FINAL

Appendix K
Remedial Technology Assignment Options for Areas with RAL Exceedances

1 Preliminary Remedial Technology Assignments

This appendix summarizes the rationale used to assign a preliminary remedial technology option(s)[1] to each Lower Duwamish Waterway middle reach area with remedial action level (RAL) exceedances. Figures 19 and 20 in the Record of Decision (ROD) (EPA 2014)[2] describe the process by which remedial technologies are to be assigned during the design process. ROD Figure 19 presents a decision flowchart for intertidal areas, while ROD Figure 20 presents a decision flowchart for subtidal areas. A variety of factors govern the preliminary selection of applicable remedial technologies, including mudline elevation, RAL exceedance factor (EF), depth of contamination, and recovery category designation.

Areas that span both intertidal and subtidal elevation ranges or that include the Federal Navigation Channel (FNC) are presented herein as distinct subareas within a RAL exceedance area. This is because different remedial technology applications, as noted in the flowcharts, apply. In addition, different remedial technologies may apply as a result of other factors that vary within an intertidal or subtidal subarea, including the range of RAL exceedance factors or multiple recovery categories. Engineering and constructability considerations have not been considered at this stage; they will be evaluated during 30% and 60% remedial design (RD) to select the remedial technology for each area. Additionally, several areas have not been bounded vertically yet, so final technologies will be selected for those areas after data from the Phase III Pre-Design Investigation are available. Remedial technology assignments will be defined during 30% RD based on available data, site condition information, and engineering considerations. Remedial technologies are expected to be finalized during 60% RD, pending any relevant Phase III data, which would be provided during 90% RD.

Not including a preliminary technology assignment as an option for a RAL exceedance area does not preclude that technology from consideration during RD. For example, in an area where enhanced natural recovery (ENR) is the preliminarily assigned technology, engineering considerations during RD could suggest that dredge would be more appropriate. Similarly, large areas designated as dredge or partial dredge and cap (PD&C) may include subareas eligible for ENR.

Potential remedial technologies identified in the ROD for intertidal and subtidal areas include the following:

- Intertidal:
  - Monitored natural recovery (MNR) to benthic sediment cleanup objective
  - Area-specific technology[3]
  - ENR

[1] Multiple technologies may be used within a single area with RAL exceedances.
[2] Figure 20 was corrected after the ROD had been published. Reference to Figure 20 herein refers to the corrected version, which was published in a memorandum from the U.S. Environmental Protection Agency dated August 26, 2015 (EPA 2015).
[3] In areas with structural or access restrictions, area-specific cleanup technologies will be applied, as described in ROD Section 13.2.1.3 (EPA 2014).

  - PD&C
  - Dredge and backfill
- Subtidal:
  - MNR
  - Area-specific technology
  - ENR
  - PD&C
  - Dredge (with backfill in habitat areas)[4]
  - Cap or armored cap

Each RAL exceedance area was evaluated using the appropriate ROD flowchart questions (i.e., depending on location relative to the FNC, subtidal or intertidal). Each flowchart question is included in Table K1-1. Annotated versions of ROD Figures 19 and 20 are included in Attachment K-1 to provide a clear connection between the flowchart questions and the organization of Table K1-1.

The preliminary remedial technology options for each area are summarized in Table K1-1. Note that some areas may be divided into subareas in the 30% RD with different remedial technologies. RAL exceedance areas spanning multiple water depths were subdivided for individual evaluations per depth category: FNC, subtidal, and intertidal. For larger RAL exceedance areas spanning more than 1/10 of a river mile (RM), remedial technologies may apply to only a portion of the area. For example, RAL exceedance area 27 spans approximately RM 2.05 to 2.25. Table K1-1 indicates that dredge, PD&C, ENR, and area-specific technology are all suitable preliminary remedial technology options; however, it is expected that ENR would only be considered for the area north of the pier at RM 2.1W but south of sample SS1404, which exceeds the ENR upper limit.

[4] Habitat areas were defined in the feasibility study as all areas above -10 ft mean lower low water (MLLW).

