5.0 DATA INTERPRETATION

5.1 CHEMICALS OF CONCERN

5.1.1 Selection Criteria

The EBDRP Panel has used the Washington State SMS to help establish the level of sediment cleanup. Therefore, identification of COCs for the Duwamish/Diagonal Study Area was based on comparison to SMS marine sediment chemical criteria (i.e., SQS and CSL levels per Chapter 173-204 WAC), which are considered protective of marine organisms. There are currently no equivalent numerical SMS marine sediment chemical criteria established for the protection of human health.

The SMS provides for site cleanup standards that may range from SQS to CSL/MCUL criteria, based on balancing associated cost and net environmental benefit. Therefore, estimation of the areas of contaminated sediments above SQS and CSL/MCUL chemical criteria is the first step in determining potential cleanup areas for the Study Area. These potential cleanup areas may then be refined based on results of sediment bioassay testing.

Since the SMS chemical criteria do not address potential human health risks, a semi-quantitative risk evaluation was conducted to identify potential COCs for protection of human health, and to evaluate potential human health impacts due to consumption of fish harvested from the Study Area. Results of this evaluation are summarized in **Section 5.1.2.7** and included as **Appendix O**.

5.1.2 Chemicals of Concern Based on SMS Comparison

Selection of COCs for the Study Area focuses on conditions in the North Inshore Area because the intent of the Consent Decree is to remediate contaminated sediment associated with KCDNR and City CSOs and SDs. The North Inshore Area includes stations located near the Duwamish/Diagonal outfalls. The surface sediment characterization (**Section 4.4**) identified SQS/CSL chemical exceedances in the North Inshore Area based on 34 surface sediment samples collected. Data from the 1998 EPA study that are in the same section of river as the Duwamish/Diagonal outfalls were incorporated into the analysis as well (Weston 1999).

The number of exceedances for each COC is listed in **Table 5.1**.

Table 5.1 SQS/CSL EXCEEDANCES IN THE NORTH INSHORE AREA

Chemical	Number of SQS Exceedances	Number of CSL Exceedances
Arsenic	0	1
Lead	1	0
Mercury	5	2
Zinc	4	0
1,2-Dichlorobenzene	0	1
1,4-Dichlorobenzene	0	2
PCBs	24	6
bis (2-ethylhexyl) phthalate	9	27
Butyl benzyl phthalate	23	3
Total HPAHs	2	0
Total LPAHs	2	1
4-Methylphenol	0	2

Based on the total number of SQS/CSL exceedances, four of the chemicals listed in **Table 5.1**, mercury, PCBs, bis (2-ethylhexyl) phthalate, and butyl benzyl phthalate, are identified as COCs around the Duwamish/Diagonal outfalls. The other chemical exceedances are limited to a few stations that are remote from the Duwamish/Diagonal outfall area and do not appear to represent a contamination footprint of the outfalls.

For the primary COCs (i.e., mercury, PCBs, bis (2-ethylhexyl) phthalate, and butyl benzyl phthalate), surface concentration contour maps were generated (Figures 5-1, 5-3, 5-5, and 5-7). In addition to surface concentration contours, subsurface sediment chemistry data are also presented (Figures 5-2, 5-4, 5-6, and 5-8) to evaluate the vertical extent of contamination for each of the primary COCs.

5.1.2.1 Mercury

Figure 5-1 illustrates the concentration contours for total mercury in surface sediment. The contour plot shows three hot spot areas that exceed the CSL for mercury, but each area consists of only one station above the CSL. The highest concentration occurred at the station offshore from the former Diagonal Treatment Plant outfall (five times CSL) and the next highest value was inshore and downstream of the Diagonal Way CSO/SD outfall (three times CSL). The third station above the CSL is located at the east channel line and a little upstream of the Siphon. The SQS boundary consists of five individual SQS boundary circles (including three CSL areas). In total, there are four stations where mercury values exceed SQS and are below CSL. Two of these SQS stations are clustered with the single highest station located offshore from the former Diagonal Treatment Plant outfall and results in the largest SQS boundary circle. The other SQS stations are located near the east channel line in two different SQS boundary circles. It appears that discharge pipes are not currently a significant continuing source of mercury.

Bioassay tests were not performed at any stations that exceed SQS or CSL values for mercury; therefore, it is not possible to determine whether toxicity is overestimated by the SMS values. All seven stations tested were below the SQS and five of these stations had no toxicity. Station DUD204 had a single toxic response (amphipod) and station DUD206 had two toxic responses (polychaete and echinoderm) that are unexplained.

Figure 5-2 presents the concentration of total mercury in subsurface sediment. The maximum mercury concentration was reported at core Station DUD254, which is located adjacent to the Duwamish/Diagonal outfalls. At this station, mercury concentration exceeds CSL criteria in both the 0 to 3 foot and 3 to 6 foot segments, but is below SQS criteria in the 6 to 9 foot core segment. Thus, a decreasing mercury concentration trend with depth is evident near these outfalls. At the next downstream core station (DUD252), there are no mercury exceedances. However, mercury exceedances are noted in subsurface core segments (up to 6 feet deep) for core stations located further out towards the channel (DUD253 and DUD255).

Mercury that is released to the aquatic environment is chemically persistent, although its form (inorganic or organic) may change over time. The organic form (methyl mercury) is readily accumulated by fish and can present human health concerns. As indicated in **Section 4.4.2**, methyl mercury represents a small fraction (0.10 to 1.4 percent) of the total mercury concentration for Phase 1 surface sediments.

Mercury has been used in British Columbia as a marker of the extent of sediment contamination resulting from untreated sewage discharges (Chapman et al. 1996). Data presented in the *Pollutant Loading Analyses for the Elliott Bay Waterfront Recontamination Study* (Herrera Environmental Consultants 1995) identify a mercury concentration range of 0.38 to 3.22 mg/kg in sediments collected from within KCDNR and City CSOs. The same study presented geometric mean mercury concentrations of 0.20 to 0.26 mg/kg in particulate material discharged from SDs from residential, commercial, and industrial areas. Finally, the KCDNR collected stormwater samples from the Diagonal Avenue SD system as part of the EBDRP study and reported a maximum average mercury concentration of 0.12 mg/l (**Appendix D**). KCDNR modeling results (**Appendix H**) indicate that current SD mercury loadings from the Diagonal Way CSO/SD outfall should not result in sediment recontamination following sediment cleanup. Mercury was not evaluated by the mass balance modeling activity conducted by WEST Consultants in 1999 (**Appendix I**).

5.1.2.2 PCBs

Figure 5-3 illustrates the concentration contours for total PCBs in surface sediment. The surface contours show total PCB concentrations below SQS levels near the shoreline, with concentrations increasing further offshore. CSL exceedances are present near the channel and in a larger area located off the former Diagonal Avenue Treatment Plant outfall. The surface sediment PCB concentration contours appear unrelated to any recent discharges from the Duwamish/Diagonal outfalls, and therefore do not define the outfall footprint.

There are three distinctive hot spot areas for PCBs. One is located offshore from the former Diagonal Avenue Treatment Plant outfall and this area has two stations that exceed five times the CSL (highest value 15 times CSL). The two other hot spot areas are located on either side of the Siphon. The hot spot downstream of the Siphon consists of three stations, one of which exceeds five times the CSL. The hot spot upstream of the Siphon is composed of two stations that each exceed one times the CSL. The SQS boundary line runs along the west channel line and extends upstream to Slip 1. Most of the inshore area near the former Duwamish Avenue Treatment Plant outfall (behind the Pier) is below the SQS. The lower PCB values near the outfalls appear to be from the more recently deposited sediments discharged from the Diagonal

Way CSO/SD outfall. A sediment core sample taken offshore from the outfalls shows that there are much higher PCB values in sediments more than 2 feet below the river bottom. It appears that discharge pipes are not currently a significant continuing source of PCBs. The primary source of PCB recontamination in this part of the river would be from disturbing contaminated bottom sediments.

Bioassay results show that four of the seven stations tested had less toxicity then predicted by sediment chemistry for PCBs. Stations DUD200, DUD201, DUD202, and DUD205 exceeded the SQS, but bioassays showed no toxicity. Station DUD204 was the only station that exceeded the SQS and also had one bioassay toxicity response (amphipod). Stations DUD203 and DUD206 were below the SQS, but station DUD206 showed an unexplained toxicity in two tests (polychaete and echinoderm) despite low levels of PCB detected in the sediment.

Figure 5-4 presents the concentration of total PCBs in subsurface sediment based on EPA data (two stations) and Phase 2 core data (16 stations). Sixteen of these stations exceed SMS values for PCBs, 13 exceed the CSL, and another three are above the SQS but below the CSL. **Figure 5-4** shows that most of the stations that exceed the SMS are located either in the channel or not far inshore from the edge of the channel. The concentrations tended to be lower near the outfalls.

At core stations located adjacent to the Duwamish/Diagonal outfalls (DUD254 and DUD253), PCB concentrations slightly exceed SQS criteria in the top segment (0 to 3 feet), but exceed CSL criteria in deeper segments (3 to 6 feet and 6 to 9 feet). An intertidal delta extends into the river in front of the Diagonal Way CSO/SD outfall. Chemistry data from coring stations DUD020 and DUD254 indicate that about 2 to 3 feet of sediment has accumulated on this delta since the siphon was completed in 1967. At these stations, sediments with high PCB concentrations (3,000-5,000 ppb DW) are covered over with two to three feet of sediments containing lower PCB values (300-700 ppb DW). The PCB content in deeper sediments may represent historical PCB releases, or PCBs in upper layers may have been mixed down to the deeper layer during dredging to install the Siphon pipe across the river. Core stations located immediately upstream and downstream of the Duwamish/Diagonal outfalls include PCB SQS/CSL exceedances down to 6 feet in depth, but no exceedances in the 6 to 9 foot segments. With the exception of Station DUD206, located relatively near the shoreline, every Phase 2 core station exceeded PCB SQS or CSL criteria in the 0 to 3 foot segment.

Part of the Siphon trench near the east channel line was not backfilled to the previous grade and results in a "U" shaped contour line extending towards shore. Sampling stations located on either side of this old unfilled trench, near the east channel line (DUD030 and DUD032) showed the surface sediments had greater PCB values than surface sediment located closer to the outfalls. This suggests that, at the edges of this old construction trench, there is an area where the historic sediments with higher PCB may be closer to surface.

The 1984 USACE emergency dredging action discussed in **Section 2-3** removed one barge load of contaminated sediment. Alex Sumeri (USACE) reported the dredged material was contaminated with numerous metals and organic chemicals including PCBs (4,500 ppb DW), DDD, DDE, cadmium, arsenic, copper, lead (190 ppm DW), and zinc (359 ppm DW). A slope failure is thought to have been the cause of the shoal and this could help explain why there is

such a localized area of contaminated sediment remaining offshore from the former Diagonal Avenue Treatment Plant outfall.

For comparison, total PCBs were detected in surface sediment at concentrations exceeding the SQS chemical criterion throughout the Harbor Island Inshore area, which included the East and West Waterway, north Harbor Island, and Kellogg Island (Weston 1993). PCBs were also detected throughout the sediment cores.

Current uses of PCBs are restricted to insulating materials in electrical capacitors and certain transformers employed in enclosed areas. Historically, PCBs were used in hydraulic fluids, as plasticizers in waxes, as additives in paints, adhesives, and caulking compounds, and as components in paper manufacture (Mearns et al. 1991). Thus, PCB concentrations in the site sediment are most likely due to historical discharges, rather than current sources. The potential for PCB recontamination was therefore not evaluated by either the KCDNR or the WEST Consultants modeling efforts. PCBs released to the aquatic environment are chemically persistent, and have a strong tendency to accumulate in aquatic sediments and in the tissue of aquatic organisms. Thus PCBs present a human health concern due to potential exposure via consumption of contaminated fish and shellfish or direct exposure to sediments.

5.1.2.3 bis (2-ethylhexyl) phthalate

Figure 5-5 illustrates the concentration contours for bis (2-ethylhexyl) phthalate in surface sediment. The contour plot shows two distinctive hot spot areas for bis (2-ethylhexyl) phthalate. One area near the Duwamish/Diagonal outfalls has two stations that exceed five times the CSL (highest value over six times CSL). The second hot spot is offshore from the former Diagonal Avenue Treatment Plant outfall and the highest value in this area is four times the CSL. Much of the CSL boundary is near the east channel line, except for two circles that occur in the channel both upstream and downstream of the Siphon. The SQS boundary line extends into the channel. Some of the inshore area located near the former Diagonal Way Treatment Plant outfall and behind the pier is below the SQS. The old treatment plant stopped discharging in 1969 and the Duwamish CSO has not overflowed since 1989. The Diagonal Way CSO/SD outfall is the only continuing discharge source. The CSO volume has been reduced 80 percent (less than 65 MGY remaining), but the annual volume of stormwater is about 1,230 MGY and could be a potential source of recontamination for bis (2-ethylhexyl) phthalate.

Only seven stations were subjected to bioassay testing in 1996 because the focus of testing was to establish the upstream and downstream boundary for a sediment remediation project designed to address phthalate contamination. Five of the seven stations tested showed no bioassay failures (DUD200, DUD201, DUD202, DUD203 and DUD205), but there was one SQS exceedence (Station DUD204) and one CSL exceedence (Station DUD206). At five stations, the bioassay results showed less toxicity than predicted by sediment concentrations of bis (2-ethylhexyl) phthalate. The largest difference was at Stations DUD202 and DUD205, where both stations exceeded one times the CSL, but bioassays showed no toxicity. Station DUD200 and DUD201 exceeded the SQS, but bioassays showed no toxicity. Station DUD204 exceeded the CSL, but bioassay testing showed only one SQS exceedence (amphipod). Station DUD203 was the only station where chemistry was below the SQS and bioassay testing gave corresponding results showing no toxicity. One intertidal station was subjected to bioassay testing (DUD206, behind

the pier), but this station gave the most conflicting results. Sediment chemistry was below the SQS, but two bioassay tests had an SQS exceedence (polychaete and echinoderm), which indicates the station could be listed as exceeding the CSL based on bioassay testing. All of the SMS chemical results were low at Station DUD206, so the cause of the toxicity may be related to some other factors such as ammonia or sulfides, but this has not been investigated.

