosparging, and monitor biological degradation parameters and groundwater PAH concentrations.
13. Remove and inspect extraction wellhead assemblies and downhole pumps, remove injection wellhead assemblies and replace with wellheads for biosparging injection, disassemble piping (excluding air lines to injection wells) and manifolds, and refurbish all for reuse, as much as practical, in the second half of the LNAPL target areas.
14. Initiate the introduction of amendments, as necessary, to optimize the biological degradation of residual contamination by adjusting redox conditions and adding electron donors, acceptors, and nutrients as needed.
15. Repeat application of the thermal treatment in the remaining LNAPL areas as described above.
16. Assess groundwater conditions and the need for more aggressive intervention in select areas to attain remedial goals.
17. Restore site as described in Section 5.1 and Appendix D, Common Element Descriptions.

H1.3 North Area DNAPL and Deeper Core Volume

DNAPL in this target zone will be thermally treated using steam and hot water injection to mobilize DNAPL for recovery and enhanced dissolution of soluble DNAPL components. Target temperatures may be lower than steam temperatures to facilitate horizontal distribution of heat and maximize dissolution rates. The installed clay barrier in the excavated footprint of the Core Area, described in Section H1.1, would further promote horizontal distribution of the heat.

This alternative component would be implemented in the following steps:

1. Install process wells for application of the thermal remedy.
2. Surface components of the thermal treatment system will be available from operations performed in the North Shallow (LNAPL) and East Shallow (LNAPL) target zones, as described above, and include the steam generator, process equipment for extracted liquids, and the soil vapor extraction system.
3. Install piping between process equipment and process wells.
4. Install downhole pumps in extraction wells and connect to process lines.
5. Initiate groundwater extraction to recover mobile DNAPL as much as practical.
6. Apply a slight vacuum to the extraction wells.
7. Perform steam and hot water Injection to bring the target soil volume to a temperature of 160 °F corresponding to a 10-fold increase in the DNAPL solubility.
   a. Estimate 75 days to bring the target DNAPL volume to a temperature of approximately 160 °F with a total energy injection rate of 4,800,000 British thermal units (Btu) per hour (hr) (5,000 pph steam equivalent).
   b. Continue injection to attain a treatment intensity of 1.16 million BTU (MBtu) per CY (equivalent to 1,200 lbs of steam per CY).
8. Cease thermal injection and continue liquid extraction.

9. As NAPL recovery and groundwater concentrations subside but soil temperatures remain elevated, initiate low-level air injection to introduce oxygen for EAB.
10. Cease liquid extraction, continue biosparging, and monitor biological degradation parameters and groundwater concentrations.
11. Remove thermal treatment system components.
12. Initiate the introduction of amendments, as necessary, to optimize the biological degradation of residual contamination by adjusting redox conditions and adding electron donors, acceptors, and nutrients as needed.
13. Assess groundwater conditions and the need for more aggressive intervention in select areas to attain remedial goals.
14. Restore site as described in Section 5.1 and Appendix D, Common Element Descriptions.

H1.4 Other Periphery Areas

The primary treatment technologies for the Other Periphery target areas are thermal enhanced extraction, implemented as part of the volumes described in Sections H1.3, and MTTD for a small area. These technologies would be supplemented with EAB using an array of air and amendment injection points and wells.

H2. Design Criteria and Basis for Approach

The following subsections present the design criteria and design basis for each of the key Alternative 6 components.

H2.1 Excavation and MTTD - Upper Core Area

The design basis for the MTTD treatment is based primarily upon the expected throughput rate for treating contaminated soil of 20 tons per hour. Other general design parameters are:

- Soil treatment rate = 1,500 CY/week (wk)
- Sheet pile wall and shoring totaling 1,100 linear feet will be installed for hydraulic isolation.
- The water table can be lowered by 20 feet with 2 months of pumping at 80 gallons per minute (gpm).
- Drawdown can be maintained with an extraction rate of 23 gpm.
- Total soil volume excavated = 128,000 CY
- Total soil volume treated with MTTD unit = 96,000 CY (approximately 75 percent of the excavated material)
- Duration of MTTD operations in the core area = 15 months

H2.2 Thermal Treatment - North Shallow (LNAPL) and East Shallow (LNAPL)

The design basis for the thermal treatment is based primarily upon a specified groundwater extraction and treatment rate available to the thermal process of 55 gpm (assumed to occur simultaneously with MTTD in the upper Core Area) and treating sequentially in two parcels. Based on these assumptions, other design parameters are:

- Average steam injection rate = 7,200 pph
- LNAPL soil treatment volume for heating = 46,000 CY
- 7,200 pph provides sufficient energy to heat 46,000 CY to steam temperature in 35 days.

- Treatment “intensity” of 1,000 lbs of steam per CY
- Parcel LNAPL area treatment time = (1,000 lbs/CY) x (46,000 CY) / (7,200 pph) = 9 months
- Total LNAPL treatment time = 2 x 9 months = 18 months

H2.3 Thermal Treatment - Deeper Core Area and North (Deep) NAPL

The design basis for the deep thermal treatment is based primarily upon a specified groundwater extraction and treatment rate available to the thermal process of 80 gpm, a mix of steam and hot water injection at relatively low pressure to minimize adverse DNAPL migration, and a target soil treatment temperature of 160 °F to optimize dissolution of soluble components from residual DNAPL. Based on these assumptions, other design parameters are:

- Average energy injection rate = 4,800,000 Btu per hr (5,000 pph steam equivalent)
- DNAPL soil treatment volume for heating = 55,000 CY
- 4.8 MBtu/hr provides sufficient energy to heat 55,000 CY to 160 °F in about 75 days.
- Treatment “intensity” of 1.16 MBtu per CY (approximately 1,200 lbs of steam equivalent per CY)
- DNAPL treatment time = (1.16 MBtu/CY) x (55,000 CY) / (4.8 MBtu/hr)
- DNAPL treatment time = 18 months

H2.4 EAB - Other Periphery Areas

The Other Periphery target zones are included in the thermal enhanced extraction or MTTD options described above. The design basis for implementing EAB in lesser contaminated target areas and as a polishing step will vary across the Site and depend upon the following factors:

- Oxygen requirement for aerobic biological degradation based on contaminant mass estimates (e.g., 1,000 standard cubic feet of air per kilogram of contaminant mass)
- Evaluation of radius of influence (i.e., the number and depth of biosparging points required)
- Anticipated air injection rate for soil properties, air distribution patterns, NAPL dissolution rates, and biological degradation rates of individual creosote components.

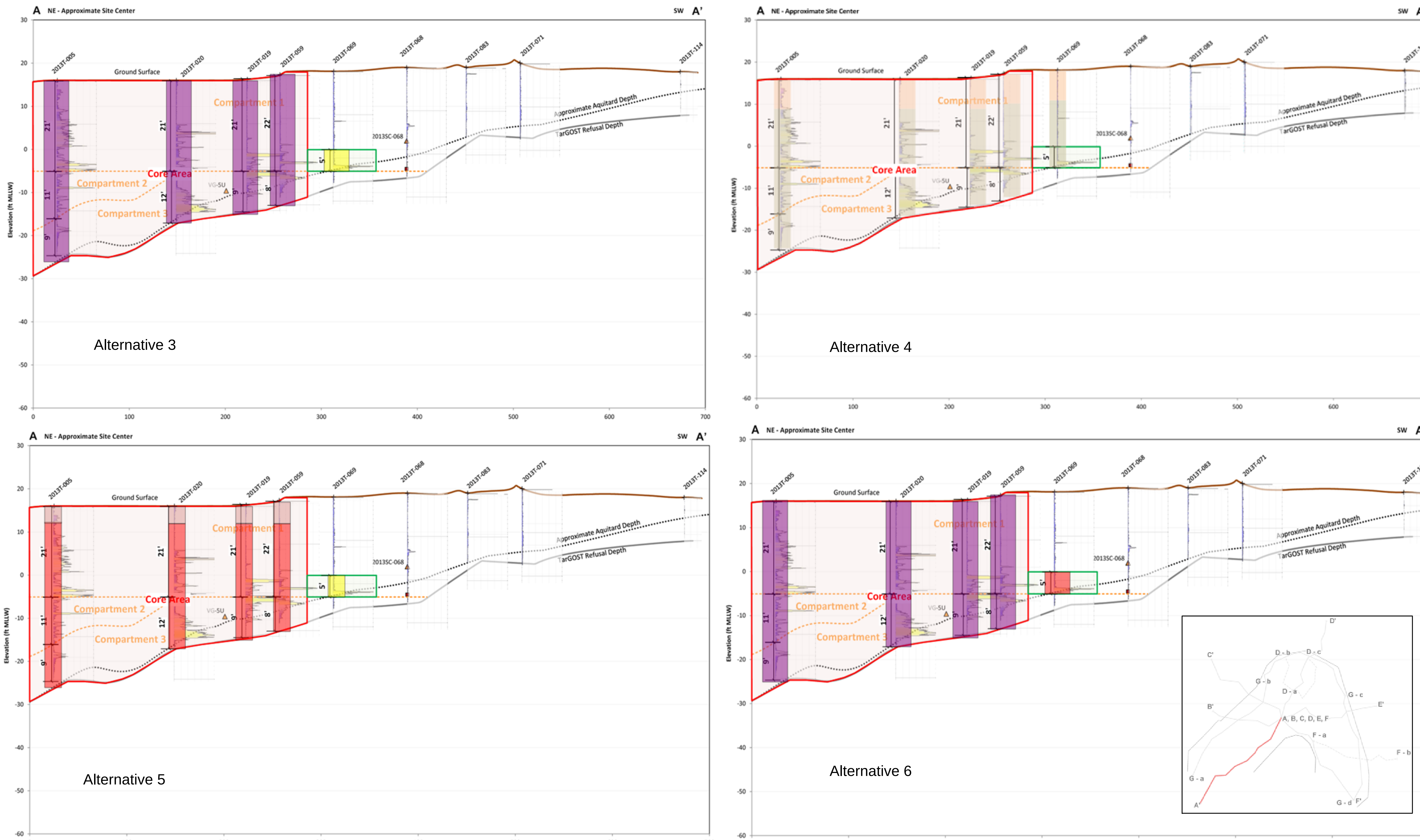
NAPL dissolution, oxygen distribution and diffusion, and reaction rates combine to slow the process and reduce the efficiency of oxygen utilization, thereby requiring the injection of an excess of oxygen into the subsurface. The air injection rate in the biosparging system will be estimated from the anticipated half-lives of contaminants in the groundwater at the Site and the partitioning of oxygen from air into groundwater. For naphthalene, observed half-lives under ambient conditions range from 1 to 250 days. For bioventing in the vadose zone, the half-life of naphthalene ranges from 16 to 48 days.