Table K1-1
Preliminary Remedial Technology Options for Areas with RAL Exceedances

Phase II RAL Exceedance Area	Location	List of COCs > RALs	Any Sediment COC Concentration > RALs in Samples within RAL Exceedance Area ? (Max EF is Presented)	Structural or Access Limitations ? [2]	Area Within a Recovery Category 1 Area? [3]	Sediment COC Concentration > ENR Upper Limit?[2] [4]	Room for ENR Without Dredging?[3] [5]	Room for a Cap Without Dredging?[3] [6]	Would >1 foot of Sediment with COCs > Human Health RALs or Benthic SCOs Remain Following Partial Dredging to Accommodate Cap? [7]	Preliminary Remedial Technology Options
1	FNC	PCBs[4]	0–10 cm: none > RAL 0–60 cm: max EF = 4.3	No	Yes	NA (RC 1)	NA (RC 1)	No	Yes (north), No (south)	Dredge, PD&C
2	FNC	PCBs	0–60 cm: max EF = 2.9	No	Yes	NA (RC 1)	NA (RC 1)	No	No vertical data available	Dredge, PD&C
3	Intertidal/subtidal	PCBs	0–10 cm: max EF = 1.3 0–60 cm: none > RAL	Yes	No	No	Yes	No	NA (surface-only exceedance)	Dredge, AST,[5] ENR
4	Subtidal	PCBs	0–60 cm: max EF = 1.1	No	Yes	NA (RC 1)	NA (RC 1)	Yes	No vertical data available	Dredge, PD&C, cap
5	Intertidal/subtidal	PCBs	0–10 cm: max EF = 8.7 0–45 cm: max EF = 3.2	Yes	Partially	Yes	NA (ENR UL exceeded)	No	TBD in 30% design	Dredge, PD&C, AST
6	Intertidal/subtidal	SVOCs	0-10 cm: max EF = 5.8 0-45 cm: none > RAL	No	No	Yes	NA (ENR UL exceeded)	No	NA (surface-only exceedance)	Dredge
7	Subtidal/FNC	PCBs[4]	0–10 cm: none > RAL 0–60 cm: max EF = 1.4	No	Yes	NA (RC 1)	NA (RC 1)	No	Yes	Dredge, PD&C
8	Intertidal	PCBs, dioxins/furans, mercury, PAHs, other SVOCs	0–10 cm: max EF = 78 0–45 cm: max EF = 20	Yes	Partially	Mixed results	Yes	No	TBD in 30% design	Dredge, PD&C, AST, ENR
8	Subtidal	Dioxins/furans	0–10 cm: none > RAL 0–60 cm: max EF = 1.0	No	Yes	NA (RC 1)	NA (RC 1)	No	TBD in 30% design	Dredge, PD&C
9	Intertidal	PCBs, dioxins/furans, arsenic, copper, lead, mercury, zinc, PAHs	0–10 cm: max EF = 23 0–45 cm: max EF = 96	Yes	Partially	Yes	NA (ENR UL exceeded)	No	TBD in 30% design	Dredge, PD&C, AST
9	Subtidal	PCBs, dioxins/furans, PAHs	0–10 cm: max EF = 17 0–60 cm: max EF = 2.0	No	Yes	NA (RC 1)	NA (RC 1)	Partially	TBD in 30% design	Dredge, PD&C, cap
9	FNC	PCBs	0–10 cm: max EF = 1.4 shoaling core: max EF = 12	No	Partially	NA (shoaled area)	No	No	Yes	Dredge, PD&C
10	FNC	PCBs	Interpolation-only area;[6] will be verified during PDI Phase III.	No	No	NA (shoaled area)	No	No	TBD in 30% RD	Dredge, PD&C
11	FNC	PCBs	0–10 cm: max EF = 4.9 shoaling core: max EF = 1.3	No	No	NA (shoaled area)	No	No	Yes	Dredge, PD&C
12	Intertidal/subtidal	PCBs	0–10 cm: none > RAL 0–45 cm: max EF = 1.9	No	Yes	NA (RC 1)	NA (RC 1)	No	No vertical data available	Dredge, PD&C
13	Subtidal	PCBs	Interpolation-only area;[6] will be verified during PDI Phase III.	No	Yes	NA (RC 1)	NA (RC 1)	No	No vertical data available	Dredge, PD&C
14	FNC	PCBs	0–10 cm: none > RAL shoaling core: max EF = 2.8	No	No	NA (shoaled area)	No	No	TBD in 30% design	Dredge, PD&C