Figure 5-6 presents the concentrations of bis (2-ethylhexyl) phthalate in subsurface sediment. At Station DUD254, located closest to the outfalls, CSL exceedances were reported in the 0 to 3 foot and 3 to 6 foot core segments. The SQS criteria, however, is not exceeded in the 6 to 9 foot segment. Immediately downstream, Station DUD252 had no SQS/CSL exceedances in core segments. SQS and/or CSL exceedances were found for adjacent Stations DUD253, DUD255, and DUD256 down to 6 feet depth; however, the numerical concentrations were not as high as reported at Station DUD254. Subsurface contamination at Stations DUD253 and DUD254, located along the Siphon pipe alignment, may represent vertical mixing of the sediment during the Siphon installation.

For comparison, bis (2-ethylhexyl) phthalate and butyl benzyl phthalate were most frequently detected in surface sediment at concentrations exceeding SQS chemical criteria for most of the Harbor Island Inshore area (Weston 1993); however, in the Kellogg Island area, neither phthalate frequently exceeded screening criteria.

Bis (2-ethylhexyl) phthalate released to aquatic systems will biodegrade fairly rapidly in the water column (half-life of two to three weeks) following acclimation (Howard 1989). It will also strongly adsorb to sediment due to its low water solubility, and has the potential to bioconcentrate in aquatic organisms (Howard 1989). Under aerobic conditions, bis (2-ethylhexyl) phthalate also biodegrades fairly rapidly in water/sediment systems following acclimation; however, under anaerobic conditions, no biodegradation occurs (Howard 1989).

Phthalates have been used as plasticizers since the 1930s, primarily for production of polyvinyl chloride (PVC) and other polymers. They are also used in household products. Their distribution in the environment is widespread and source control, other than control of CSO overflows, would be difficult due to their ubiquity. KCDNR has reported that the primary source of bis (2-ethylhexyl) phthalate in the Diagonal drainage basin may have been from historical commercial operations associated with Janco United (**Chapter 3.2.1** and **Appendix G**). In 1994 KCDNR collected stormwater samples from the Diagonal Avenue SD system and reported a maximum average bis (2-ethylhexyl) phthalate concentration of 7.15 mg/l (**Appendix D**). Initial KCDNR modeling results in 1996 (**Appendix H**) indicated that current SD bis (2-ethylhexyl) phthalate loading from the Diagonal Way CSO/SD outfall should not result in significant sediment recontamination following a sediment cleanup. The City's subsequent revision of the assumed Diagonal Way SD discharge volume, and subsequent modeling in 1997 by KCDNR (**Appendix H**) indicated that recontamination by bis (2-ethylhexyl) phthalate could occur. This revised conclusion lead to an attempt at mass balance modeling conducted in late 1999 by WEST Consultants (**Appendix I**). This effort also concluded that recontamination of the Study Area by bis (2-ethylhexyl) phthalate could occur due solely to background concentrations of bis (2-ethylhexyl) phthalate in the Duwamish River.

5.1.2.4 Butyl Benzyl Phthalate

Figure 5-7 illustrates the concentration contours for butyl benzyl phthalate in surface sediment. Only one station exceeded the CSL value for butyl benzyl phthalate and this station was located offshore from the former Diagonal Avenue Treatment Plant outfall. The SQS boundary line extends primarily along the east channel line. In addition to the nearshore band of stations with levels between the SQS and the CSL, there are two stations in the navigation channel with levels between the standards. The Diagonal Way CSO/SD outfall annually discharges about 1,230 MGY of stormwater and could be a potential source of recontamination for butyl benzyl phthalate.

Bioassay results show that four of the seven stations tested had less toxicity than predicted by sediment chemistry for butyl benzyl phthalate. Stations DUD200, DUD201, DUD202, and DUD205 exceeded the SQS, but bioassays showed no toxicity. Station DUD204 was the only station that exceeded the SQS and also had one bioassay toxicity response (amphipod). Stations DUD202 and DUD206 were both below the SQS, but Station DUD206 showed an unexplained toxicity in two tests (polychaete and echinoderm) despite low butyl benzyl phthalate in sediment chemistry results.

Figure 5-8 presents the concentrations of butyl benzyl phthalate in subsurface sediment. Only one station (DUD006) exceeded the CSL value for butyl benzyl phthalate, located offshore between the Duwamish/Diagonal outfalls. There were a limited number of SQS exceedances, primarily limited to the 0 to 3 feet core segment. Only at Station DUD254, located adjacent to the Duwamish/Diagonal outfalls, was a SQS exceedance reported in the 3 to 6 foot core segment.

Butyl benzyl phthalate released to aquatic systems will adsorb to sediments and biota. However, biodegradation appears to be the primary fate mechanism, which can proceed rapidly under both aerobic and anaerobic conditions (Howard 1989).

Butyl benzyl phthalate is used as a plasticizer for polyvinyl and cellulosic resins, primarily in PVC. Possible sources of butyl benzyl phthalate release to the environment are from its manufacture, distribution, and PVC blending operations. Release from consumer products is expected to be minimal (Howard 1989). In 1994, KCDNR collected stormwater samples from the Diagonal Avenue SD system and reported a maximum average butyl benzyl phthalate concentration of 0.59 mg/l (**Appendix D**). Initial KCDNR modeling results in 1996 (**Appendix H**) indicate that current SD butyl benzyl phthalate loadings from the Diagonal Way CSO/SD outfall would require a stream mixing width of 52 feet to maintain sediment concentrations below SQS criteria. The model incorporated a stormwater concentration of 2.2 mg/l, compared to the KCDNR stormwater value of 0.59 mg/l; thus, model results were considered conservative. The mass balance modeling conducted in late 1999 by WEST Consultants (**Appendix I**) however, indicates that recontamination of a cleanup area would likely occur due solely to background concentrations of butyl benzyl phthalate in the Duwamish River.

5.1.2.5 Cleanup Areas Defined by Duwamish/Diagonal Chemicals of Concern

The surface areas for SQS/CSL chemical exceedances determined by contour plotting were overlaid for all four COCs: PCBs, mercury, butyl benzyl phthalate, and bis(2-thylhexyl)phthalate. These chemical SQS/CSL exceedance areas were then refined based on

Phase 2 sediment bioassay results. Bioassays conducted for Stations DUD201 and DUD202 both passed SQS biological criteria; therefore, these stations were used to define the northern boundary of the SQS/CSL exceedance area. Similarly, bioassays were conducted for Stations DUD204 and DUD205 to define a southern boundary. Station DUD205 passed SQS biological criteria, while Station DUD 204 failed SQS biological criteria, but passed CSL criteria. Therefore, the southern boundary of the SQS/CSL exceedance area was refined based on these bioassay results. The western SQS/CSL boundary was based solely on chemical exceedances, since confirmatory bioassays were not conducted in this area.

Figure 5-9 illustrates the composite SQS/CSL exceedance areas for all four COCs. The composite CSL boundary is dominated by the CSL boundary for bis (2-ethylhexyl) phthalate and PCBs. Most of the CSL boundary is near the east navigation channel line. There is a distinct hot spot located offshore from the former Diagonal Avenue Treatment Plant outfall, where one or more stations exceeded the CSL for all four chemicals plotted. The remaining area of CSL exceedance is centered on the outfalls and is dominated by bis (2-ethylhexyl) phthalate. Both upstream and downstream of the Siphon, the CSL boundary extends to the navigation channel where Station DRO81 (upstream) and Station DUD044 (downstream) exceed the CSL for PCBs and bis (2-ethylhexyl) phthalate. The composite SQS boundary is driven by PCBs and includes more of the channel area. One small area below the SQS is located inshore near the former Diagonal Avenue Treatment Plant outfall (behind the pier).

In general, the bioassay results show that sediments are less toxic than indicated by the composite sediment chemistry. The only exception to this trend is at Station DUD206, which was below the SQS for all chemicals, but showed an unexplained toxic response.

Figure 5-9 also presents a proposed rectangular sediment cleanup area. This proposed cleanup area was guided by the following considerations: 1) a preferred rectangular dredge cut pattern; 2) setting the western boundary to the physical constraints imposed by the navigation channel; and 3) focusing sediment cleanup to the North Inshore Area, which represents contamination due to Duwamish/Diagonal outfall discharges. The proposed sediment cleanup area is estimated at 4.8 acres.

5.1.2.6 Relationships Between Hot Spots

The two hot spots located upstream and downstream of the siphon extend into the channel and contain many of the same chemicals found in the hot spot offshore from the former Diagonal Avenue Treatment Plant. Due to the similarities in these three hot spots, it is possible that the 1984 emergency dredging action could have caused sediment to move from the former Diagonal Avenue Treatment Plant area and deposit on either side of the Siphon. To investigate this issue, King County staff tried to determine if there were specific chemical signatures that could confirm whether these three areas are uniquely related to each other. This limited analysis did not find any unique chemical features that could prove these three areas are composed of the same sediment material.

For surface samples, the highest concentration of PCBs (10,000 ppb - 85,000 ppb DW) occurred in the three stations offshore from the former Diagonal Avenue Treatment Plant outfall; however, within these stations there was no consistent pattern regarding which Aroclors had the

highest and lowest values (Aroclor 1248, 1254, or 1260). The two hot spots near the Siphon had lower PCB values (1140 ppb – 2440 ppb DW), and neither site had a consistent Aroclor pattern. Core samples from nine stations generally appeared to have a more consistent Aroclor pattern; however, this pattern was not always consistent. In general, Aroclor 1248 was highest about 80 percent of the time and Aroclor 1260 was second highest about 50 percent of the time.

Three benzene compounds (1,4-dichlorobenzene, 1,2-dichlorobenzene, and 1,2,4-trichlorobenzene) had the highest surface sediment values at Station DUD027 (also some at Station DUD012). These benzene chemicals were not found elevated at any other surface stations except right in front of the Diagonal Way CSO/SD outfall (DUD005 and DUD006). The core samples offshore from Diagonal Way CSO/SD outfall had higher values of 1,4-dichlorobenzene than the surface samples, but even these samples were not as high as the surface sample at Station DUD027.

Metals do not degrade over time like organic chemicals; however, for metals to be a good tracer, the concentrations need to be high enough to be distinguished from general increases. The highest concentration of metals in a surface sample occurred offshore from the former Diagonal Avenue Treatment Plant at Station DUD027 (mercury at 3.59 ppm, zinc at 900 ppm, and lead at 550 ppm DW). In the hot spot upstream of the Siphon, both Stations DUD032 and DR081 had elevated levels of metals (mercury at 0.38 – 0.81 ppm, zinc at 357 – 674 ppm, and lead at 255 – 411 ppm DW). In the hot spot downstream of the siphon, only one of the three stations (DUD028) had elevated metals levels (mercury at 0.40 ppm, zinc at 487 ppm, and lead at 389 ppm DW). Surface sediments off the Diagonal Way CSO/SD outfall are not very high for metals, but the core samples taken in this area (DUD020 and DUD254) show there are elevated concentrations of metals buried 3 feet deep (mercury at l.56 ppm, zinc at 461 ppm, and lead at l,l60 ppm). If these buried sediments with high metals levels were spread around during the siphon construction activities this could have influenced the two hot spots near the Siphon. Although the former Diagonal Avenue Treatment Plant hot spot cannot be ruled out as a potential source of metals, the proximity of the two other hot spots to the Siphon raises the possibility that historic construction activities could be the source.

5.1.2.7 Chemicals of Concern Based on Human Health

Identification of COCs based on screening to SMS criteria does not account for potential human health impacts, since current SMS criteria were developed for the protection of aquatic organisms only. Therefore, to assess potential human health risks due to consumption of fish harvested from the Study Area, a semi-quantitative human health risk assessment was conducted. Results of this risk assessment are summarized below, while the complete evaluation is included in **Appendix O**.

Fish tissue chemistry data were not collected as part of the Duwamish/Diagonal Study Area assessment. However, fish muscle tissue data were available through the Puget Sound Ambient Monitoring Program (PSAMP) database. In 1992, PSAMP collected English sole (*Pleuronectes vetulus*) from a station located adjacent to the Duwamish/Diagonal outfalls, and analyzed the muscle tissue for a suite of contaminants. These tissue concentrations were used in standard fish ingestion equations developed by the Washington State Department of Health (1995), to determine potential carcinogenic and non-carcinogenic risks to humans due to fish consumption.

Risk for exposure to non-carcinogens is considered acceptable if the calculated Hazard Quotient (HQ) is less than one (HQ < 1), while the EPA- and Ecology-acceptable carcinogenic risk probability range is from one chance in a million (10^{-6}) to one chance in ten thousand (10^{-4}) of developing cancer.

Based on the results of the human health risk assessment, PCBs, total DDT, and arsenic are potential COCs. Bis (2-ethylhexyl) phthalate was also evaluated. Results of the human health risk assessment indicate that: 1) fish tissue concentrations do not present a non-carcinogenic risk; 2) excess carcinogenic risks posed by PCBs and arsenic ($7x10^{-4}$ and $9x10^{-3}$, respectively) in fish tissue are greater than the EPA- and Ecology-acceptable carcinogenic risk probability range; and 3) concentrations of bis (2-ethylhexyl) phthalate in fish tissue do not present a carcinogenic risk ($3x10^{-7}$) or a non-carcinogenic risk (HQ = 0.0012) at the Study Area. It should be emphasized that the limited database, plus the incorporation of several conservative exposure assumptions, result in significant uncertainties in the human health risk estimates.