H3. Sequencing and Schedule

Implementing this alternative will require close coordination between the ex situ treatment effort with MTTD and the in situ thermal treatment. However, significant synergies exist among MTTD, steam injection and extraction, and heat-enhanced biological degradation. The sequence of activities would include the initial operation of MTTD in the Core Area with a lagged start of LNAPL treatment with steam injection. These operations are expected to require 1.5 to 2 years. These activities are followed by simultaneous thermal treatment in the deeper Core Area and north (deep) NAPL in a subsequent 1.5 to 2 years. EAB will occur in less contaminated areas throughout these treatment operations and continue for several more years. Residual thermal treatment energy would spread and dissipate throughout the entire treatment volume to enhance biological degradation. Implementing this alternative will take approximately 7 to 10 years from initial design to site restoration, as shown below.

Component	Schedule in Years
Design	1 to 1.5
Construction	0.5 to 1
– Hydraulic Isolation and Dewatering	
– Installation of LNAPL thermal treatment	
Operation	
– Core Excavation, Treatment, Backfill	1.5 to 2
– LNAPL Thermal Treatment	Concurrent
– DNAPL and Core In Situ Thermal Treatment	1.5 to 2
– EAB for Polishing	2 to 3
Site Restoration	0.5

Appendix I
Summary of Remedial Alternatives on Fence and Cluster Diagrams



Excavate and treat with MTTD
ISCO for LNAPL (eg, H2O2)
ISCO for DNAPL (eg, Cool-Ox)
Enhanced Aerobic Biodegradation
Shallow: Dig & dispose
In Situ Thermal Treatment
In Situ Stabilization - Auger
In Situ Stabilization - Jet Grout

Figure I-1
Fence Diagram A-A' with Alternative Treatments
Focused Feasibility Study Remedial Action Technology Screening and Preliminary Remedial Action Alternatives
Wyckoff/Eagle Harbor Superfund Site

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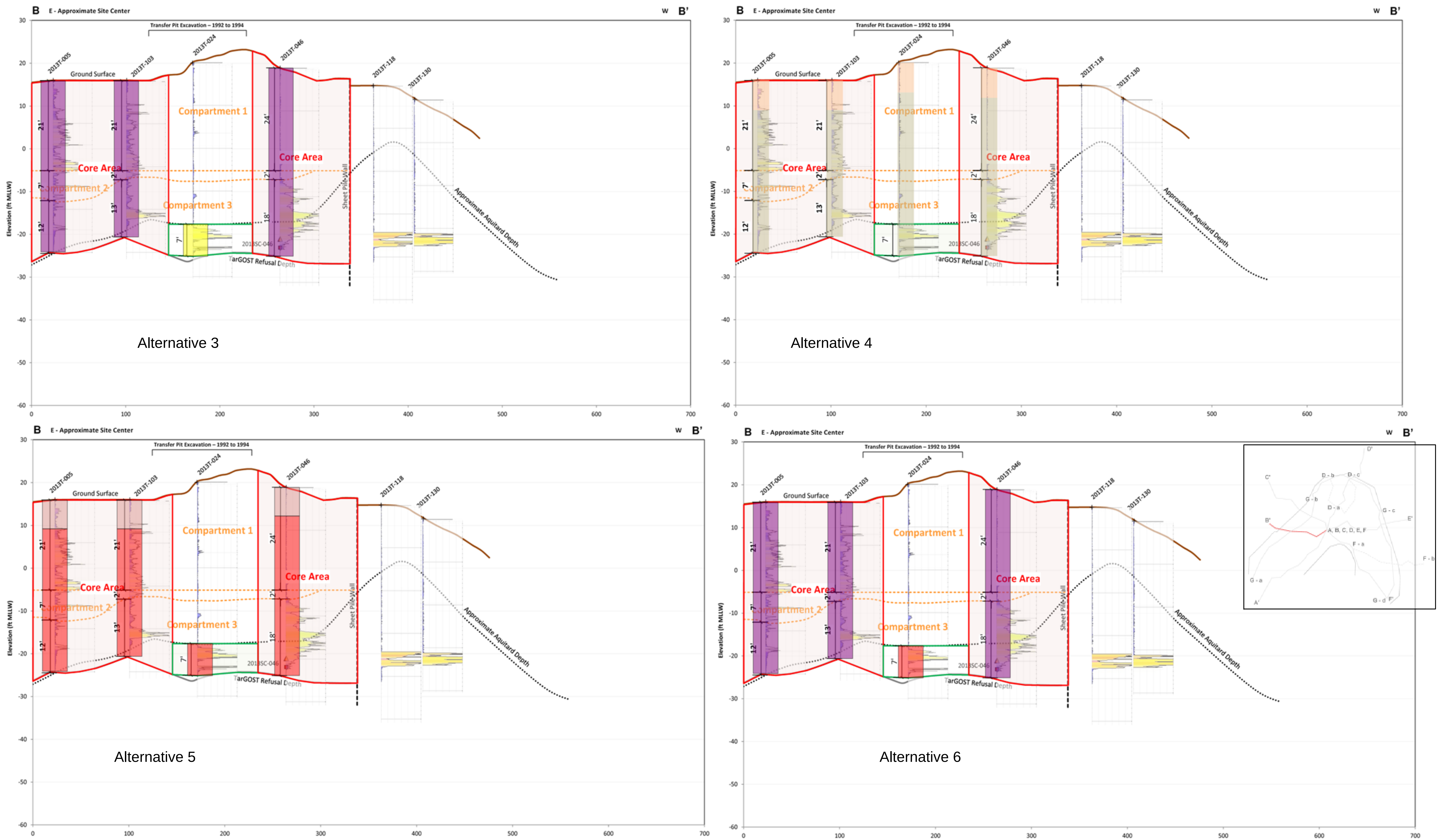