Phase II RAL Exceedance Area	Location	List of COCs > RALs	Any Sediment COC Concentration > RALs in Samples within RAL Exceedance Area ? (Max EF is Presented)	Structural or Access Limitations ? [2]	Area Within a Recovery Category 1 Area? [3]	Sediment COC Concentration > ENR Upper Limit?[2] [4]	Room for ENR Without Dredging?[3] [5]	Room for a Cap Without Dredging?[3] [6]	Would >1 foot of Sediment with COCs > Human Health RALs or Benthic SCOs Remain Following Partial Dredging to Accommodate Cap? [7]	Preliminary Remedial Technology Options
15	Subtidal	PCBs[4]	0–10 cm: none > RAL 0–60 cm: max EF = 1.7	No	Yes	NA (RC 1)	NA (RC 1)	No	Yes	Dredge, PD&C
16	Subtidal	PCBs	0–10 cm: max EF = 1.1 0–60 cm: none > RAL	Yes	Yes	NA (RC 1)	NA (RC 1)	No	No vertical data available	Dredge, PD&C, AST
17	Intertidal/subtidal	Dioxins/furans	0–10 cm: max EF = 9.9	No	No	Yes	NA (ENR UL exceeded)	No	No	Dredge
18	FNC	PCBs	0–10 cm: max EF = 1.3 shoaling core: none > RAL	No	No	NA; shoaled area	No	No	No	Dredge
19	Subtidal	PCBs[4]	0–10 cm: max EF = 640 0–60 cm: none > RAL	No	Yes	NA; RC 1	NA (RC 1)	Yes	Yes	Dredge, PD&C
20	Intertidal/subtidal	PCBs, dioxins/furans, zinc, BEHP, BBP	0–10 cm: max EF = 13 0–45 cm: max EF = 2.7 0–60 cm: none > RAL	Yes	Partially	Yes	NA (ENR UL exceeded)	No	Yes	Dredge, PD&C, AST
21	Intertidal/subtidal	PCBs, dioxins/furans	0–10 cm: max EF = 83 0–45 cm: max EF = 53	No	Partially[7]	No (North of RM 2.32) Yes (South of RM 2.32)	Yes	No	TBD in 30% design	Dredge, PD&C, ENR
22	Subtidal	PCBs	0-60 cm: max EF = 1.0	No	Yes	NA (RC 1)	NA (RC 1)	No	No vertical data available	Dredge, PD&C
22	FNC	PCBs, mercury	0–10 cm: none > RAL shoaling core: max EF = 3.2	No	No	NA (shoaled area)	No	No	Yes	Dredge, PD&C
23	Intertidal	PCBs	0–10 cm: max EF = 1.3 0–45 cm: none > RAL	No	No	No	Yes	No	NA (surface-only exceedance)	Dredge, ENR
23	Subtidal	PCBs[4]	0–10 cm: max EF = 1.3 0–60 cm: max EF = 9.2	No	Yes	NA (RC 1)	NA (RC 1)	No	Yes	Dredge, PD&C
24a	Intertidal	PCBs	0–10 cm: max EF = 1.3 0-45 cm: none > RAL	No	No	No	Yes	No	NA (surface-only exceedance)	Dredge, ENR
24b	Intertidal/subtidal	PCBs, dioxins/furans, arsenic, cadmium, chromium, lead, mercury, zinc, PAHs, phthalates, other SVOCs	0–10 cm: max EF = 12,000 0–45 cm: max EF = 360 0–60 cm: none > RAL	Yes	No	Yes	NA (ENR UL exceeded)	No	TBD in 30% design	Dredge, PD&C, AST
25	Subtidal	PCBs	0–10 cm: max EF = 12 0–60 cm: none > RAL	Yes	No	Yes	NA (ENR UL exceeded)	No	NA (surface-only exceedance)	Dredge, AST
26	Intertidal/subtidal	Dioxins/furans, zinc, PAHs, BBP, other SVOCs	0–10 cm: max EF = 180 0–45 cm: none > RAL	Yes	No	Yes	NA (ENR UL exceeded)	No	NA (surface-only exceedance)	Dredge, AST