A 1999 human health risk assessment report prepared for the West Waterway Operable Unit of the Harbor Island Superfund Site also looked at the potential risk of eating seafood from the Duwamish River. For the highest consumption rate scenario evaluated (reasonable maximum exposure), this report listed the PCB risk in the lower Duwamish River near Kellogg Island to be elevated by two additional cases of cancer per 10,000 people (risk factor $2 X 10^{-4}$) who eat seafood potentially influenced by local bottom sediment (ESG 1999). This report listed the HQ value for PCBs at 14. A water quality report prepared by King County in 1999 (KCDNR 1999) determined a range of "incremental exposure increase values" for people eating Duwamish River seafood and the results included risk values that were either lower, similar, or in one case higher than the maximum consumption value in the 1999 report. The King County risk analysis included returning adult salmon, although the chemical levels in these salmon are not caused by exposure to Duwamish River sediments.

5.2 POTENTIAL FOR CONTAMINANT MIGRATION

The possible mechanisms for contaminant migration include: 1) sediment erosion and subsequent resettling; 2) sediment reworking, including bioturbation; and 3) contaminant repartitioning to the overlying water column. The Duwamish River is generally a region of sedimentation. The mudflat in front of the Duwamish/Diagonal outfalls is considered to be a stable depositional region created by discharged sediments from the outfalls. Estimates of sedimentation rates vary from 0.6 cm/year (EBDRP 1996b) to 5 cm/year (Harper-Owes 1983). However, a sediment transport study performed by the University of Washington estimated erosional velocities in the vicinity of the site of 16 cm/sec and observed tidal velocities of 30 cm/sec (Dail 1996). An erosional velocity of 16 cm/sec would be typical for fine sand on the order of 0.2 mm in diameter, which is typical of the bed material away from the immediate vicinity of the outfalls. The report concluded that sediment erosion and migration should be expected; however, none was observed to occur. Therefore, it is not clear whether significant erosion of the existing contaminated materials near the Duwamish/Diagonal outfalls, or at upstream hot spots, would occur under typical tidal conditions.

As the overlying water becomes cleaner, linear-isotherm partitioning could transfer some of the contaminants from the sediment to the overlying water column. This would reduce sediment concentrations and increase water-column concentrations. Once in the lower water column, which in this location is the salt wedge, there would, on average, be transport upstream. However, because the Study Area is relatively close to the point where the Duwamish River enters Elliott Bay, the tidal flushing to Elliott Bay would be strong during the ebb tide, and overall fluxes to the water column should be quickly mixed below detection levels.

Overall, the potential for significant (sufficient to cause concern) sediment migration is unknown due to uncertainty regarding the erosion potential in the Study Area.

5.3 POTENTIAL FOR NATURAL RECOVERY

The mechanisms for natural recovery include: 1) natural sedimentation and burial; 2) sediment reworking; 3) contaminant repartitioning to the water column; and 4) chemical biodegradation.

Natural sedimentation does occur in the Duwamish River, as the river velocities decrease where the river meets saltwater and the river widens. As noted above, however, actual rates are uncertain, but may be in the range of 0.6 to 5 cm/year. In addition, the potential for sediment erosion is also uncertain.

Some sediment will be reworked by a number of processes including bioturbation and vessel wake turbulence. However, these processes will generally diffuse the contamination vertically through the sediment column and thus will dilute sediment concentrations.

Contaminant repartitioning to the overlying water column could occur if the water column concentrations were less than those estimated from equilibrium partitioning theory. Now that the Duwamish CSO discharges are successfully controlled (none since 1989), we expect to see lower ambient water column concentrations of the COCs. While contaminant concentrations in the sediment are expected to decrease, the rate of recovery is uncertain. The recovery period could be long due to the persistence of some of the COCs. The continuing stormwater discharge of 1,230 MGY plus CSO discharges from the Diagonal Way CSO/SD outfall (exceeding twenty events per year and comprising about 65 MGY) also continue to be potentially significant factors in retarding chances for natural recovery.

Of the COCs identified at the study site, both mercury and PCBs are chemically persistent and will not biodegrade. Bis (2-ethylhexyl) phthalate has been reported to undergo rapid biodegradation under aerobic conditions, but not under anaerobic conditions. Butyl benzyl phthalate can undergo rapid biodegradation under both aerobic and anaerobic conditions.

It is clear that, as contaminated discharges are controlled and contaminant sources are eliminated or reduced, natural recovery mechanisms will be enhanced for some chemicals. However, with the ongoing CSO discharges from the Diagonal Way CSO/SD outfall, it is not possible to accurately predict whether natural recovery will occur or how long successful natural recovery may require. It is likely that, with current conditions, the combined processes would, at best, require a relatively long time (more than 10 years) to meet SQS.

5.4 POTENTIAL FOR SEDIMENT RECONTAMINATION

The two chemical groups of greatest interest for potential recontamination at Duwamish/Diagonal are phthalates and PCBs.

5.4.1 Phthalates

As discussed in **Section 3.4.2**, butyl benzyl phthalate recontamination is indicated, even if discharge from the SDs is completely eliminated. Virtually the same is true for bis (2-ethylhexyl) phthalate, the most abundant phthalate.

The mass balance model (**Appendix I**) predicted that two phthalates (benzyl butyl phthalate and bis (2-ethylhexyl) phthalate) would accumulate on the cap to levels that exceed the SQS. The model indicated that about 87 percent of the discharge source would need to be eliminated to maintain sediment concentrations below the SQS. This result suggested that the background levels in the surrounding river sediment are high enough that it would not take much additional input from a stormwater or CSO discharge to exceed the SQS at this location. Despite the potential recontamination by phthalates, **Section 5.5** discusses various factors that could justify proceeding ahead with sediment remediation at this site.

5.4.2 PCBs

Current discharges are not a concern for PCB recontamination, but care must be taken to minimize the potential that the existing PCB-contaminated sediment could be disturbed in the future and pose a source of recontamination. The PCBs present in sediments were introduced by historic sources and subsurface sediments typically have higher PCB values than surface sediments. If PCB-contaminated sediments are disturbed, they could be mobilized and then redeposited on a nearby clean sediment remediation site. The degree of recontamination would vary depending on the amount of sediment that is redeposited on the remediation site and the PCB concentrations in the redeposited sediment. An analysis of PCB recontamination and natural recovery is presented in **Section 7.3** and in **Appendix P**.

The greatest threat of PCB recontamination in this section of the river is from potential dredging activities that disturb and mobilize contaminated sediments. To minimize the risk that the Duwamish/Diagonal sediment remediation project could be recontaminated from nearby dredging activities, it is important to identify the location of sediment contamination and the potential dredging projects that could disturb these sediments. There are several potential projects in this area that might release sediments:

1. Maintenance dredging in the navigation channel to remove a 350 meter (1150 feet) long shoal that is developing on the east side of the channel immediately upstream of the Diagonal Way CSO/SD outfall
2. Repair work on the two sewer siphons buried in the river bottom
3. Piling removal activities at the loading dock located offshore from the former Diagonal Avenue Treatment Plant outfall

4. Removal of the localized PCB hot spot located offshore from the former Diagonal Avenue Treatment Plant outfall.

Any dredging activities that cannot be completed in one dredging season would cause additional sediment disturbance in a following year, thus increasing the time during which potential recontamination could occur. Coordination of dredging projects could reduce potential recontamination. Ideally, a comprehensive plan would be developed to coordinate dredging projects and sediment remediation projects to minimize recontamination potential.

A natural recovery/recontamination model for PCBs is described in Section 7.3.

5.5 FINAL FOCUS AREA FOR ALTERNATIVES EVALUATION

Even though modeling results show phthalates will recontaminate the area near the Duwamish/Diagonal outfalls, there are factors that could justify proceeding with a sediment remediation action to remove PCBs. Some of these factors deal with the following issues: 1) the relative toxicity of the PCBs and phthalates to human health and biota; 2) the relative difficulty of achieving adequate phthalate source control to prevent recontamination; and 3) the relative size of potential phthalate recontamination compared to the total size of the PCB cleanup area.

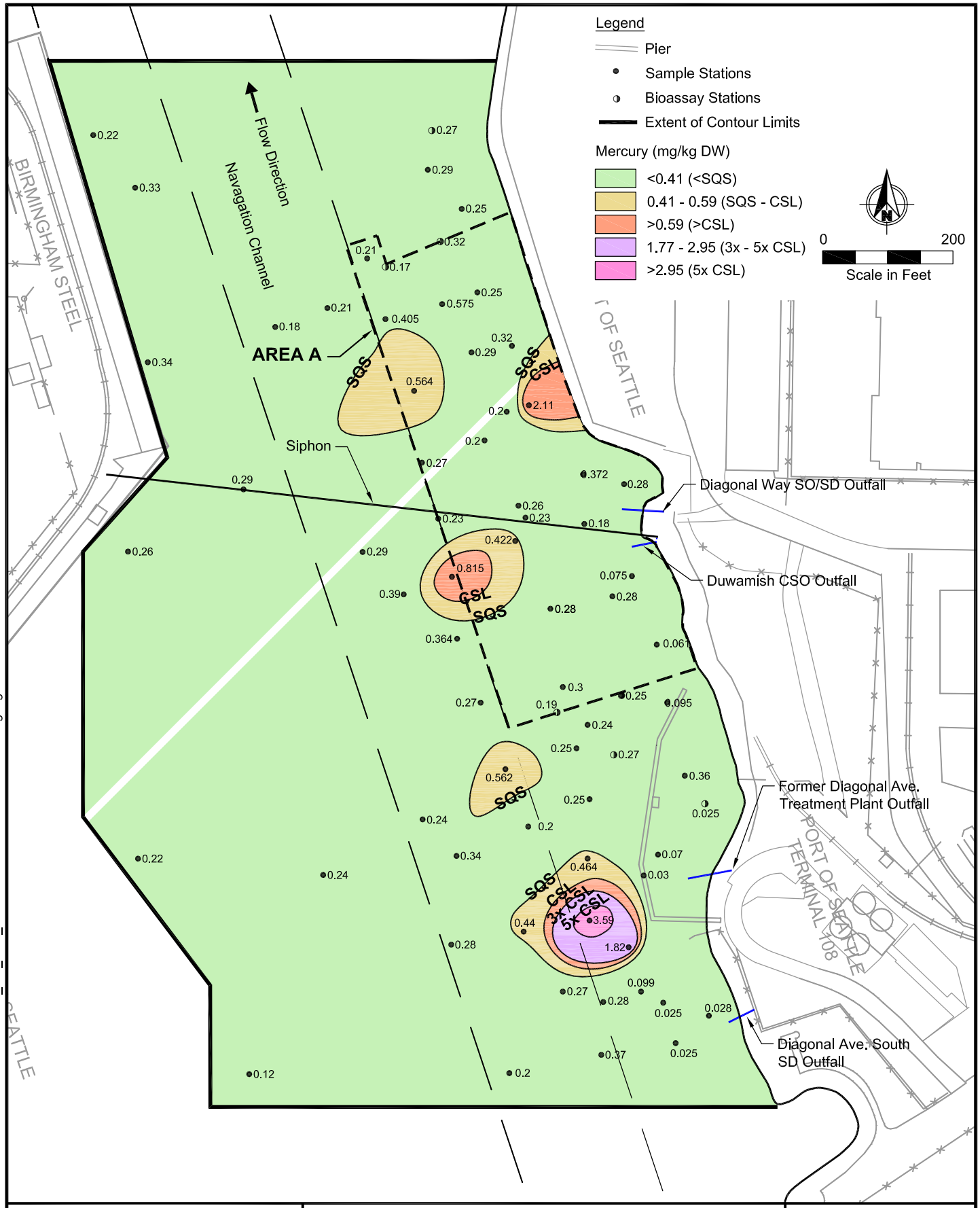
PCBs are chlorinated bioaccumulative chemicals that have been banned from production because they are toxic and persistent in the environment. PCBs represent both a human health and ecological risk and are a major chemical of concern for the Duwamish River sediment. Fish living in the Duwamish River have tissue concentrations of PCBs that represent an increased cancer risk of two cases in 10,000 people that consume this seafood at the highest consumption rate evaluated (ESG 1999).

The toxicity of phthalates does not appear to be as great as suggested by the SMS criteria values. Several sediment samples from the Duwamish/Diagonal study area were subjected to the three standard SMS bioassay tests. Three stations (DUD201, DUD202, and DUD203) showed no toxicity even though they exceeded the SMS for bis (2-ethylhexyl) phthalate. The highest concentration that showed no effects was at 1.4 times the CSL value. Similar results were found in a sediment dilution study conducted on sediments from the Thea Foss Waterway in Commencement Bay, Washington. The highest concentration of bis (2-ethylhexyl) phthalate that showed no toxicity was 1.7 times the CSL value (45 percent Thea Foss sediment plus 55 percent dilution sediment).

It may be very difficult to achieve phthalate source control in a timely manner, so the pros and cons of waiting or proceeding with a cleanup project must be examined. Phthalates are a common chemical found in stormwater and CSO discharges. Although the concentrations are fairly low, the large stormwater volume of 1,230 MGY results in substantial loading. A review of business activities in the drainage basin indicates there are no major point sources to be controlled. A large outfall like the Diagonal Way CSO/SD would require a very large and expensive treatment plant to remove the suspended particulates that contain phthalates. Sediment remediation projects will be held up a long time if phthalate source control is required in advance.