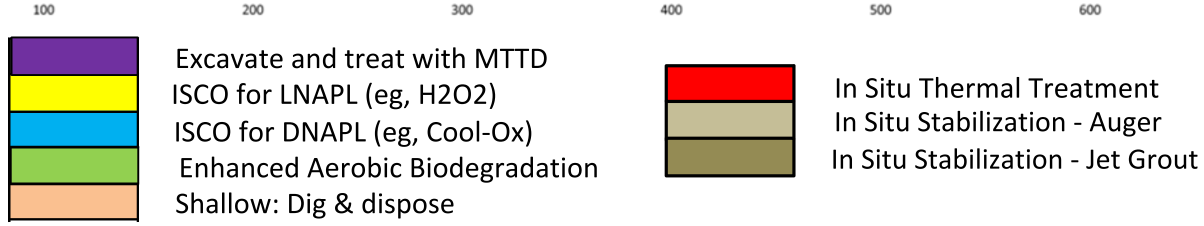
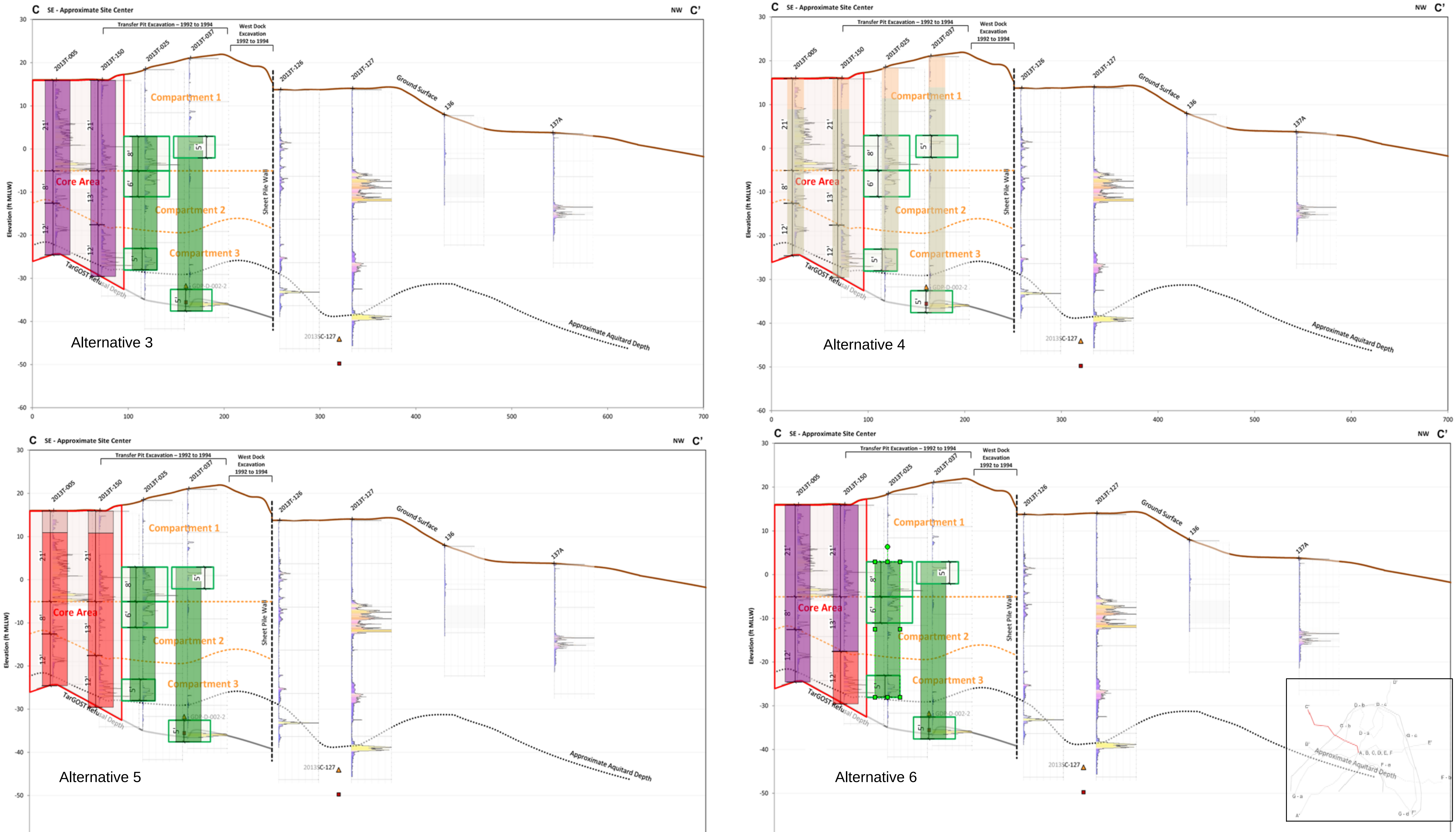


Figure I-2
Fence Diagram B-B' with Alternative Treatments
Focused Feasibility Study Remedial Action Technology Screening and Preliminary Remedial Action Alternatives
Wyckoff/Eagle Harbor Superfund Site



Excavate and treat with MTTD
ISCO for LNAPL (eg, H2O2)
ISCO for DNAPL (eg, Cool-Ox)
Enhanced Aerobic Biodegradation
Shallow: Dig & dispose
In Situ Thermal Treatment
In Situ Stabilization - Auger
In Situ Stabilization - Jet Grout

Figure I-3
Fence Diagram C-C' with Alternative Treatments
Focused Feasibility Study Remedial Action Technology Screening and Preliminary Remedial Action Alternatives
Wyckoff/Eagle Harbor Superfund Site

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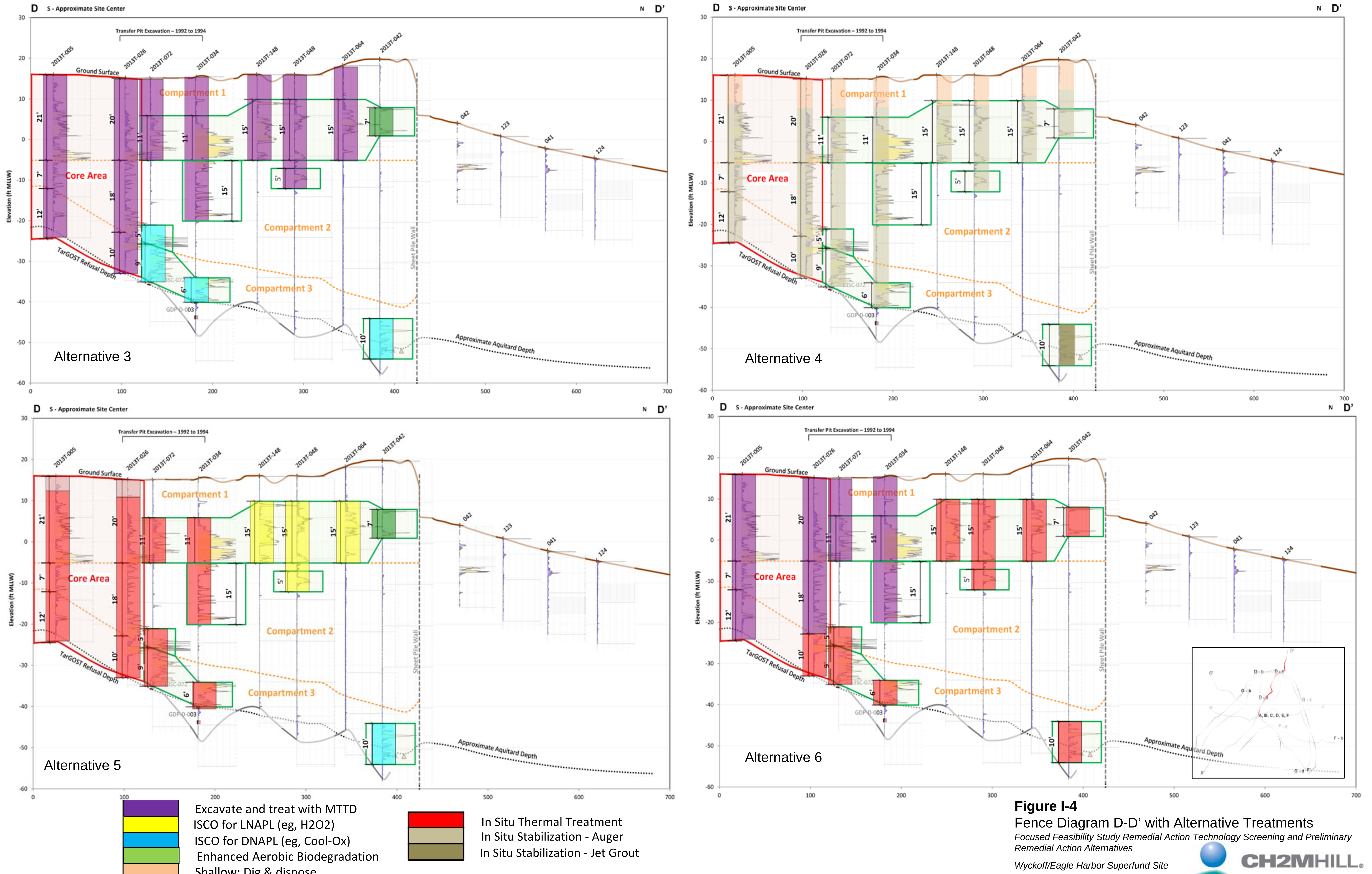

Figure I-4

Fence Diagram D-D' with Alternative Treatments

Focused Feasibility Study Remedial Action Technology Screening and Preliminary Remedial Action Alternatives