Phase II RAL Exceedance Area	Location	List of COCs > RALs	Any Sediment COC Concentration > RALs in Samples within RAL Exceedance Area ? (Max EF is Presented)	Structural or Access Limitations ? [2]	Area Within a Recovery Category 1 Area? [3]	Sediment COC Concentration > ENR Upper Limit?[2] [4]	Room for ENR Without Dredging?[3] [5]	Room for a Cap Without Dredging?[3] [6]	Would >1 foot of Sediment with COCs > Human Health RALs or Benthic SCOs Remain Following Partial Dredging to Accommodate Cap? [7]	Preliminary Remedial Technology Options
27	Intertidal	PCBs	0–10 cm: max EF = 24 0–45 cm: max EF = 3.7	Yes	No	No (North of RM 2.15) Yes (South of RM 2.15)	Yes	No	Yes	Dredge, PD&C, AST, ENR
27	Subtidal	PCBs	0–10 cm: max EF = 1.2 0–60 cm: none > RAL	Yes	No	No	No (within berthing areas)	No	No vertical data available	Dredge, PD&C, AST
28	Intertidal	PCBs	0-10 cm: max EF = 1.2	No	No	No	Yes	No	No vertical data available	Dredge, ENR
29	Intertidal/subtidal	PCBs, BBP	0–10 cm: max EF = 10 0–60 cm: none > RAL	Yes	No	Yes	NA (ENR UL exceeded)	Partially	Yes	Dredge, PD&C, cap, AST
30	Subtidal	PCBs	0–10 cm: none > RAL 0–60 cm: max EF = 2.5	Yes	Yes	NA (RC 1)	NA (RC 1)	Yes	Yes	Dredge, PD&C, cap, AST
30	FNC	PCBs, dioxins/furans, mercury	0–10 cm: max EF = 1.7 0–60 cm/shoaling core: max EF = 8.3	Yes	Partially	NA (RC 1 and shoaled area)	NA (RC 1 and No)	No	Yes	Dredge, PD&C, AST
31	Intertidal	PCBs, dioxins/furans, BEHP	0–10 cm: max EF = 32 0–45 cm: max EF = 140	Yes	No	Yes	NA (ENR UL exceeded)	No	Yes	Dredge, PD&C, AST
31	Subtidal	PCBs	0–10 cm: EF = 31 0–60 cm: EF = 3.4	Yes	No	Yes	NA (ENR UL exceeded)	No	Yes	Dredge, PD&C, AST
32	Intertidal	PCBs, arsenic	0–10 cm: EF = 1.4 0–45 cm: max EF = 1.3	Yes	No	No	Yes	No	No vertical data available	Dredge, PD&C, AST, ENR
33	Intertidal	PCBs	0–10 cm: max EF = 1.7 0–45 cm: none > RAL	No	No	No	Yes	No	NA (surface-only exceedance)	Dredge, ENR
34	Subtidal	PCBs[4]	0–10 cm: none > RAL 0–60 cm: max EF = 33	Yes	Yes	NA (RC 1)	NA (RC 1)	No	Yes	Dredge, PD&C, AST
35	Intertidal	PCBs	0–10 cm: max EF = 7.8 0–45 cm: none > RAL	No	No	Yes	Yes	No	No	Dredge
35	Subtidal	PCBs	0–10 cm: max EF = 1.9 0–60 cm: none > RAL	No	No	No	Yes	No	NA (surface-only exceedance)	Dredge, ENR
36	Subtidal	PCBs	0–10 cm: none > RAL 0–60 cm: max EF = 2.8	No	Yes	NA (RC 1)	NA (RC 1)	No	No	Dredge