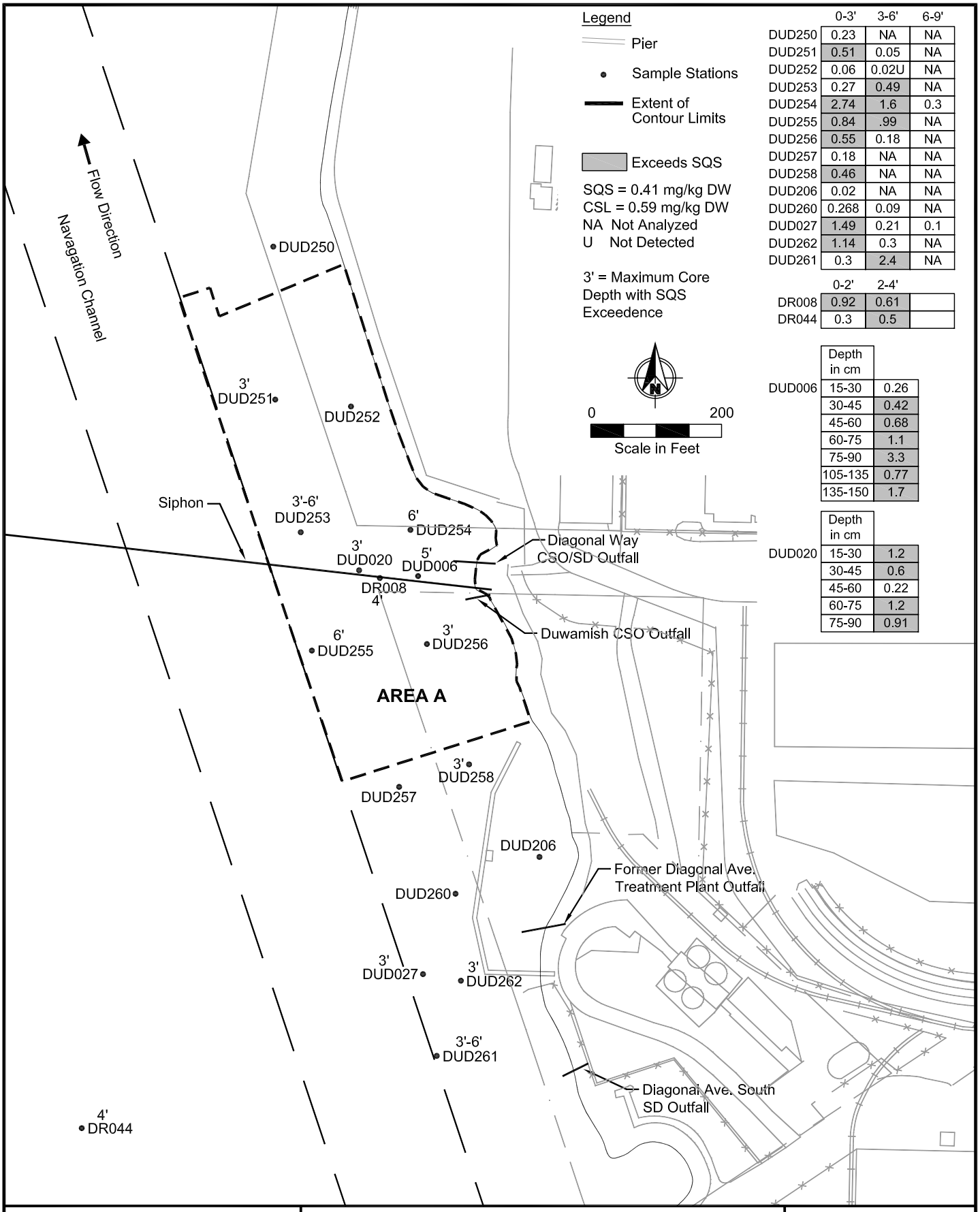
Ecology has the authority to authorize a cleanup action even if some recontamination will occur. As part of the SMS regulations there is a provision for Ecology to authorize a sediment impact zone for sediments that can be justified as not being able to meet sediment standards. There is no set limit for what percentage of the site must remain clean. Under these circumstances, the long-term goal of the SMS regulation is to achieve adequate source control and eventually eliminate the need for a sediment impact zone.

The identification of a localized area of PCB contamination in this section of the river justifies switching to the use of PCBs as the primary COC rather than phthalates. Currently the local regulatory agencies have concerns about whether SQS values are low enough to protect sensitive juvenile salmon or humans from cancer. Even without comprehensive regulations regarding this chemical, the removal of PCB hot spots is a priority for regulatory agencies, the tribes, and project sponsors. The EBDRP Panel has expressed a concern that PCBs pose a greater risk to human health and the environment than do phthalates. Because of this concern about PCBs, it is considered important to move ahead with a sediment remediation action to remove PCBs even if there is a potential for part of the cleanup site to recontaminate with continuing phthalate discharges.



EcoChem Team	Duwamish/Diagonal Sediment Remediation Project	Figure 5-1
	Mercury Concentrations in Surface Sediments	

Sep 28, 2005 3:09pm cdavidson K:\Jobs\020067-KING_CO_SED_MANAG\02006701\02006701-31.dwg Fig 5-1



	0-3'	3-6'	6-9'
DUD250	0.23	NA	NA
DUD251	0.51	0.05	NA
DUD252	0.06	0.02U	NA
DUD253	0.27	0.49	NA
DUD254	2.74	1.6	0.3
DUD255	0.84	.99	NA
DUD256	0.55	0.18	NA
DUD257	0.18	NA	NA
DUD258	0.46	NA	NA
DUD206	0.02	NA	NA
DUD260	0.268	0.09	NA
DUD027	1.49	0.21	0.1
DUD262	1.14	0.3	NA
DUD261	0.3	2.4	NA

	0-2'	2-4'
DR008	0.92	0.61
DR044	0.3	0.5

	Depth in cm	
DUD006	15-30	0.26
	30-45	0.42
	45-60	0.68
	60-75	1.1
	75-90	3.3
	105-135	0.77
	135-150	1.7

	Depth in cm	
DUD020	15-30	1.2
	30-45	0.6
	45-60	0.22
	60-75	1.2
	75-90	0.91

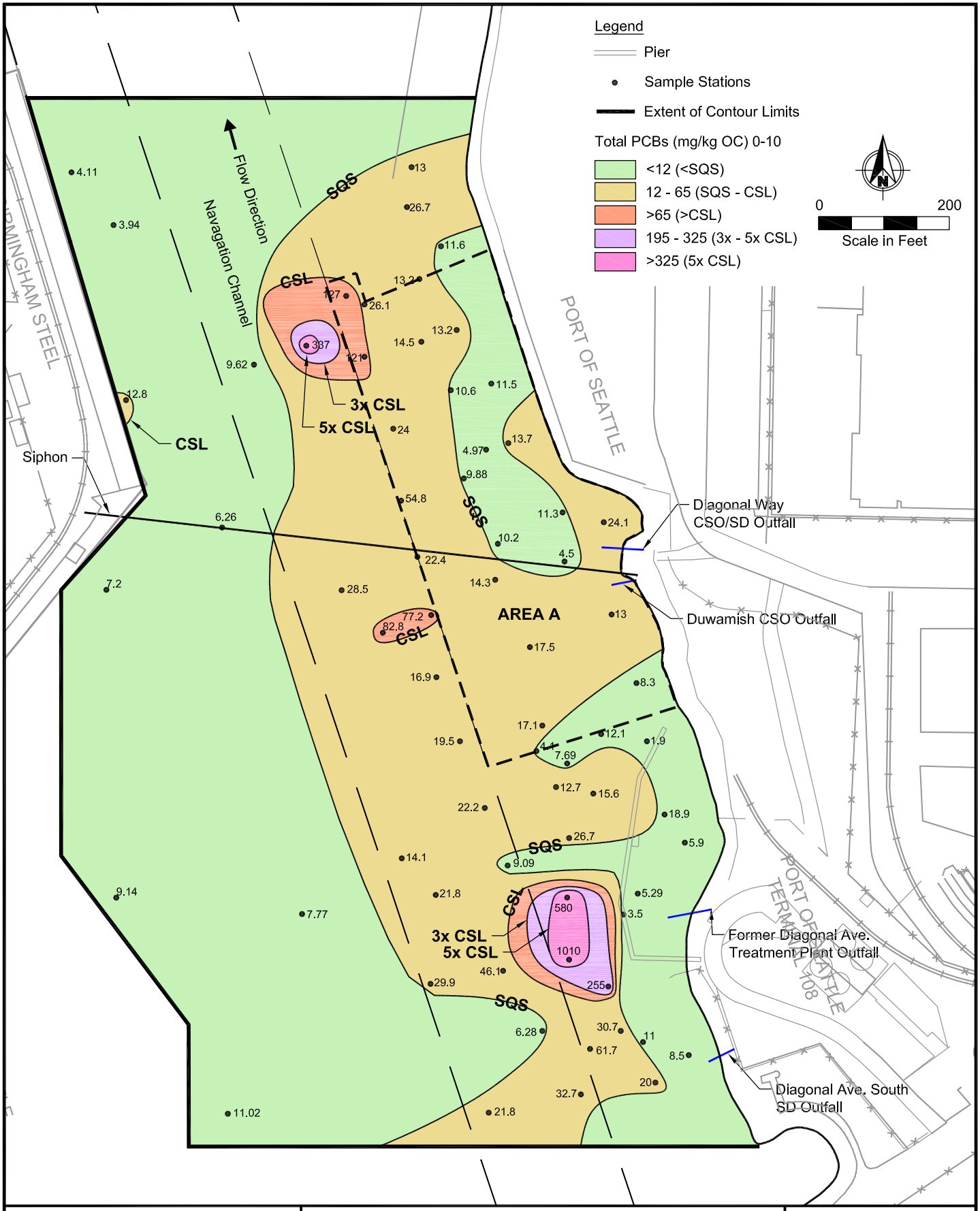
EcoChem Team

Duwamish/Diagonal Sediment Remediation Project

Mercury Concentrations in Subsurface Sediments

Figure 5-2

Sep 28, 2005 3:12pm cdavidson K:\Jobs\020067-KING_CO_SED_MANAG\02006701\02006701-33.dwg Fig 5-2



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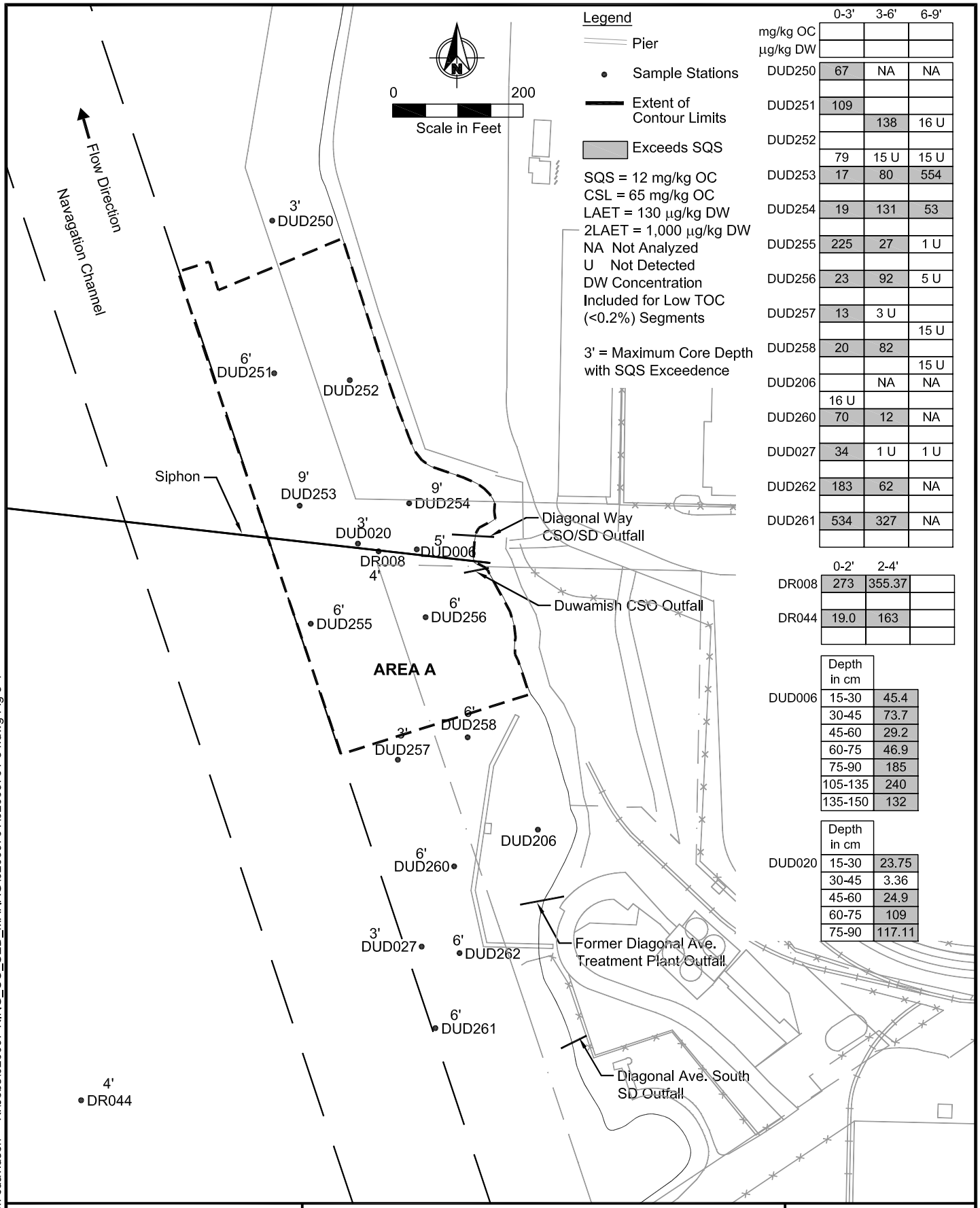
Duwamish/Diagonal Sediment Remediation Project

Total PCBs (mg/kg OC) Contours in Surface Sediments (0-10 cm)

Figure 5-3

Sep 28, 2005 3:13pm cdavidson K:\Jobs\020067-KING_CO_SED_MANAG\02006701\02006701-32.dwg Fig 5-3



	0-3'	3-6'	6-9'
mg/kg OC			
µg/kg DW			
DUD250	67	NA	NA
DUD251	109		
		138	16 U
DUD252			
	79	15 U	15 U
DUD253	17	80	554
DUD254	19	131	53
DUD255	225	27	1 U
DUD256	23	92	5 U
DUD257	13	3 U	
			15 U
DUD258	20	82	
			15 U
DUD206		NA	NA
	16 U		
DUD260	70	12	NA
DUD027	34	1 U	1 U
DUD262	183	62	NA
DUD261	534	327	NA