Wyckoff/Eagle Harbor Superfund Site

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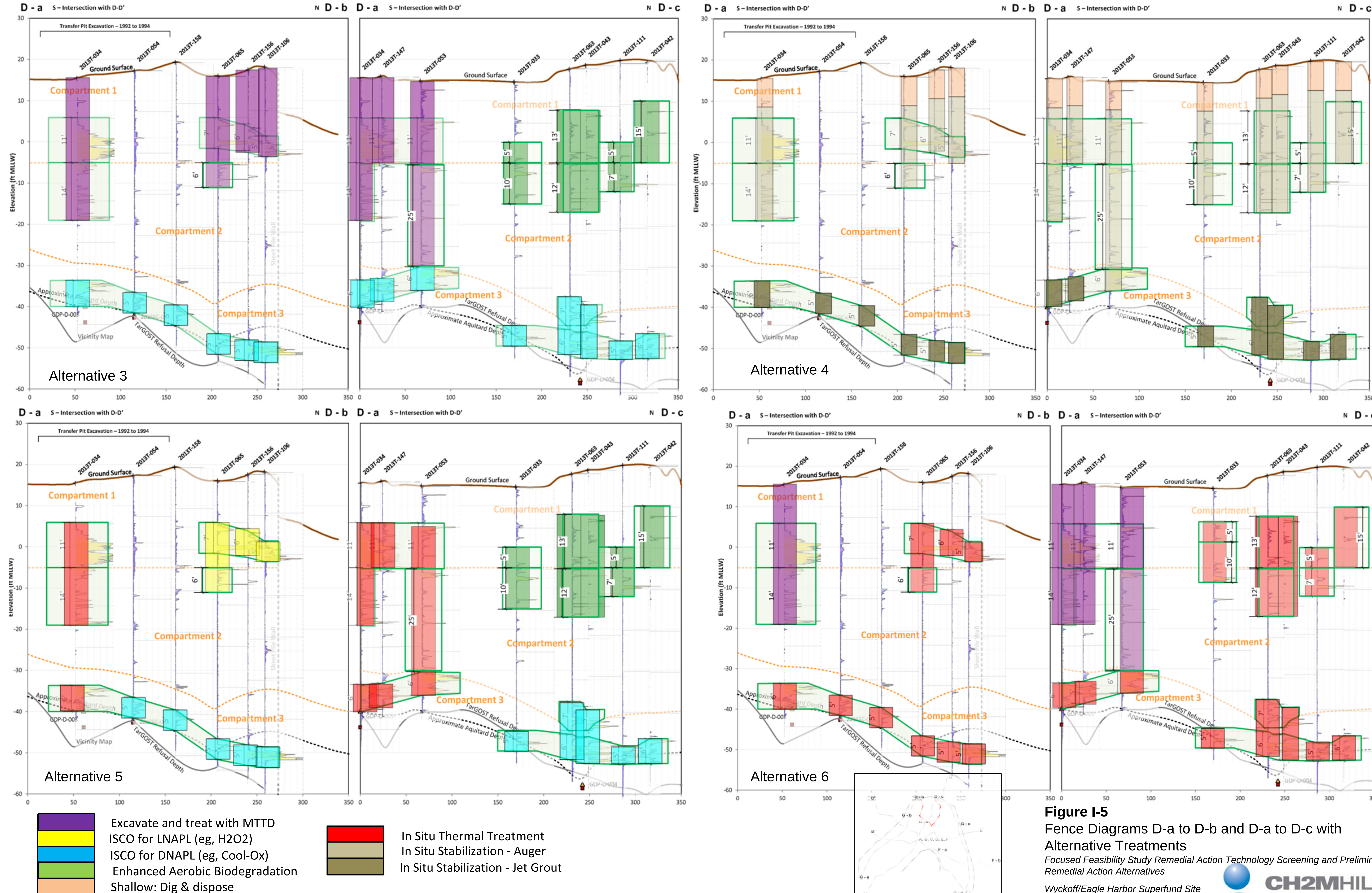

Figure I-5

Fence Diagrams D-a to D-b and D-a to D-c with Alternative Treatments

Focused Feasibility Study Remedial Action Technology Screening and Preliminary Remedial Action Alternatives

Wyckoff/Eagle Harbor Superfund Site

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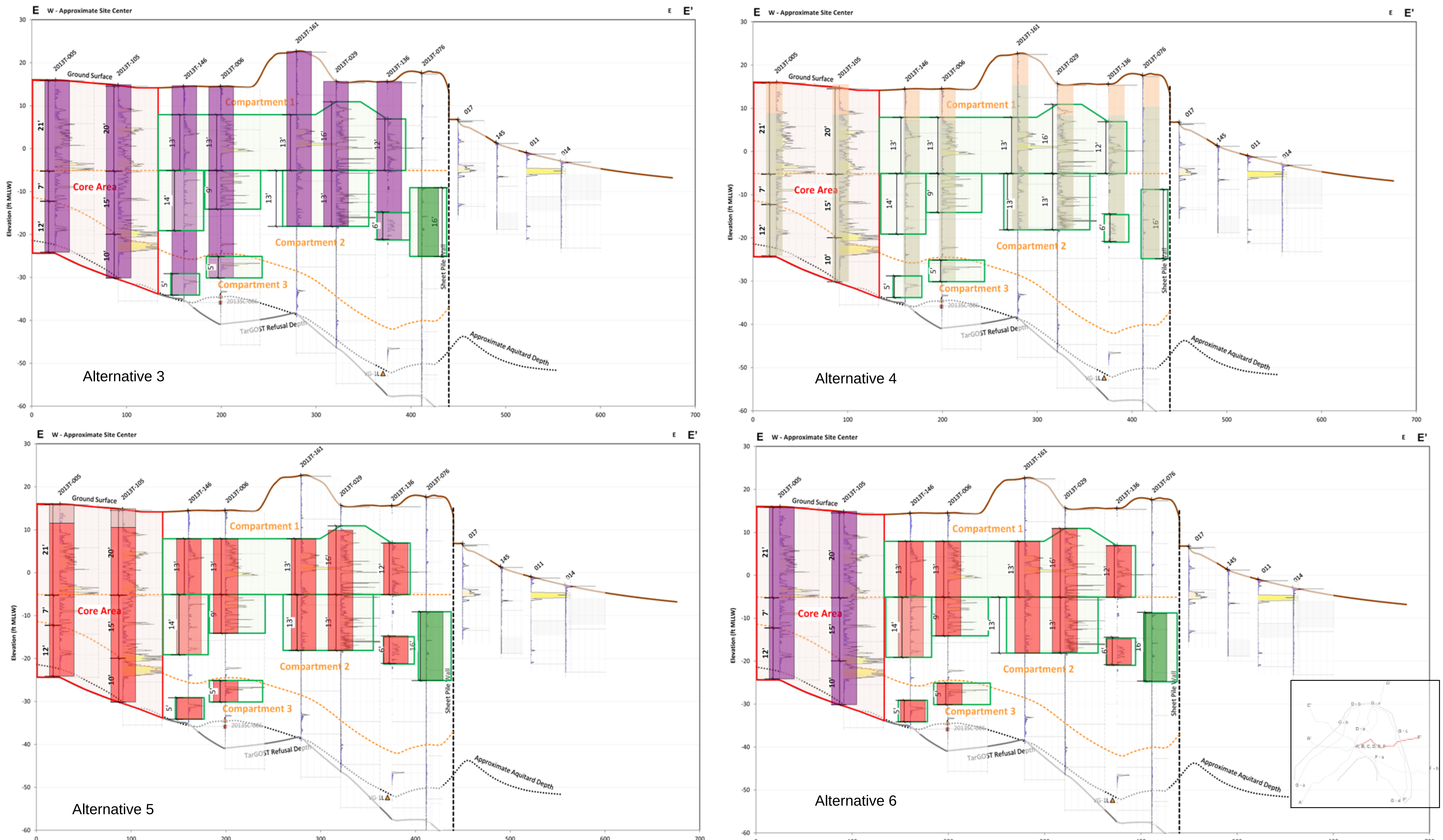

- Excavate and treat with MTTD
- ISCO for LNAPL (eg, H2O2)
- ISCO for DNAPL (eg, Cool-Ox)
- Enhanced Aerobic Biodegradation
- Shallow: Dig & dispose
- In Situ Thermal Treatment
- In Situ Stabilization - Auger
- In Situ Stabilization - Jet Grout

Figure I-6

Fence Diagram E-E' with Alternative Treatments

Focused Feasibility Study Remedial Action Technology Screening and Preliminary Remedial Action Alternatives

Wyckoff/Eagle Harbor Superfund Site

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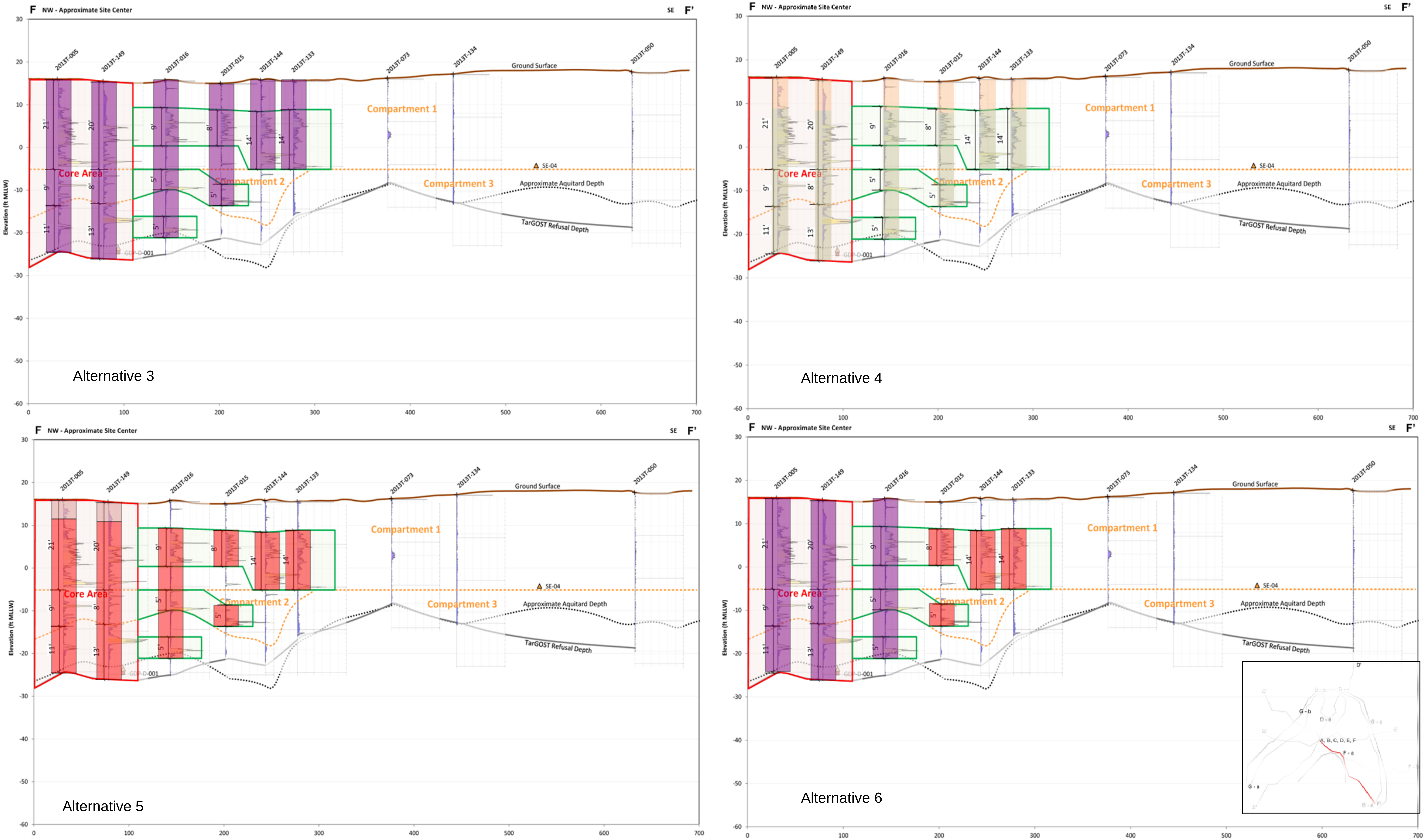