Notes:
General note: Dredging between -4 feet and -10 feet MLLW will also require backfill for habitat.
1. Question [1] on ROD Figures 19 and 20 (EPA 2014) is not addressed in this table as the answer is 'Yes' for all remedial action area exceedance areas evaluated. That is, MNR is not suitable at locations where COC concentrations exceed one or more remedial action levels.
2. ENR is not a designated technology for Recovery Category 1 areas or shoaled areas in federal navigation channel.
3. Questions [5] and [6] areas are not included on ROD Figure 19.
4. This RAL exceedance area also had a surface sediment RAL exceedance for phenol. Phenol concentrations exceeded the RAL in 31 samples in Phase I; 23 of these locations were reoccupied and analyzed for phenol in Phase II. There were no RAL exceedances in the Phase II reoccupied locations. Thus, while the remaining locations with phenol concentrations greater than the RAL were not reoccupied (primarily because they were co-located with other COCs), it is logical to assume that if these locations were reoccupied, concentrations would be similarly lower (i.e., less than the RAL).
5. For the purpose of preliminary technology evaluations, AST refers to any technology, or combination of technologies, that was not contemplated in the ROD and may be necessary to address the transition from the in-water remedy to upland conditions, or to address access limitations or structural setbacks.
6. Interpolation-only areas are artifacts from the interpolation analysis and do not include a sample location with an RAL exceedance.
7. A small portion of this area (roughly 400 square feet south of core location LDW24-IT1456) is within recovery category 1.
AST: area-specific technology
BBP: butyl benzyl phthalate

BEHP: bis(2-ethylhexyl) phthalate
cm: centimeter
COC: contaminant of concern
EF: Exceedance Factor
ENR: enhanced natural recovery
MLLW: mean lower low water
NA: not applicable
PAH: polycyclic aromatic hydrocarbon
PCB: polychlorinated biphenyl
PD&C: Partial Dredge and Cap
PDI: pre-design investigation
RAL: Remedial Action Level
RC: Recovery Category
RD: remedial design
SCO: Sediment Cleanup Objective
SVOC: semivolatile organic compound
TBD: to be determined
UL: Upper Limit

2 References

EPA. 2014. Record of Decision. Lower Duwamish Waterway Superfund Site. US Environmental Protection Agency.

EPA. 2015. Lower Duwamish Waterway Record of Decision Table and Figure Revisions. Environmental Protection Agency, Seattle, WA.