	0-2'	2-4'	
DR008	273	355.37	
DR044	19.0	163	

	Depth in cm	
DUD006	15-30	45.4
	30-45	73.7
	45-60	29.2
	60-75	46.9
	75-90	185
	105-135	240
	135-150	132

	Depth in cm	
DUD020	15-30	23.75
	30-45	3.36
	45-60	24.9
	60-75	109
	75-90	117.11

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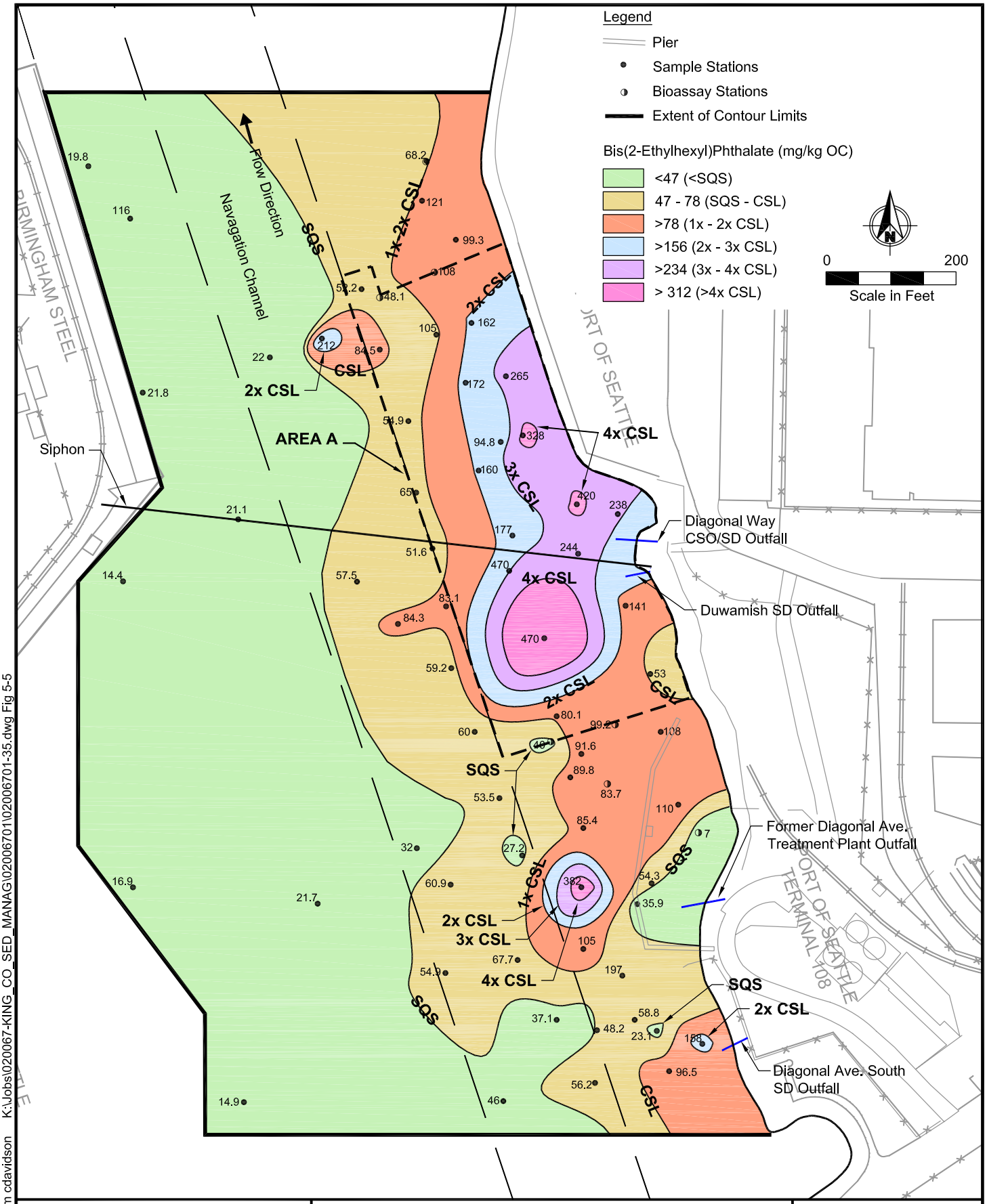
Duwamish/Diagonal Sediment Remediation Project

Total PCBs in Subsurface Sediments

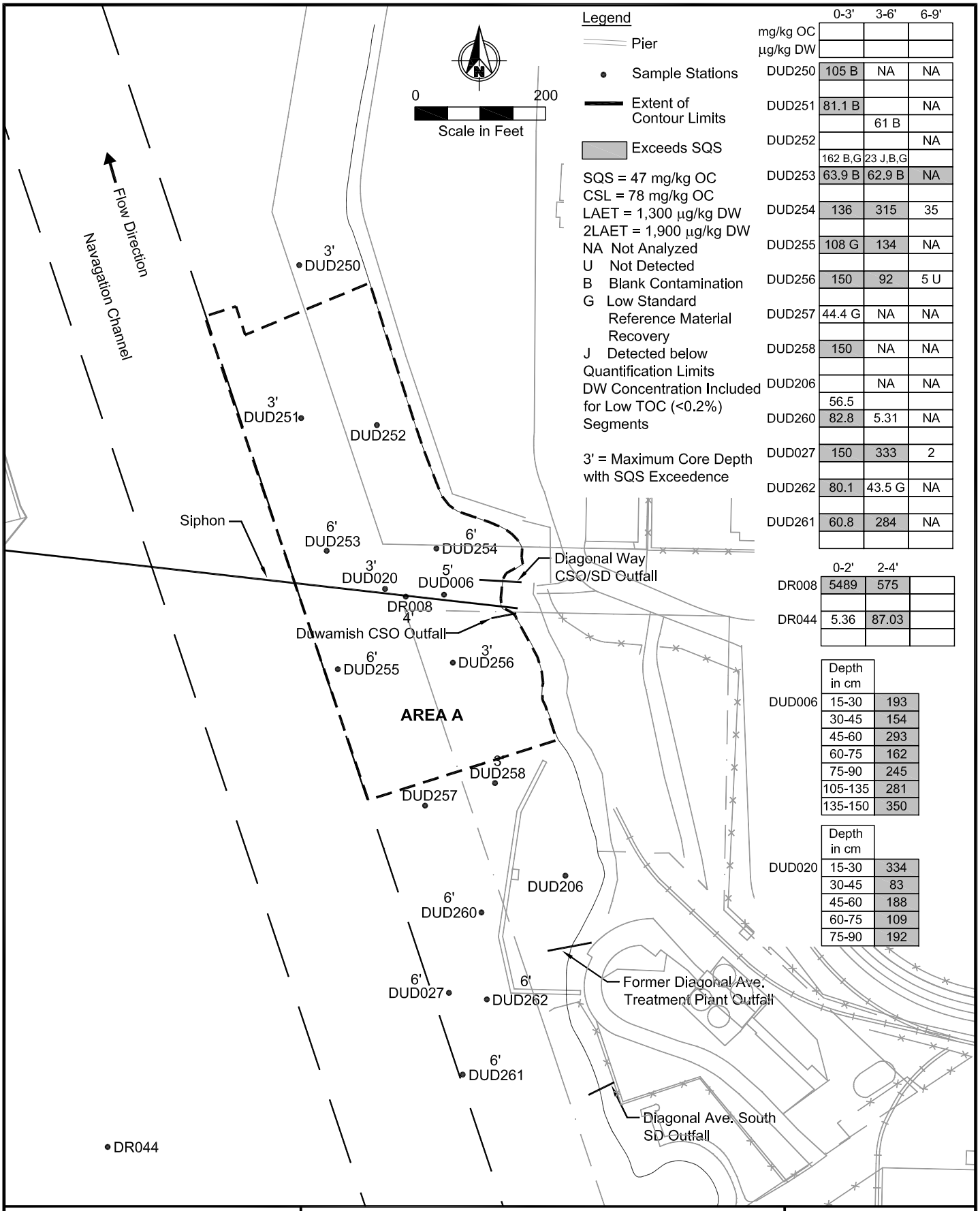
Figure 5-4

Sep 28, 2005 3:14pm cdavidson K:\Jobs\020067-KING_CO_SED_MANAG\02006701\02006701-34.dwg Fig 5-4



Sep 28, 2005 3:15pm cdavidson K:\Jobs\020067-KING_CO_SED_MANAG\02006701\02006701-35.dwg Fig 5-5

EcoChem Team	Duwamish/Diagonal Sediment Remediation Project	Figure 5-5
	Bis(2-ethylhexyl)phthalate Concentrations in Surface Sediments	



	0-3'	3-6'	6-9'
mg/kg OC			
µg/kg DW			
DUD250	105 B	NA	NA
DUD251	81.1 B		NA
		61 B	
DUD252			NA
	162 B,G	23 J,B,G	
DUD253	63.9 B	62.9 B	NA
DUD254	136	315	35
DUD255	108 G	134	NA
DUD256	150	92	5 U
DUD257	44.4 G	NA	NA
DUD258	150	NA	NA
DUD206		NA	NA
	56.5		
DUD260	82.8	5.31	NA
DUD027	150	333	2
DUD262	80.1	43.5 G	NA
DUD261	60.8	284	NA

	0-2'	2-4'	
DR008	5489	575	
DR044	5.36	87.03	

	Depth in cm	
DUD006	15-30	193
	30-45	154
	45-60	293
	60-75	162
	75-90	245
	105-135	281
	135-150	350

	Depth in cm	
DUD020	15-30	334
	30-45	83
	45-60	188
	60-75	109
	75-90	192

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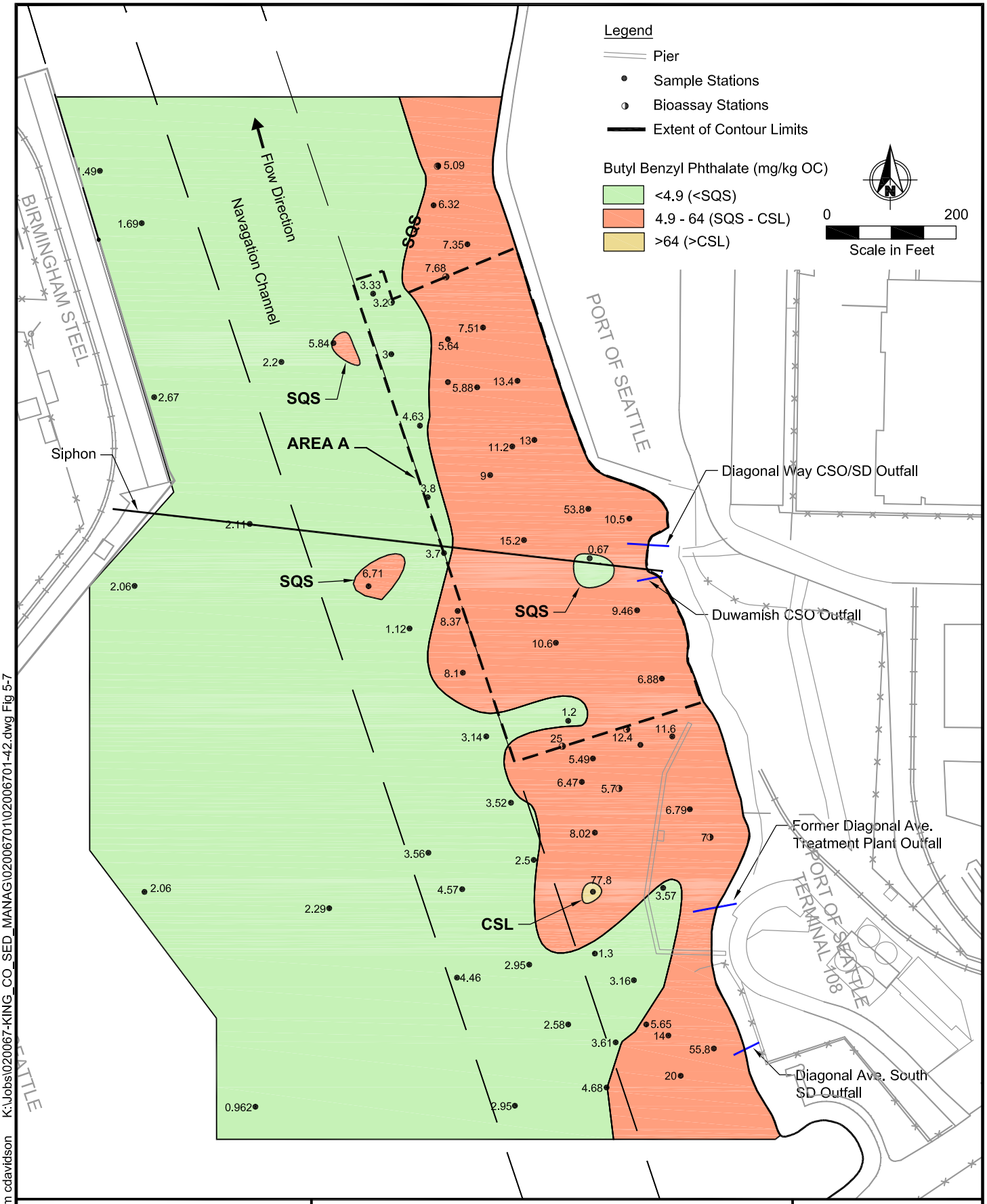
Duwamish/Diagonal Sediment Remediation Project