Excavate and treat with MTTD
ISCO for LNAPL (eg, H2O2)
ISCO for DNAPL (eg, Cool-Ox)
Enhanced Aerobic Biodegradation
Shallow: Dig & dispose
In Situ Thermal Treatment
In Situ Stabilization - Auger
In Situ Stabilization - Jet Grout

Figure I-7
Fence Diagram F-F' with Alternative Treatments
Focused Feasibility Study Remedial Action Technology Screening and Preliminary Remedial Action Alternatives
Wyckoff/Eagle Harbor Superfund Site

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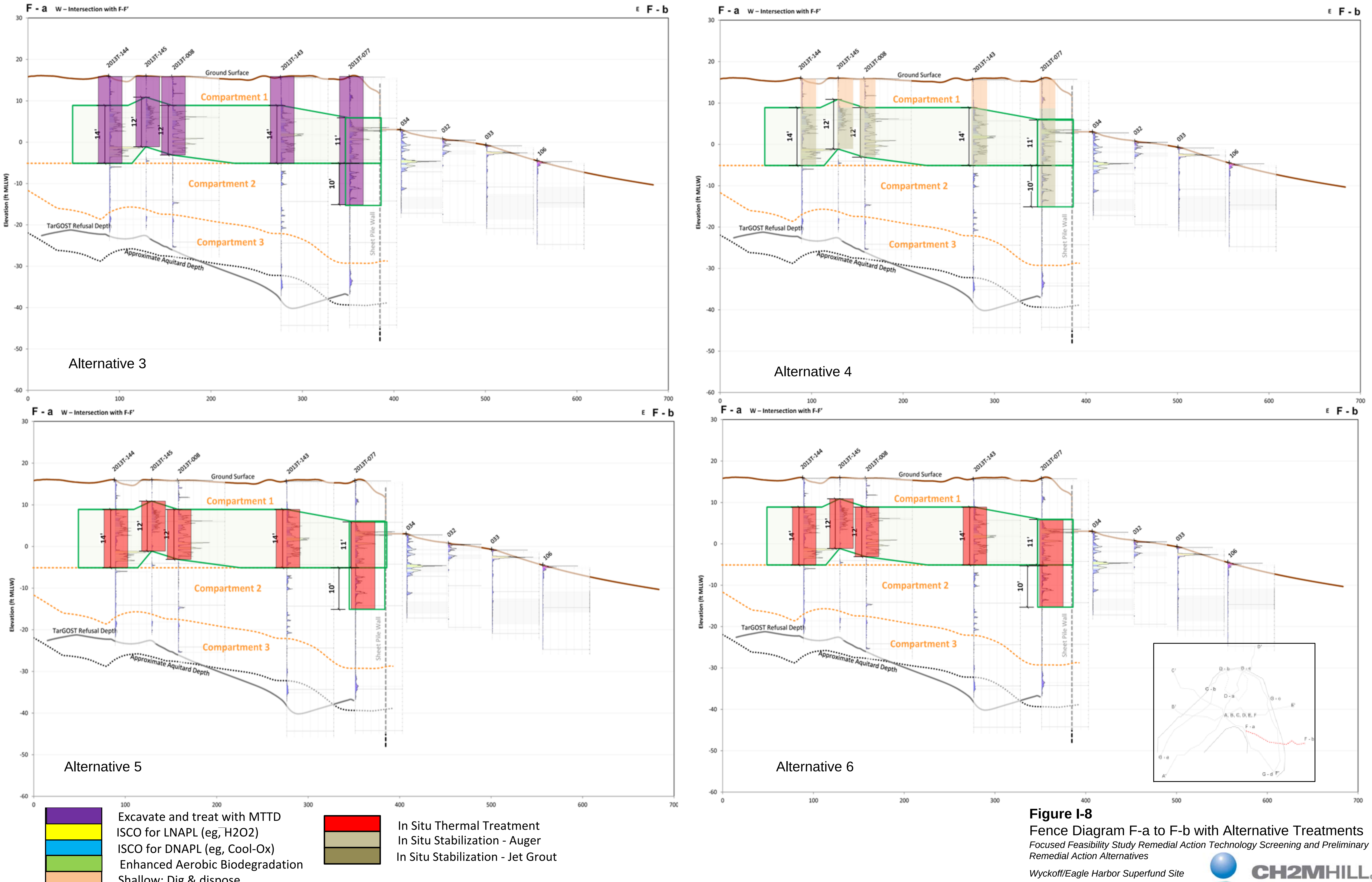

Figure I-8

Fence Diagram F-a to F-b with Alternative Treatments

Focused Feasibility Study Remedial Action Technology Screening and Preliminary Remedial Action Alternatives

Wyckoff/Eagle Harbor Superfund Site

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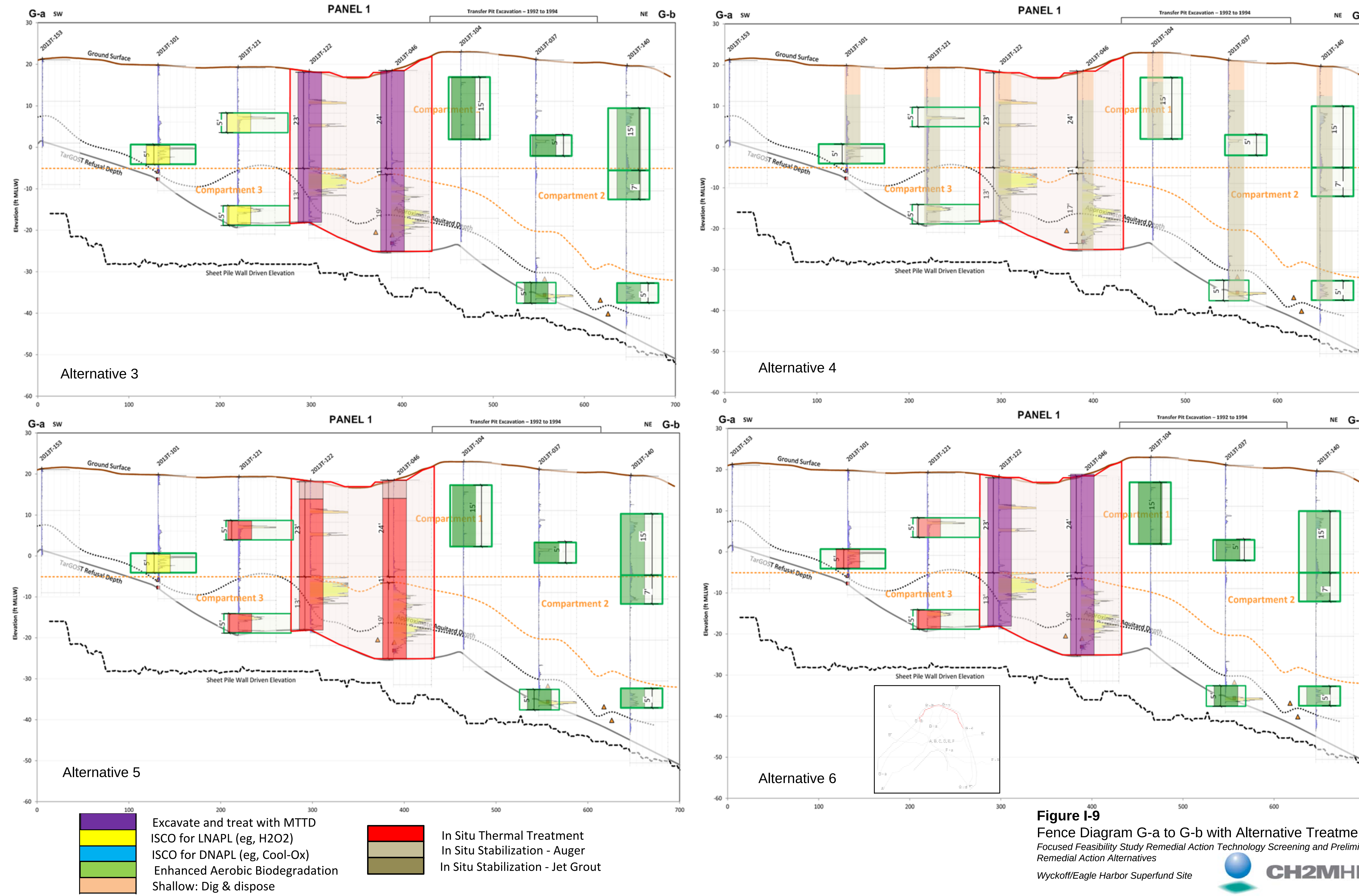