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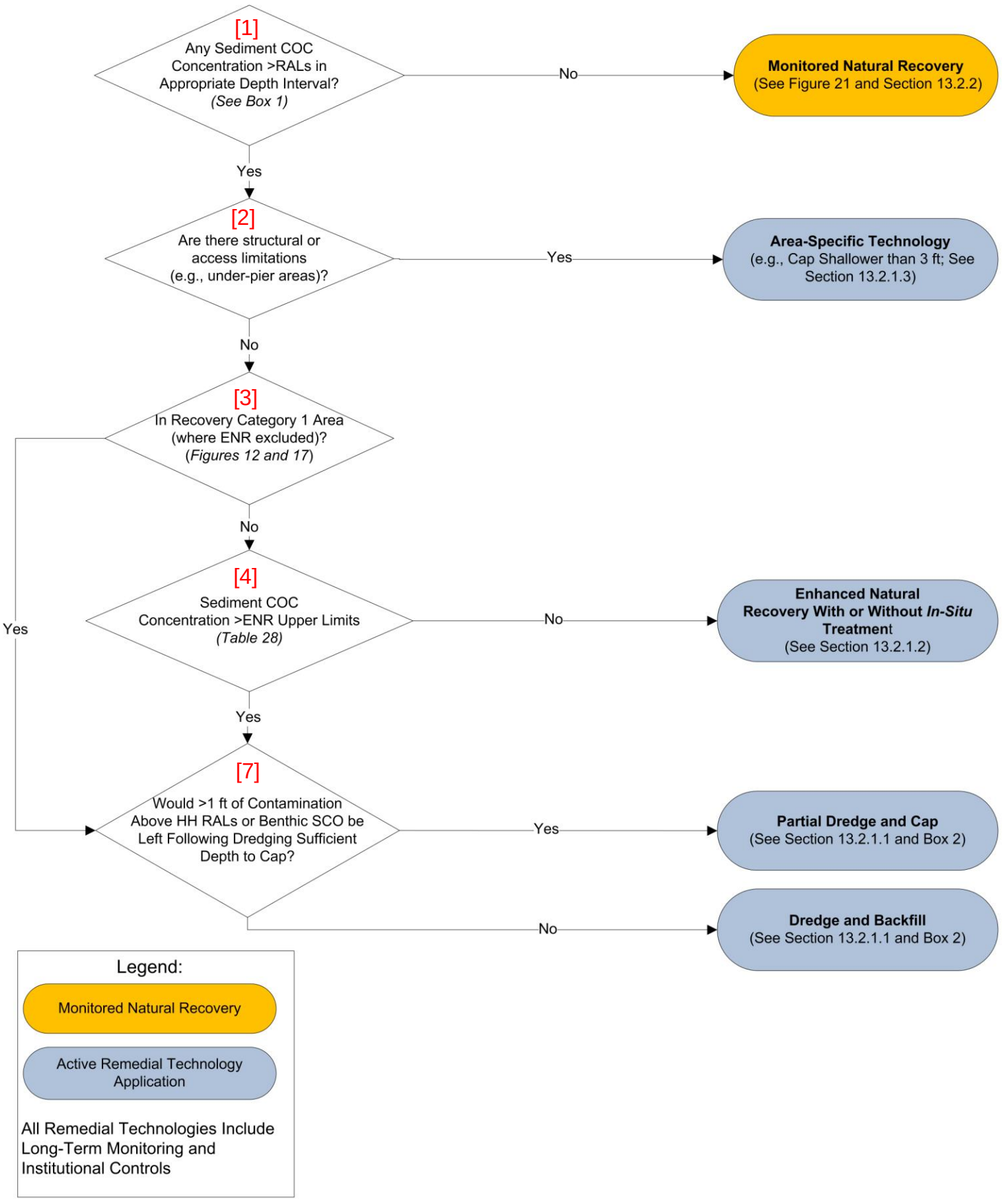
Attachment K-1
Record of Decision Flowcharts



Box 1. Intertidal Sediments (+11.3 ft MLLW to -4 ft MLLW)

Remedial Action Levels (RALs) and Depth Interval to Which They Apply

Contaminant	Units	Recovery Category 1 Areas		Recovery Category 2 and 3 Areas		Risk Reduction Associated with RALs
		4 in (10 cm) depth interval	1.5 ft (45 cm) depth interval	4 in (10 cm) depth interval	1.5 ft (45 cm) depth interval	
PCBs (Total)	mg/kg-OC	12	12	12	65	Human Health [a,b,c,e]
cPAH	µg TEQ/kg-dw	1000	900	1000	900	
Dioxins/Furans	ng TEQ/kg-dw	25	28	25	28	
Arsenic (Total)	mg/kg-dw	57	28	57	28	
39 SMS COCs	Varies by COC	SCO (see Table 27)	--	2xSCO (see Table 27)	--	Ecological [d,e]

Notes:

1. The average concentrations in depth Interval (e.g., vertically composited samples) are compared to RALs.
2. Human Health RALs and RAO 3 RALs must be met immediately following construction.

[a] RAO 1 - Human health seafood consumption

[b] RAO 2 - Human health direct contact includes beach play, clamming, and netfishing

[c] RAO 4 - Ecological protection for river otter (addressed by meeting human health PCB RAL)

[d] RAO 3 - Ecological protection of benthic community

[e] There are 41 SMS COCs, but PCB and arsenic are principally RAO 1 COCs. SMS also lists toxicity test-out criteria using bioassays. Test-out is not allowed for PCBs or arsenic.