Bis(2-Ethylhexyl)Phthalate in Subsurface Sediments

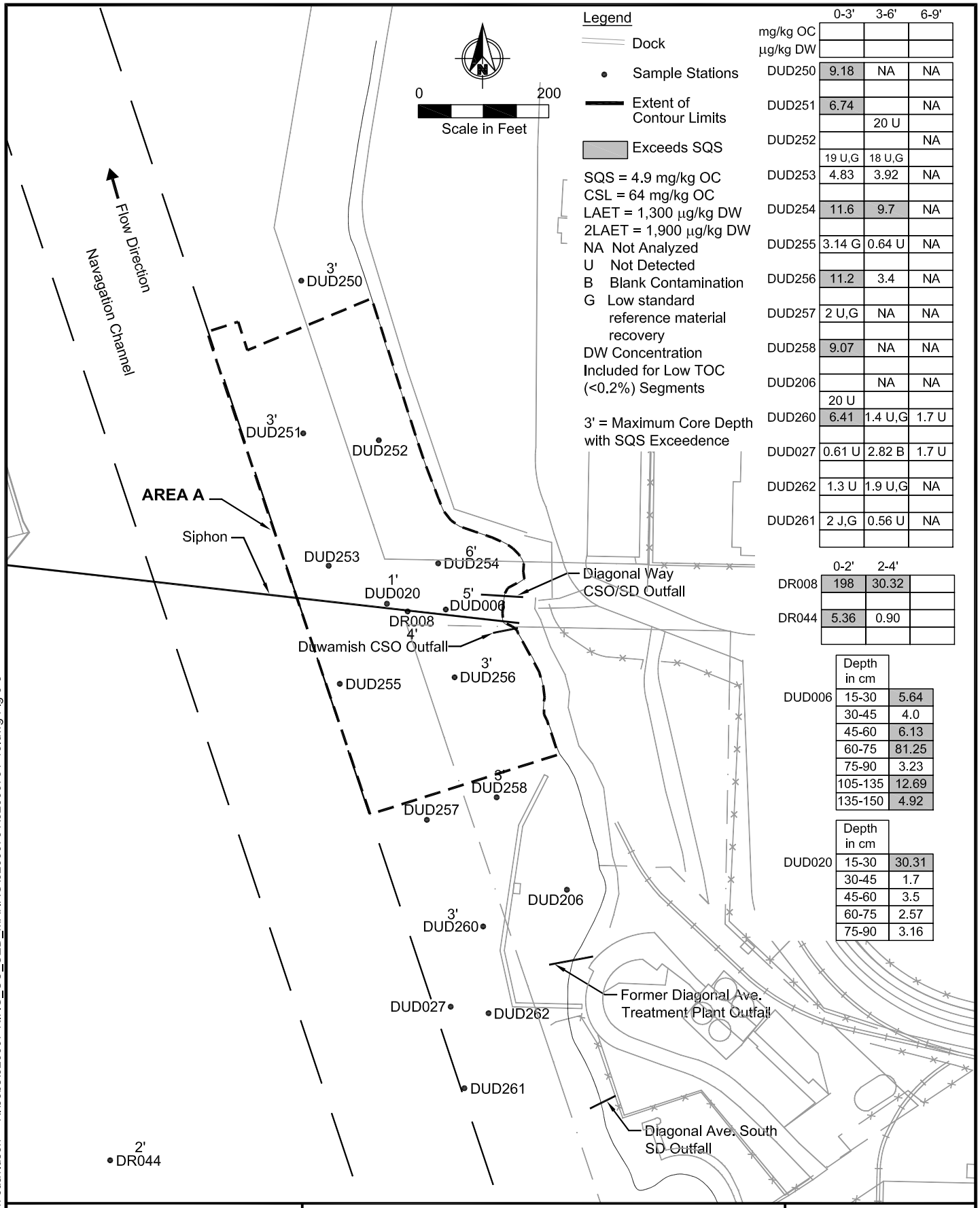
Figure 5-6

Sep 28, 2005 3:16pm cdavidson K:\Jobs\020067-KING_CO_SED_MANAG\02006701\02006701-36.dwg Fig 5-6



Sep 28, 2005 3:17pm cdavidson K:\Jobs\020067-KING_CO_SED_MANAG\02006701\02006701-42.dwg Fig 5-7

EcoChem Team	Duwamish/Diagonal Sediment Remediation Project	Figure 5-7
	Butyl Benzyl Phthalate (mg/kg OC) Contours in Surface Sediments (0-10 cm)	



	0-3'	3-6'	6-9'
mg/kg OC			
µg/kg DW			
DUD250	9.18	NA	NA
DUD251	6.74	20 U	NA
DUD252	19 U,G	18 U,G	NA
DUD253	4.83	3.92	NA
DUD254	11.6	9.7	NA
DUD255	3.14 G	0.64 U	NA
DUD256	11.2	3.4	NA
DUD257	2 U,G	NA	NA
DUD258	9.07	NA	NA
DUD206	20 U	NA	NA
DUD260	6.41	1.4 U,G	1.7 U
DUD027	0.61 U	2.82 B	1.7 U
DUD262	1.3 U	1.9 U,G	NA
DUD261	2 J,G	0.56 U	NA

	0-2'	2-4'
DR008	198	30.32
DR044	5.36	0.90

	Depth in cm	
DUD006	15-30	5.64
	30-45	4.0
	45-60	6.13
	60-75	81.25
	75-90	3.23
	105-135	12.69
	135-150	4.92

	Depth in cm	
DUD020	15-30	30.31
	30-45	1.7
	45-60	3.5
	60-75	2.57
	75-90	3.16

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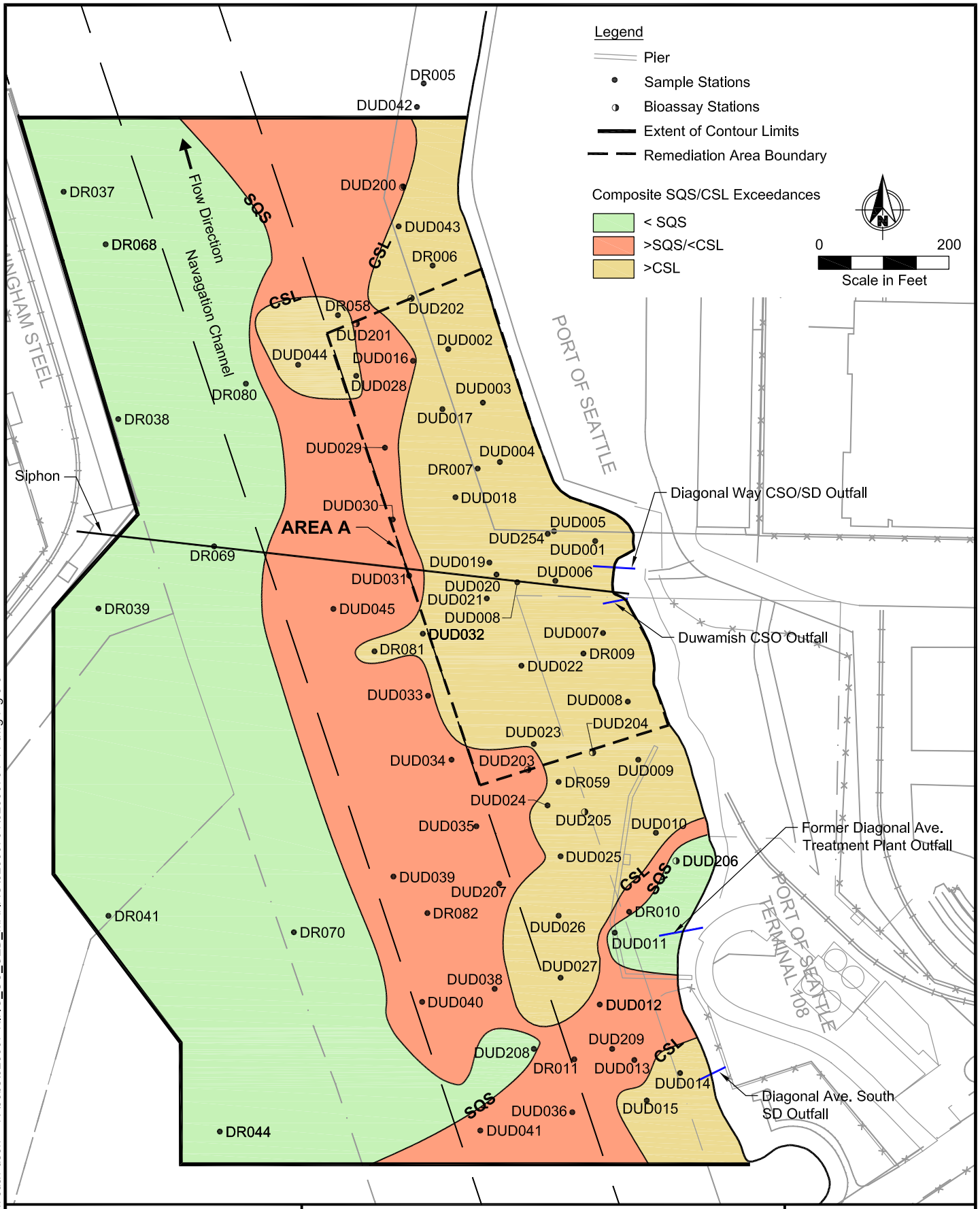
Duwamish/Diagonal Sediment Remediation Project

Butyl Benzyl Phthalate in Subsurface Sediments

Figure 5-8

Sep 28, 2005 3:18pm cdavidson K:\Jobs\020067-KING_CO_SED_MANAG\02006701\02006701-43.dwg Fig 5-8



Sep 28, 2005 3:20pm cdavidson K:\Jobs\020067-KING_CO_SED_MANAG\02006701\02006701-44.dwg Fig 5-9

EcoChem Team	Duwamish/Diagonal Sediment Remediation Project	Figure 5-9
	Composite SQS/CSL Exceedance Areas	

6 APPLICABLE LAWS AND REGULATIONS

6.1 IDENTIFICATION OF APPLICABLE LAWS AND REGULATIONS

This chapter presents a review of applicable laws and regulations that may govern cleanup at the Duwamish/Diagonal site, and the cleanup standards which will likely be applied to site sediments under such laws and regulations. Many federal, state, and local laws, regulations, and ordinances may affect the Duwamish/Diagonal sediment remediation project. Some of these programs directly address the management of contaminated materials, dredged material, or sediments. Other programs may impose requirements that affect the manner in which the sediment cleanup will be implemented.

The applicability of individual laws and regulations to a given cleanup action depends on a range of factors including site characteristics and location, the remedial actions selected, the substances present at the site and the exposure pathways by which contaminants at the site may become a risk to human health or the environment. A brief review of potentially applicable laws and regulations that may pertain to the Duwamish/Diagonal cleanup action is presented below.

6.1.1 Federal Laws and Regulations

6.1.1.1 Comprehensive Environmental Response, Compensation and Liability Act, 42 USC 9601 and National Oil and Hazardous Substances Pollution Contingency Plan, 40 Code of Federal Regulations (CFR) 300

The Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA), also known as Superfund, and the National Oil and Hazardous Substances Pollution Contingency Plan provide the national policy and procedures to identify and clean up contaminated sites on the National Priority List (NPL). The Duwamish/Diagonal site is part of the Lower Duwamish Waterway, which was placed on the NPL on September 13, 2001, pursuant to Section 105. Consistent with this Administrative Order, a remedial investigation of the Lower Duwamish Waterway is currently underway under EPA and Ecology oversight.

The Duwamish/Diagonal project was underway before the Lower Duwamish NPL listing and has proceeded under the SMS cleanup project process with Ecology as the lead regulatory agency. Ecology may be the lead regulatory agency of a sediment cleanup project located in the Lower Duwamish Superfund area, and Ecology may administer the project under SMS or MTCA. Now that the river has been listed, there is interest by EPA in ensuring that the Duwamish/Diagonal project is CERCLA-equivalent so that the site does not have to be revisited when EPA develops a final Superfund remedy for the entire Lower Duwamish. Both Ecology and EPA consider the Duwamish/Diagonal project to be a partial cleanup action that can proceed before a final cleanup decision is made for this part of the river.

6.1.1.2 Consent Decree No. C90-395 WD, U.S. District Court, Western District of Washington

CERCLA also provides for natural resource trustees to assess and seek compensation for damages to natural resources resulting from releases of hazardous materials (42 USC 9607). Under its authority as a natural resource trustee provided by CERCLA, the National Oceanic and Atmospheric Administration (NOAA) sued the City and Metro (now KCDNR) on March 19,

1990 to recover damages caused by the releases of hazardous substances discharged from their CSOs and SDs located in the Duwamish River and Elliott Bay (EBDRP 1994a). Joining in this suit were other natural resource damage assessment (NRDA) trustees including the USFWS, Ecology, Muckleshoot Indian Tribe, and the Suquamish Indian Tribe. A Consent Decree (Consent Decree 1991) was signed to settle the lawsuit, which required the City and Metro to expend a total of $24 million for source control, remediation, and habitat restoration activities to mitigate the alleged damages. This remediation at the Duwamish/Diagonal site is being performed under the authority of the Consent Decree.

6.1.1.3 National Environmental Policy Act 42 USC, 4321 et seq. and 40 CFR 1500 et seq.

The National Environmental Policy Act (NEPA) was enacted in 1969 to establish a national policy for the protection of the environment. The Council of Environmental Quality (CEQ) was established to advise the President and to carry out certain other responsibilities relating to implementation of NEPA by federal agencies. Pursuant to Presidential Executive Order, federal agencies are obligated to comply with NEPA regulations adopted by the CEQ (40 CFR Parts 1500-1508). These regulations outline the responsibilities of federal agencies under NEPA and provide specific procedures for preparing environmental documentation to comply with NEPA.

NOAA, as the lead federal agency for the NEPA process related to the Duwamish/Diagonal cleanup action, will prepare an Environmental Assessment (EA) for the action and will publish it in the Federal Register.

6.1.1.4 Resource Conservation and Recovery Act, 42 USC 6901 and 40 CFR 260 et seq.

The Resource Conservation and Recovery Act (RCRA) was enacted to regulate the management of hazardous waste, to ensure the safe treatment, storage, and disposal of wastes, and to provide for resource recovery from the environment by controlling hazardous wastes "from cradle to grave." Because the state has been authorized to implement both Subtitles C and D of RCRA, the only regulations under the federal program would be those developed under the Hazardous and Solid Waste Act amendments for which EPA has not delegated regulatory authority to the state (e.g., land disposal restrictions). RCRA Subtitles C and D and 40 CFR 268 are applicable for upland disposal options of dredged sediments.