Figure I-9

Fence Diagram G-a to G-b with Alternative Treatments

Focused Feasibility Study Remedial Action Technology Screening and Preliminary Remedial Action Alternatives

Wyckoff/Eagle Harbor Superfund Site

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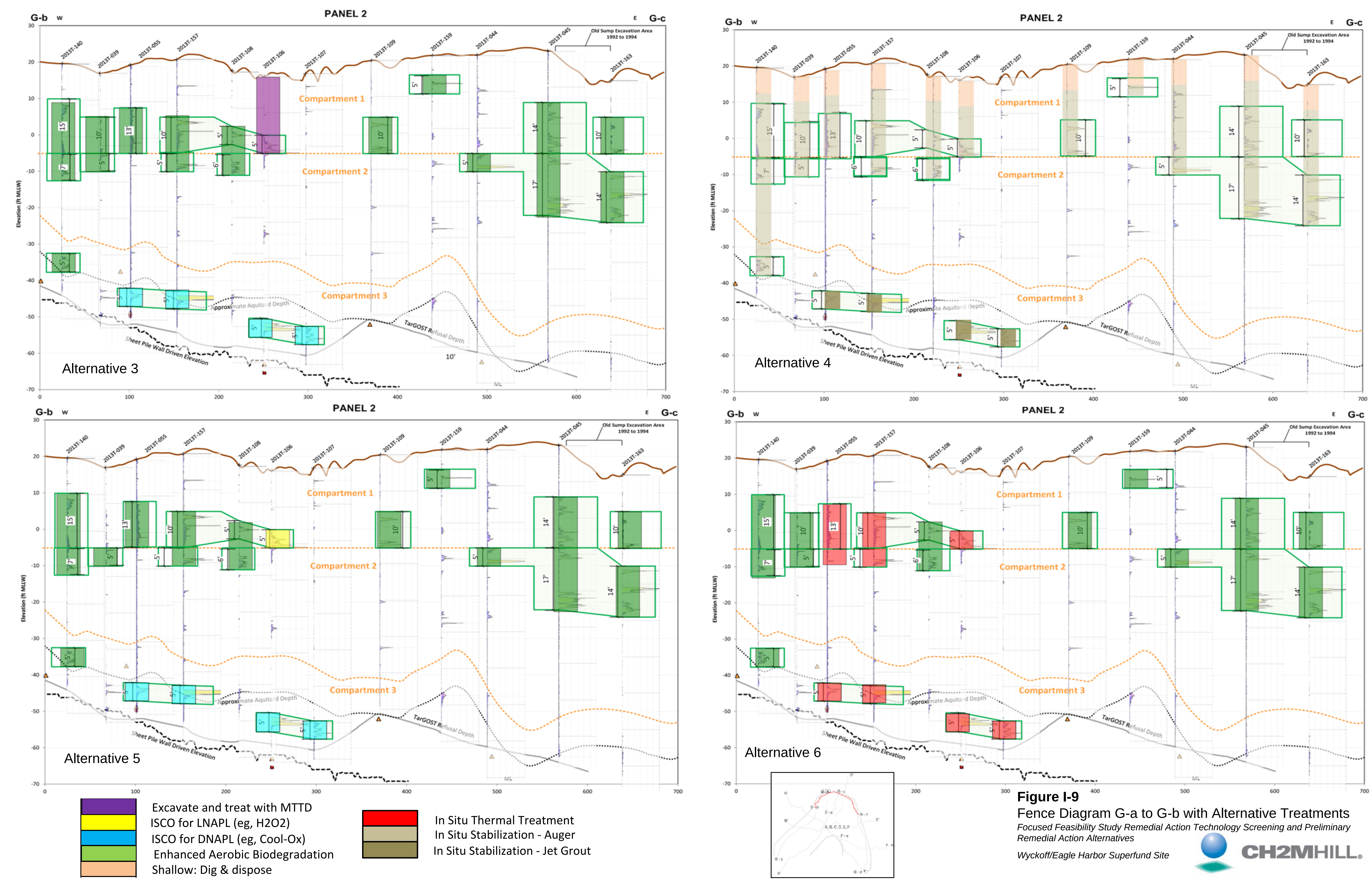

Figure I-9
Fence Diagram G-a to G-b with Alternative Treatments
Focused Feasibility Study Remedial Action Technology Screening and Preliminary Remedial Action Alternatives
Wyckoff/Eagle Harbor Superfund Site
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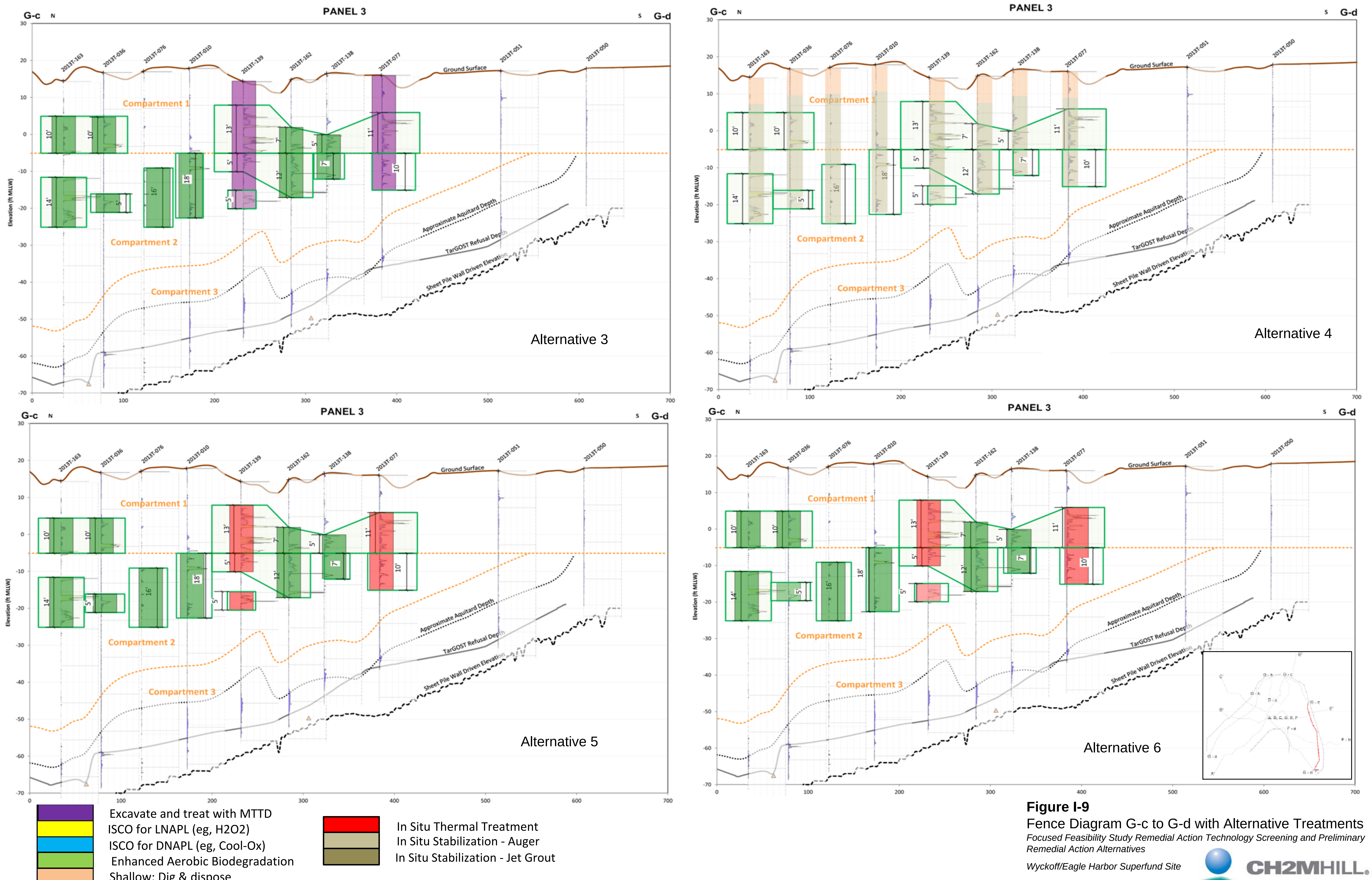

Figure I-9

Fence Diagram G-c to G-d with Alternative Treatments

Focused Feasibility Study Remedial Action Technology Screening and Preliminary Remedial Action Alternatives