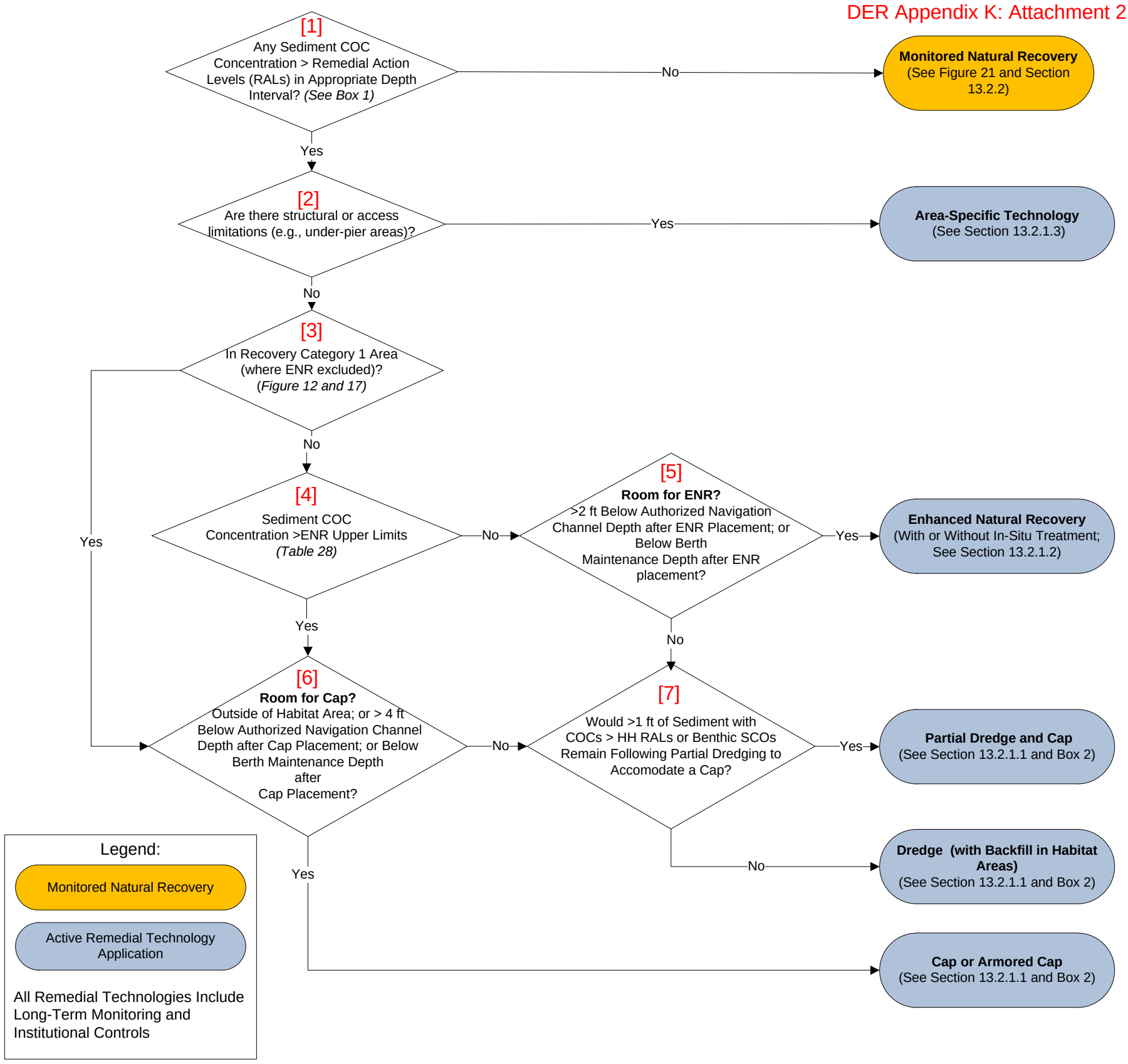
Box 2. Habitat Areas

Elevations of intertidal habitat areas are assumed to be unaffected by addition of 6-9" of suitable materials (i.e., ENR)