6.1.1.5 Clean Water Act, 33 USC 1251 et seq. and Federally Promulgated Water Quality Standards, 40 CFR 131

The Clean Water Act (CWA) requires the establishment of guidelines and standards to control the direct or indirect discharge of pollutants to waters of the United States. Effluent limitations developed for the regulated pollutants are applied to point source discharges on a case-by-case basis.

Section 304 of the CWA (33 USC 1314) requires EPA to publish Water Quality Criteria, which are developed for the protection of human health and aquatic life. These water quality criteria are promulgated in 40 CFR 131, which is also referred to as the National Toxics Rule. Federal water quality criteria are used by states to set water quality standards for surface water.

Discharges of material into navigable waters are regulated under Sections 401 and 404 of the CWA (33 USC 1341 and 1344), 40 CFR 230 (Section 404(b)(1) guidelines), 33 CFR 320 (general policies), 323 and 325 (permit requirements), and 328 (definition of waters of the

United States). These requirements regulate the discharge of dredge or fill material to navigable waters of the United States. The USACE normally has the primary responsibility for administering the Section 404 permit program, which would potentially cover Duwamish/Diagonal cleanup actions.

USACE permits are needed for the discharge of dredged or fill material into waters of the United States. There are general permits, which include permits issued by district or divisional engineers on a regional basis, and nationwide permits, which are issued by the Chief of Engineers. If a general permit does not cover the activity, an individual permit application must be filed. The Secretary of the Army acting through the Chief of Engineers authorizes the permit. Several policies are applicable to the review of permit applications which include: public interest review; effect on wetlands; fish and wildlife; water quality; historic, cultural, scenic and recreational values; effects on limits of the territorial sea; consideration of property ownership; other federal, state, or local requirements; safety impoundment and structures; water resource values; water supply and conservation; navigation; and mitigation. The public interest review involves the evaluation of probable impacts, including cumulative impacts, of the proposed activity and its intended use of the public interest. In turn, this evaluation is based on balancing the benefits of the proposal against its reasonably foreseeable detriments. The criteria used for this evaluation are outlined in 40 CFR 320.4.

For cleanup actions overseen by EPA and/or Ecology under applicable federal or state cleanup laws, the USACE has issued a Nationwide 38 permit that covers Section 404 requirements. However, Section 401 requires state water quality certification before 404 permits can be issued. This allows states to ensure that the action will be consistent with state and local water quality laws, and may lead to conditions placed on the 404 permit. In addition, issuance of a USACE permit also requires ESA consultation (**Section 6.1.1.8**) and consideration of Tribal Treaties (**Section 6.1.4**).

6.1.1.6 Rivers and Harbors Act, 33 USC 403 and 40 CFR 320, 323

The Rivers and Harbors Act prohibits unauthorized activities that obstruct or alter a navigable waterway. In particular, Section 10 of the Act applies to any dredging and/or disposal activity in navigable waters of the United States, including the Duwamish River. The Rivers and Harbors Act is potentially applicable to Duwamish/Diagonal cleanup actions.

6.1.1.7 Toxic Substances Control Act, 15 USC 2600 et seq. and 40 CFR 760 et seq.

The TSCA authorizes the EPA to establish regulations pertaining to the control of chemical substances or mixtures that pose imminent hazards. EPA has published regulations pertaining to, among other chemicals, PCBs. 40 CFR 761 Subpart D regulates the storage and disposal of PCBs including soils and sediments excavated from regulated units which have PCB concentrations greater than 50 mg/kg DW. PCB-contaminated materials exceeding these concentrations must be incinerated or disposed of in a qualifying chemical waste landfill. PCB-contaminated liquids may alternatively be disposed of in high efficiency boilers that meet specific criteria. The highest measured PCB value in the Duwamish/Diagonal remediation area was 7.6 mg/kg DW (Station DUD255 core section 0 to 3 feet), which is far below the dangerous waste limit of 50 mg/kg DW. Thus, TSCA will not determine disposal methods for the Duwamish/Diagonal materials.

6.1.1.8 Endangered Species Act of 1973 (16 USC 1531 et seq., 50 CFR Part 200, 402) and the Magnuson-Stevens Act (Public Law 94-265, 16 U.S.C. 1801)

The ESA provides protection for several species found in the vicinity of the project. Chinook salmon migrate through the Duwamish River, and anadromous bull trout are thought to use the river as well. Both of these species are listed as threatened. The river is part of critical habitat as defined for chinook salmon. Coho salmon also migrate through the area, and are a candidate for listing under ESA. Bald eagles, a threatened species, nest about 0.7 miles northwest of the site.

The Magnuson-Stevens Fishery Conservation and Management Act (also known as the Magnuson-Stevens Act) as re-authorized in 1996, mandates that Federal agencies consult with the Secretary of Commerce on all activities or proposed activities, authorized, funded, or undertaken by the agency that may adversely affect Essential Fish Habitat (EFH). EFH is defined as those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity. In addition to ESA consultations required for species listed as threatened or endangered, EFH consultations are required for non-listed, federally managed fishery species, which include Puget Sound coho and pink salmon populations. Pink salmon historically used the Duwamish, but have been extirpated since the mid-1930s (WDF 1975).

6.1.1.9 U.S. Fish and Wildlife Coordination Act (16 USC 661 et seq.) and the Migratory Bird Treaty Act of 1918 (16 USC 703 et seq.)

The U.S. Fish and Wildlife Coordination Act prohibits water pollution with any substance deleterious to fish, plant, or bird life, and requires consultation with the USFWS and appropriate state agencies. Criteria are established regarding site selection, navigational impacts, and habitat remediation, and fill material on aquatic lands must be stabilized to prevent washout.

Migratory birds may occur in the vicinity of the site. The Migratory Bird Treaty Act requires the protection of ecosystems of special importance to migratory birds against detrimental alteration, pollution, and other environmental degradation. These requirements are anticipated to be relevant and applicable to surface or intertidal areas that may be affected by dredging or sediment disposal.

6.1.2 State Laws and Regulations

6.1.2.1 Model Toxics Control Act, Chapter 70.105D RCW and Chapter 173-340 WAC

The statute, Chapter 70.105D Revised Code of Washington (RCW), was created as a result of citizens' initiative Measure No. 97. The MTCA requires Ecology to establish and periodically update minimum cleanup standards for hazardous substances, and to investigate and remediate releases or threatened releases of hazardous substances. The most recent update of the MTCA cleanup standards became effective in August 2001.

The MTCA regulation, Chapter 173-340 WAC, also establishes administrative processes and standards to identify, investigate, and clean up facilities where hazardous substances pose a threat to human health and the environment. MTCA is applicable to the Duwamish/Diagonal cleanup action.

6.1.2.2 Sediment Management Standards, Chapter 173-204 Washington Administrative Code

The SMS (Chapter 173-204 WAC) regulations are promulgated under MTCA, the Water Pollution Control Act (Chapter 90.48 RCW), and the Puget Sound Water Quality Authority Act (Chapter 90.52 RCW) to establish marine, low salinity, and freshwater surface sediment standards for Washington state. To date, only marine sediment standards for Puget Sound have been established. Marine sediments are defined as those sediments in which the interstitial porewater contains 25 ppt salinity or greater. Sediments within the Duwamish/Diagonal site are predominantly marine sediments (Section 1.2).

The SMS relies on chemical and biological criteria to designate sediments. Most of the chemical criteria are derived from the AET method, an empirical method based on Puget Sound chemistry and biological effects data. Chemical criteria are established for a no adverse effect level (SQS) and a minor adverse effect level (CSL/MCUL). The SMS regulations recognize that a cleanup action may not achieve the objective of no adverse effects initially; therefore, minimum cleanup levels were established. These cleanup levels are the maximum allowed chemical concentration and level of biological effects permissible at the site, and often equate to levels that are expected to result in no adverse effects by year 10 after completion of the active cleanup action. The SMS regulations are applicable for determining sediment cleanup standards for the Duwamish/Diagonal site.

6.1.2.3 Shoreline Management Act, Chapter 90.58 RCW and Chapter 173-14 WAC

The regulations in Chapter 173-14 WAC were developed pursuant to Chapter 90.58 RCW to protect shoreline values while still fostering reasonable use. These regulations normally require substantial development permits to be obtained for any project or action which occurs within 200 feet of the ordinary high water mark of marine waters and materially interferes with the normal public use of the water or shorelines of the state. The local government (City of Seattle Department of Construction and Land Use) issues substantial development permits (**Section 6.1.3.1**). Ecology and the Attorney General are normally sent copies of the permit by the local government for review.

As set forth in RCW 70.105D.090, qualifying cleanup actions performed under SMS or MTCA may be issued an exemption from the Shoreline Management Act requirement to obtain a substantial development permit. King County will submit a request to the City of Seattle for a substantial development permit exemption. Based on initial review of the prospective cleanup action described herein, it is not anticipated that remedial activities at the Duwamish/Diagonal site will deviate from the goals of the Shoreline Master Program within the City of Seattle.

6.1.2.4 Puget Sound Estuary Program

PSEP was established in 1987 under the authority of the National Estuary Program, Section 320 of the CWA (33 USC 1330). The National Estuary Program was established to protect estuaries of national significance by requiring a management conference to develop a comprehensive management plan for the estuary. PSEP is jointly managed by EPA, Ecology, and the Puget Sound Water Quality Authority (PSWQA) in cooperation with federally recognized Native American Indian tribes of western Washington. The PSWQA authored the 1991 *Puget Sound Water Quality Management Plan* (PSWQA 1991), which was adopted by EPA as the Puget Sound Comprehensive Conservation and Management Plan. Action plans within the Plan that

are applicable to the Duwamish/Diagonal site include the Contaminated Sediment and Dredging action plan, the Municipal and Industrial Discharges action plan, and the Stormwater and Combined Sewer Overflows action plan. Under Chapter 70.90 RCW, PSWQA, state agencies, and local governments are required to evaluate and incorporate as applicable, subject to the availability of appropriated funds or other funding sources, the provisions of the Plan, including any guidelines, standards, and timetables contained in the Plan. Therefore, the Plan does not have specific regulatory force but must be considered during actions that are covered by the Plan. Thus, the Plan shall be considered as guidance. Under PSEP, Puget Sound protocols were developed to standardize the collection and analysis methods used for chemical and biological testing in Puget Sound. The use of standardized protocols by all agencies, consultants, and investigators continues to increase the usefulness of the information collected by allowing comparisons with other data collected using similar methods. The protocols are updated periodically as advances in technology and changes in needs are identified or warranted.

6.1.2.5 State Environmental Policy Act, Chapter 43.21C RCW and Chapter 197-11 WAC

The State Environmental Policy Act (SEPA), Chapter 43.21C RCW, sets forth the state's policy for protection and preservation of the natural environment. Chapter 197-11 WAC contains the state's rules to implement this act. Local jurisdictions must also implement the policies and procedures of SEPA. King County, the SEPA lead agency, will prepare and issue a SEPA environmental checklist and threshold determination for the Duwamish/Diagonal project in compliance with these procedures. This is necessary prior to the issuance of state and local permits needed to conduct remedial activities at the Duwamish/Diagonal site. Ecology will review King County’s SEPA determination.

6.1.2.6 Historic Preservation Act, Chapter 27.34 RCW, Chapter 27.44 RCW, and Chapter 27.53 RCW

This act prohibits disturbing any Native American grave sites or other historical or prehistorical archeological resources without a permit or supervision from the proper department or tribes. Because the Duwamish/Diagonal site is located in the native bed of the Duwamish River, it is not expected that any historic or prehistoric remains will be encountered. If any article is uncovered, these requirements will apply, and the Suquamish Indian Tribe and the Muckleshoot Indian Tribe, as federally recognized tribes of interest, will be consulted.

6.1.2.7 Washington Dangerous Waste Regulations, Chapter 70.105 RCW and Chapter 173-303 WAC

The regulations found in Chapter 173-303 WAC were developed to implement Chapter 70.105 RCW and are based on the state's authority to administer RCRA. The Dangerous Waste Regulations provide criteria for determining whether solid wastes that are removed during remediation are dangerous or extremely hazardous. These regulations also provide rules that apply to the generators of hazardous substances and the treatment, manifesting, transporting, disposal, and storage of these substances. Removing certain contaminated sediments from the river may constitute generation of such substances. If sufficient quantities of hazardous substances are removed such that the small quantity exemption does not apply, then these regulations will potentially be used for the dredged sediments. However, based on existing site characterization data, RCRA hazardous substances are not expected to be present at the Duwamish/Diagonal site.

6.1.2.8 Washington Hydraulic Code, Chapter 75.20 RCW and Chapter 220-110 WAC

This code establishes requirements for performing work that would use, divert, obstruct, or change the natural flow or bed of any salt or freshwaters and sets forth procedures for obtaining hydraulic project approval (HPA). The Washington State Department of Fish and Wildlife (WDFW) reviews proposed hydraulic projects for approval. Submittal for review includes general plans for the overall project and complete plans and specifications for the proposed construction or work below the old high waterline of state waters and for the proper protection of fish life. If the WDFW believes that the proposed project will either directly or indirectly harm fish life, the project will be denied unless adequate mitigation can be assured by conditioning the approval or modifying the proposal. King County will apply for the WDFW HPA.

6.1.2.9 NPDES Permit Program, 33 USC 1251, 40 CFR 123, Chapter 90.48 RCW and Chapter 173-220 WAC

Section 402 of the CWA (33 USC 1251) requires EPA to issue permits for the discharge of any pollutant to navigable waters. Federal regulations (40 CFR 123) allow qualifying states to issue NPDES permits. Washington's Water Pollution Control Law (Chapter 90.48 RCW) and regulations (Chapter 173-220 WAC) meet the federal requirements for the state to issue NPDES permits. Water from dewatering activities associated with dredged sediments released to the Duwamish River would be regulated under an National Pollutant Discharge Elimination System (NPDES) permit or as part of the overall MTCA action. However, water from such activity could be released to a sanitary sewer, which would not require an NPDES permit but rather approval from KCDNR.