Wyckoff/Eagle Harbor Superfund Site

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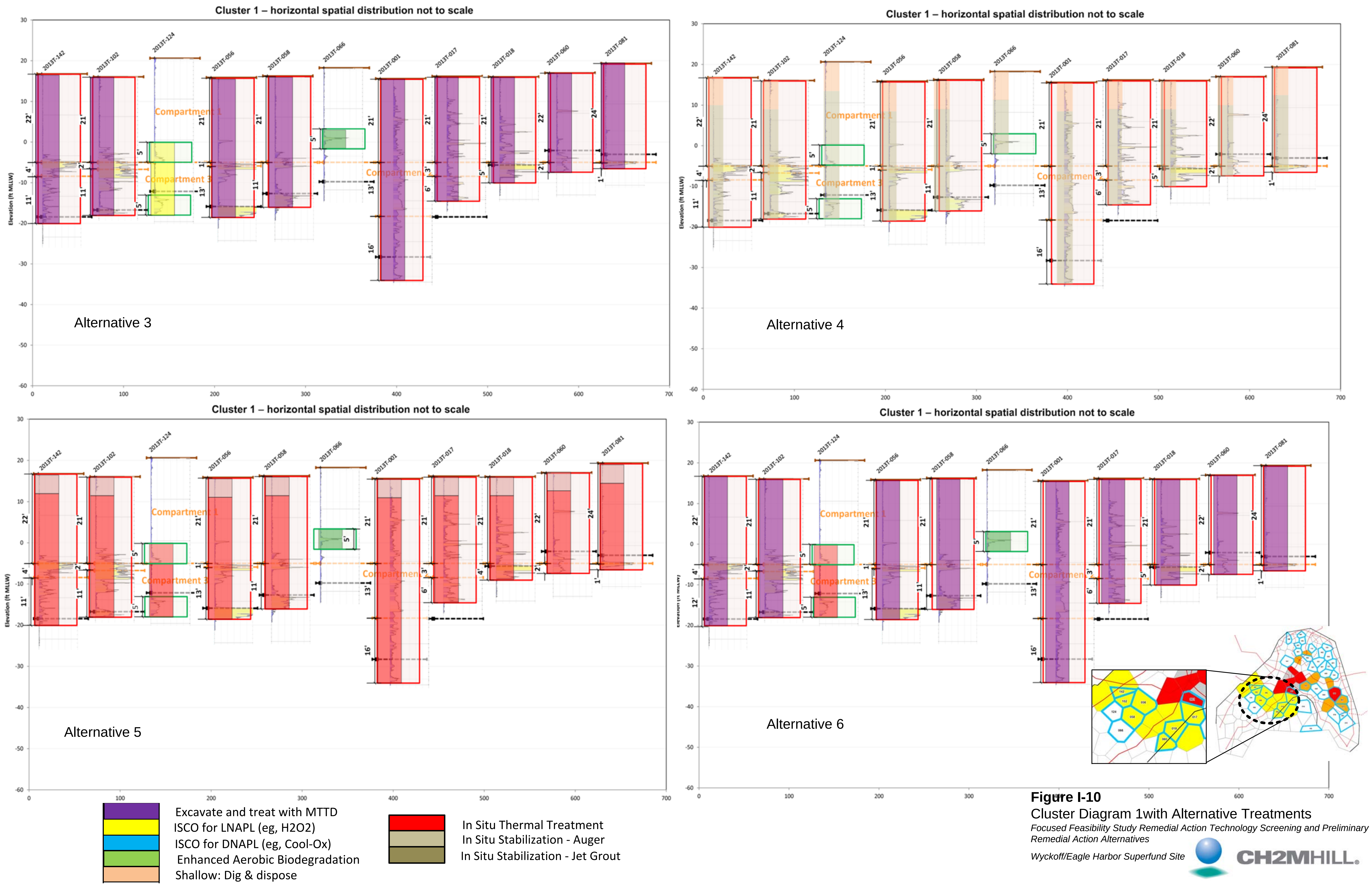

Figure I-10
Cluster Diagram 1with Alternative Treatments
Focused Feasibility Study Remedial Action Technology Screening and Preliminary Remedial Action Alternatives
Wyckoff/Eagle Harbor Superfund Site
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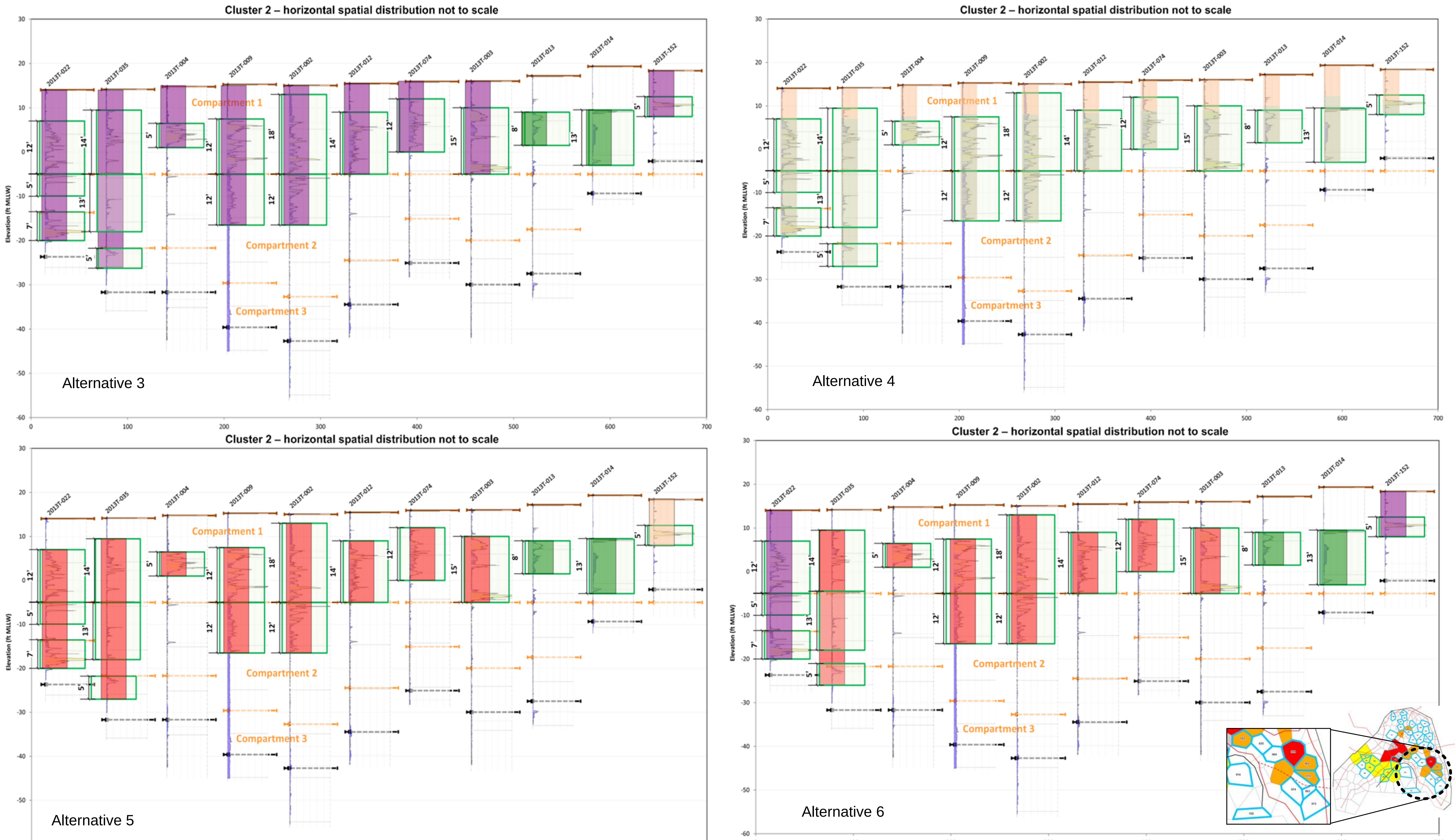

Excavate and treat with MTTD	In Situ Thermal Treatment
ISCO for LNAPL (eg, H2O2)	In Situ Stabilization - Auger
ISCO for DNAPL (eg, Cool-Ox)	In Situ Stabilization - Jet Grout
Enhanced Aerobic Biodegradation	
Shallow: Dig & dispose	