Cap,dredge and backfill,or partial dredge and cap to pre-construction grade; finish with suitable habitat layer

In clam habitat areas (Figure 6), caps will generally include 4 ft of suitable clean material Including a minimum 45 cm clam habitat layer

Figure 19. Intertidal Areas – Remedial Technology Applications



Box 1. Subtidal Sediments (-4 ft MLLW and Deeper)

Remedial Action Levels (RALs) and Depth Interval for Application of RAL

Contaminant	Units	Recovery Category 1 Areas		Recovery Category 2 and 3 Areas		Shoaled Areas of the Federal Channel	Risk Reduction Associated with RALs
		4 in (10 cm) depth interval	2 ft (60 cm) depth interval	4 in (10 cm) depth interval	2 ft (60 cm) depth interval-applied only at potential tug scour areas; See *Footnote 2* and Figure 16	See *Footnote 3*. To a depth of 2 ft below the authorized depth for waterway reach[f]	
PCBs (Total)	mg/kg-OC	12	12	12	195	12	Human Health [a,b,c]
cPAH	µg TEQ/kg-dw	1000	1000	1000	--	1000	
Dioxins/Furans	ng TEQ/kg-dw	25	25	25	--	25	
Arsenic (Total)	mg/kg-dw	57	57	57	--	57	
39 SMS COCs	Varies by COC	SCO (see Table 27)	SCO	2xSCO (see Table 27)	--	SCO (see Table 27)	Ecological [d,e]

Notes

1. The average concentrations in depth interval (e.g., vertically composited samples) are compared to RALs.
2. Potential Tug Scour Areas are Subtidal Elevations Potentially Susceptible to Propellor Wash (North of the 1st Avenue South bridge located at approximately RM 2 in Water Depths from -4 to -24 ft MLLW, and South of the 1st Avenue S Bridge, in Water Depths from -4 to -18 ft MLLW).
3. Shoaled areas are those areas in federal navigation channel with sediment accumulation above the authorized depth including a 2 ft over-dredge depth; see Table 28. For areas in the navigation channel that are not shoaled, Recovery Categories 1 or 2 & 3 RALs apply. Authorized depths are: (1) from RM 0 to 2, 30 ft below MLLW (from Harbor Island to the First Avenue South Bridge); (2) from RM 2 to RM 2.8, 20 ft below MLLW (from the First Avenue South Bridge to Slip 4); and (3) from 15 ft below MLLW from RM 2.8 to 4.7 (Slip 4 to the Upper Turning Basin).
4. Human Health RALs (and RAO 3 PRGs (Benthic SCOs) in Category 1 areas) must be met immediately following construction.

[a] RAO 1 - Human health seafood consumption

[b] RAO 2 - Human health direct contact includes beach play, clamming, and netfishing

[c] RAO 4 - Ecological protection for river otter (addressed by meeting human health PCB RAL)

[d] RAO 3 - Ecological protection of benthic community

[e] There are 41 SMS COCs, but PCB and arsenic are principally RAO 1 COCs. SMS Also lists toxicity test-out criteria using bioassays. Test-out is not allowed for PCBs or arsenic.

[f] Depth intervals to determine compliance will be determined during Remedial Design.

[g] Caps were assumed to be 3 ft for cost estimating purposes; cap thicknesses will be evaluated by EPA during Remedial Design in accordance with EPA and USACE (1998)

Box 2. Habitat Areas (see Section 13.2.1.1)

Elevations of intertidal habitat areas are assumed to be unaffected by addition of 6-9" materials (i.e., ENR)

Cap, dredge and backfill, or partial dredge and cap to pre-construction grade; finish with suitable habitat layer.

Revised Figure 20. Subtidal Areas – Remedial Technology Application