Figure I-11
Cluster Diagram 2 with Alternative Treatments
Focused Feasibility Study Remedial Action Technology Screening and Preliminary Remedial Action Alternatives
Wyckoff/Eagle Harbor Superfund Site
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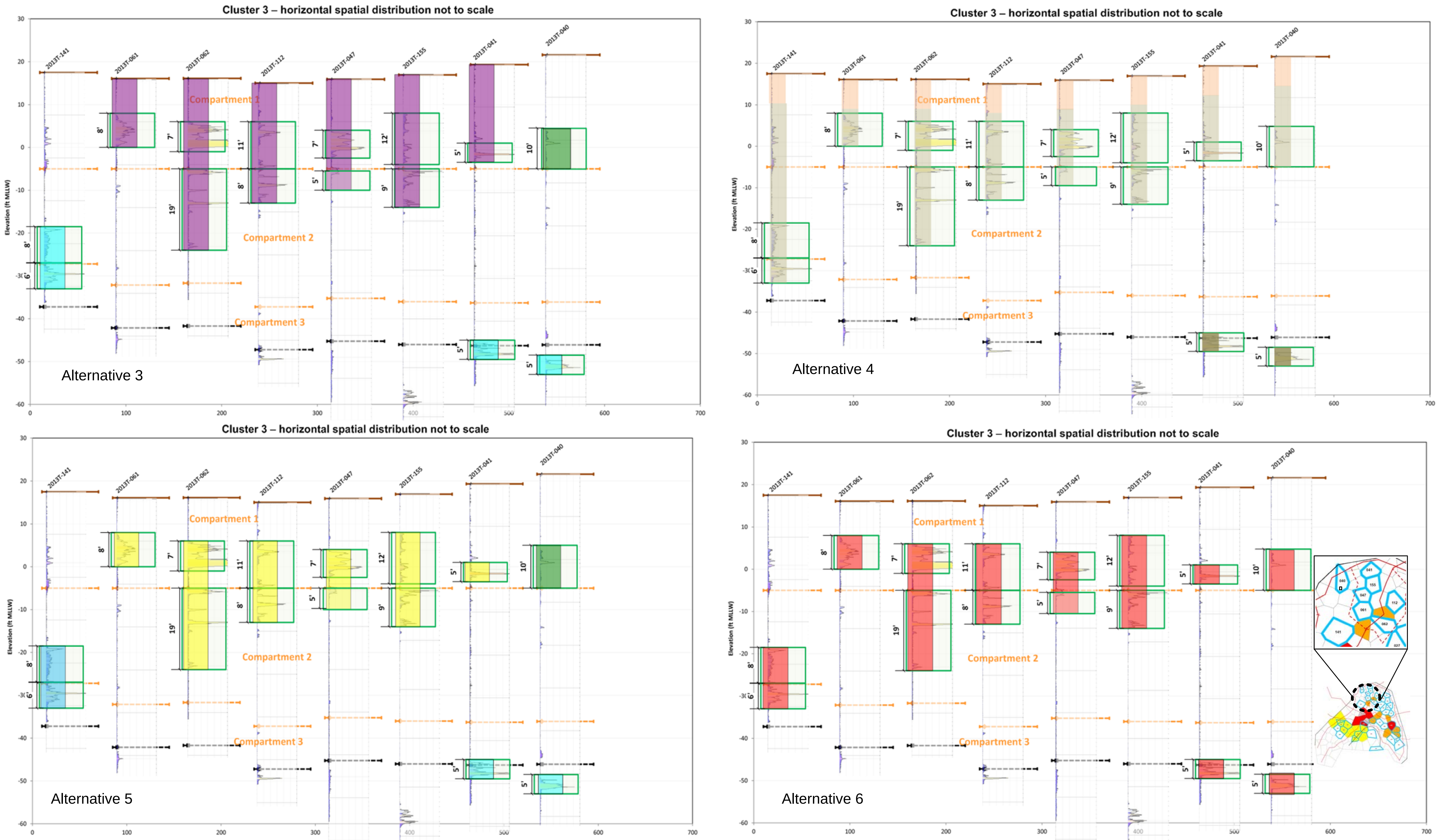

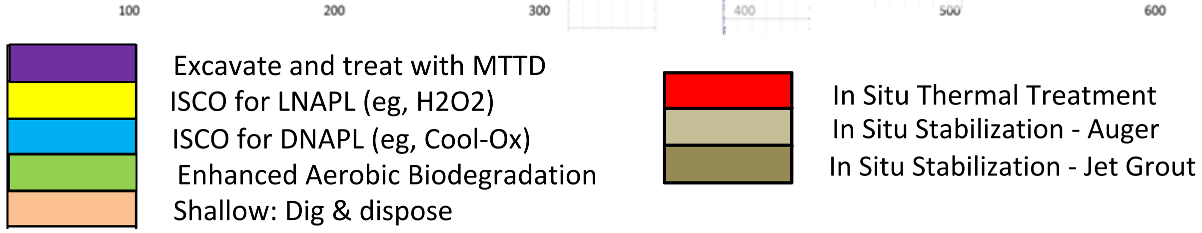

Figure I-12
Cluster Diagram 3 with Alternative Treatments
Focused Feasibility Study Remedial Action Technology Screening and Preliminary Remedial Action Alternatives
Wyckoff/Eagle Harbor Superfund Site

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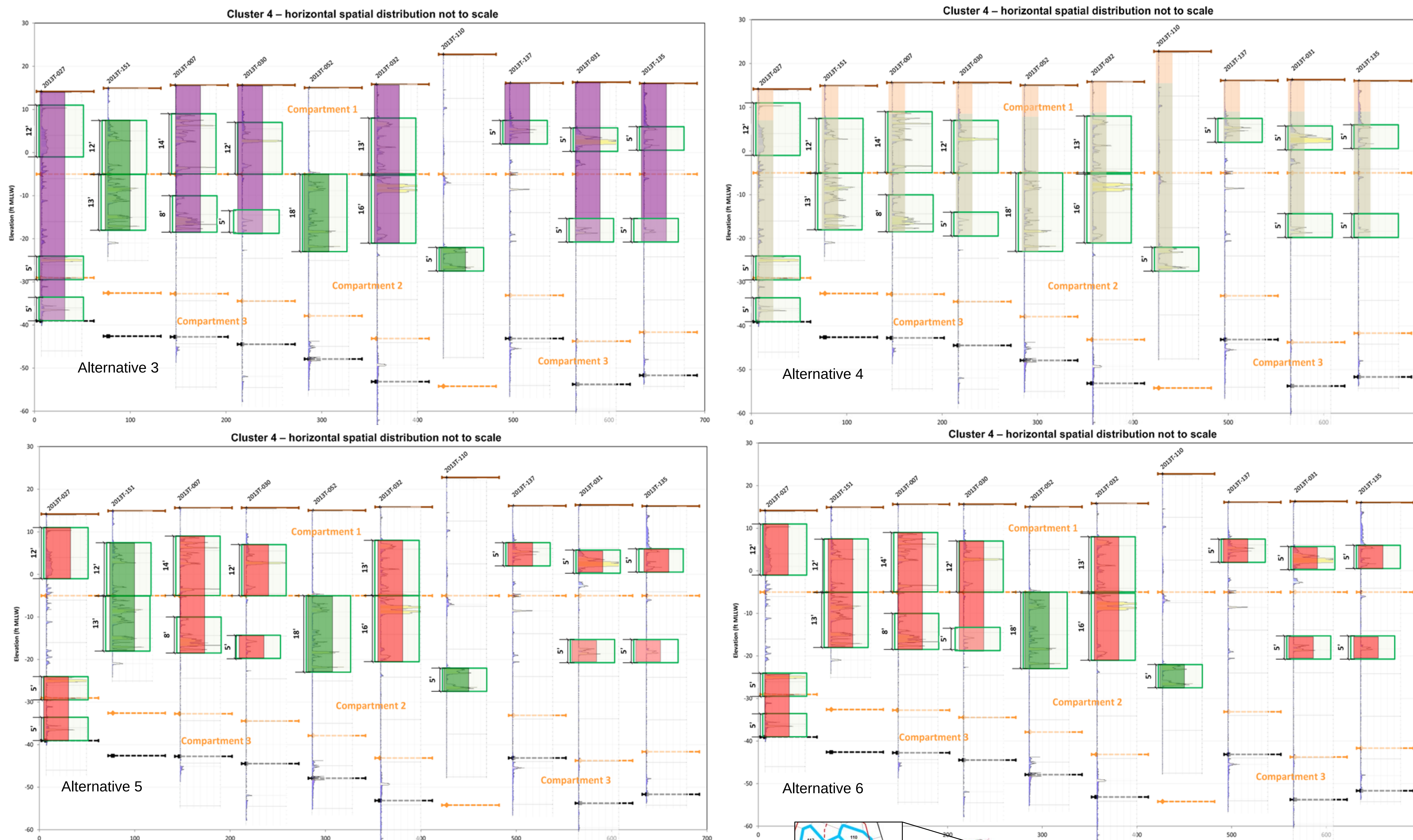

Excavate and treat with MTTD
ISCO for LNAPL (eg, H2O2)
ISCO for DNAPL (eg, Cool-Ox)
Enhanced Aerobic Biodegradation
Shallow: Dig & dispose
In Situ Thermal Treatment
In Situ Stabilization - Auger
In Situ Stabilization - Jet Grout

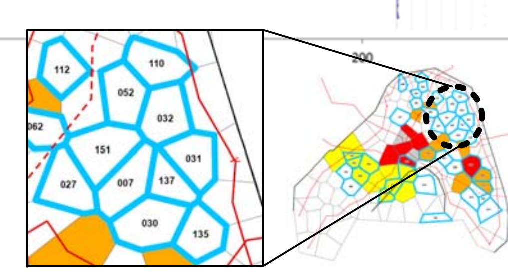

Figure I-13
Cluster Diagram 4 with Alternative Treatments
Focused Feasibility Study Remedial Action Technology Screening and Preliminary Remedial Action Alternatives
Wyckoff/Eagle Harbor Superfund Site

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