6.1.2.10 Water Quality Standards for the Surface Waters of the State of Washington, Chapter 90.48 RCW and Chapter 173-201A WAC

These regulations establish water quality standards for the surface waters of the state as required by the CWA and the Water Pollution Control Act (Chapter 90.48 RCW). Specific standards apply for many toxic substances. These surface water quality standards will be applied during all remedial activities, as applicable.

The Duwamish River appears on the State’s 303(d) list of impaired water bodies for contamination due to benzoic acid, butyl benzyl phthalate, bis (2-ethylhexyl) phthalate, dibenzo(ah)anthracene, silver, zinc, benzo(ghi)perylene, and mercury. King County will be working with Ecology to assure that the cleanup plans for the Duwamish/Diagonal project are consistent with the State’s SMS. Ecology is expected to develop a Total Maximum Daily Load (TMDL) for the sediment impaired areas in the Duwamish River and will be responsible for communicating TMDL needs associated with this sediment remediation project, and for pursuing source control measures with affected stormwater dischargers.

6.1.2.11 Solid Waste Management Act, Chapter 70.95 RCW and Chapter 173-304 WAC

The Solid Waste Management Act provides the State's policy on landfill and solid waste disposal requirements. The policy places emphasis on Washington's dedication to recycling. This act and implementing regulations will be used when considering upland disposal remediation alternatives. Waste reduction and recycling will be considered wherever appropriate.

6.1.2.12 State Aquatic Lands Management, Chapter 79.90 RCW and Chapter 332-30 WAC

Land use authorizations of state owned aquatic lands are administered by the Washington State Department of Natural Resources (WDNR). These areas include constitutionally established harbors, state tidelands, shorelands and the beds of navigable waters. Issuance of land use authorization for activities on these public lands is based upon evaluation of the proposed use by the departments Aquatic Lands Division. State law Chapter 79.90 RCW empowers WDNR to set the terms and conditions to authorize uses of state owned aquatic lands. All of the WDNR's aquatic land use authorizations are contractual in nature and involve limited conveyances of rights to use state owned aquatic lands. The primary administrative rule on aquatic lands that guides the WDNR is Chapter 332-30 WAC, Aquatic Lands Management, which established performance standards and operational procedures for aquatic lands uses.

6.1.3 Local Laws and Regulations

6.1.3.1 Shoreline Master Program, Title 23.60 Seattle Municipal Code

The Seattle Shoreline Master Program (Title 23.60 Seattle Municipal Code) was created to implement the policies and provisions of the Shoreline Management Act (**Section 6.1.2.3**) and City Council Resolution Numbers 25173 and 27618. The Shoreline Master Program's overall goals are regulating development of shorelines to protect the ecosystem, provide maximum public use, encourage water dependent use, and preserve and increase views and access. The Seattle Shoreline Master Program provides standards for dredging and dredge disposal operations including shoreline fills. The Master Program will be considered in the decision making process during all phases of remediation.

6.1.4 Tribal Treaties

6.1.4.1 Treaty of Point Elliott, 12 Statute 927

The Treaty of Point Elliott was signed with Native American tribes occupying the lands within the Puget Sound Basin lying north of Point Pulley to the Canadian border and from the summit of the Cascade Mountains to the divide between Hood Canal and Puget Sound. The treaty guarantees the right of taking fish at usual and accustomed grounds and stations to all the signatory tribes and other allied and subordinate tribes and bands of Native American Indians. The Duwamish River is a usual and accustomed fishing area. This treaty is applicable, and will be observed to ensure that cleanup activities do not interfere with the rights of the tribes.

6.2 CLEANUP STANDARDS

In the 1991 Consent Decree agreement, the EBDRP Panel was directed to follow the Washington state SMS as a minimum standard to determine the level of sediment cleanup. Therefore, identification of contaminated sediments for the purpose of this report was based on comparison with numeric SMS criteria set forth in Chapter 173-204 WAC. The SMS have established cleanup standards for chemicals in marine sediments, while cleanup standards for low salinity sediments, freshwater sediments, and protection of human health are to be determined on a case-by-case basis. As discussed in Section 4.4.1.3, salinity data for surface sediments ranged from 21 ppt (intertidal sediment) to 27 ppt (deep water sediment). Marine sediments are defined in the SMS as those sediments with porewater concentrations of 25 ppt or greater. Since no standards currently exist for low salinity sediments and many of the site sediments qualify as marine sediments, it is appropriate to use the marine sediment standards in the SMS.

The SMS marine chemical criteria for aquatic life are defined for two effects levels: 1) SQS criteria, which establishes a level that will result in no adverse effects on biological resources; and 2) CSL criteria, which establish minor adverse effects levels and MCULs that may be applicable to certain sites. The site assessment identified four chemicals of concern (i.e., mercury, bis(2-ethylhexyl) phthalate, butyl benzyl phthalate, and PCBs) associated with the Duwamish/Diagonal outfalls, based on comparison to respective SQS and CSL/MCUL criteria. Chemical criteria for these substances are listed in Table 6.1. With the exception of bioaccumulative chemicals such as PCBs, compliance with SMS criteria can be demonstrated through confirmatory biological analyses. Please refer to **Section 5.1** for a more complete discussion of how confirmatory biological analyses were used to delineate the extent of exceedance of SMS criteria.

Table 6.1 POTENTIAL SEDIMENT CLEANUP STANDARDS FOR DUWAMISH/DIAGONAL CHEMICALS OF CONCERN

Chemical of Concern	SQS Criteria	CSL (MCUL) Criteria
Mercury	0.41 mg/kg DW	0.59 mg/kg DW
Bis(2-ethylhexyl) phthalate	47 mg/kg OC	78 mg/kg OC
Butyl benzyl phthalate	4.9 mg/kg OC	64 mg/kg OC
Total PCBs	12 mg/kg OC	65 mg/kg OC

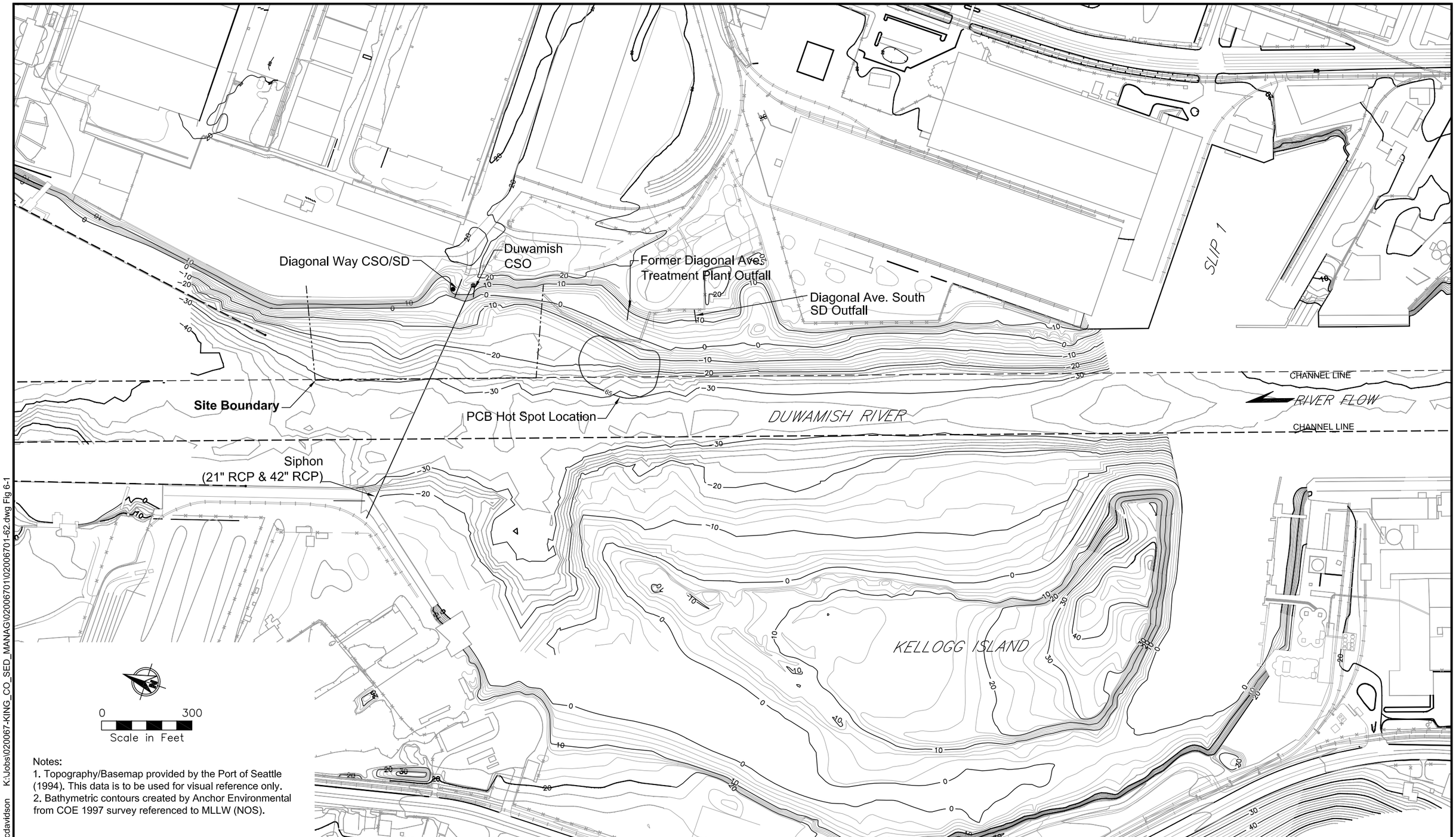
Notes: SQS: Sediment Quality Standard CSL: Cleanup Screening Level MCUL: Minimum Cleanup Level
OC: Organic Carbon DW: Dry weight

Beyond SQS criteria, the Commencement Bay Natural Resource Trustees recognize additional sediment restoration goals for active Natural Resource Restoration projects in Commencement Bay, though similar goals have not been developed for Elliott Bay or the Duwamish River (Trustees 2000). The Commencement Bay restoration goals include numeric criteria for total PAHs (2,000 mg/kg DW), PCBs (200 mg/kg DW), and TBT (6,000 mg/kg OC). These goals are not codified under any statute or regulation, but the Trustees' intent is that they will serve as default goals at restoration projects in Commencement Bay. These restoration goals have also been used at other cleanup sites within the Puget Sound region (e.g., as performance standards for sediment cap material placed at the Cascade Pole site in Olympia). The restoration goals were based on the Trustees' review of available information on contaminant effects and could change as further information is developed. As the Duwamish/Diagonal site is a remediation project in the Duwamish Waterway, these goals are recognized and may be used to develop performance standards for certain cleanup elements (e.g., cap material specification), but otherwise are not directly applicable to this cleanup project.

The proposed cleanup area for the Duwamish/Diagonal site is shown in **Figure 6-1**. **Chapter 5** has a more complete discussion of how the boundaries of this area were determined. The EBDRP is charged with cleaning up areas associated with historical CSO discharges. The cleanup area is proposed by the Panel to remediate past discharges that are associated with the Duwamish and Diagonal EBDRP outfalls.

The proposed cleanup area is approximately 4.8 acres in size and accounts for 1) all of the areas exceeding CSL; 2) a preferred rectangular dredge cut pattern; and 3) setting the offshore (western) boundary to the physical constraints imposed by the navigation channel. The downstream (northern) and upstream (southern) boundaries are set based upon sampling stations that passed SQS or CSL biological criteria (DUD201, DUD202, DUD203, and DUD204). The

nearshore limit is set based upon the physical constraint of the riprap bank. In general, the area extends approximately 800 feet along the east shoreline of the waterway and approximately 250 feet offshore (west) to the closest navigation channel line. Other nearby areas that exceed sediment thresholds will be evaluated through the Lower Duwamish River Superfund cleanup process.



Notes:
1. Topography/Basemap provided by the Port of Seattle (1994). This data is to be used for visual reference only.
2. Bathymetric contours created by Anchor Environmental from COE 1997 survey referenced to MLLW (NOS).

Sep 28, 2005 3:24pm cdavidson K:\Jobs\020067-KING_CO_SED_MANAG\02006701\02006701-62.dwg Fig 6-1

EcoChem Team

Duwamish/Diagonal Sediment Remediation Project

Site Map

Figure 6-1

7 IDENTIFICATION AND SELECTION OF TECHNOLOGIES AND PROCESS OPTIONS

In this Chapter, technologies and process options are identified for evaluation. These options represent the range of known available options capable of achieving remediation of the contaminated sediments at the Duwamish/Diagonal site.

7.1 IDENTIFICATION OF TECHNOLOGIES AND PROCESS OPTIONS

The full range of technology types and process options that potentially can be used for remediation are identified below. Technologies and process options have been compiled based on previous project experience, literature searches, and correspondence with appropriate agencies. The term "technology types" refers to general categories of technology, which for this project include:

- No Action
- Treatment
- Natural Recovery
- In-Water Containment
- Excavation
- Upland Disposal

The term "process options" refers to specific processes within each technology type. For this project, the following process options are identified:

- No Action
- Natural Recovery
- Excavation
    - Mechanical Dredging
    - Hydraulic Dredging
- Treatment
- In-Water Containment
    - In situ Capping
        - Thick Layer
        - Thin Layer
        - Inverted
    - Confined Aquatic Disposal
    - Nearshore Confined Disposal
- Upland Disposal
    - RCRA Subtitle D Landfill
    - Miscellaneous Disposal Locations
    - Construction Backfill

Technology types not identified for evaluation include in situ treatment technologies to achieve solidification, stabilization, and/or treatment. Although conceptually possible, in situ treatment technologies have not yet been adequately demonstrated or implemented to be identified at this time as capable of achieving remediation of the contaminated sediments at the

Duwamish/Diagonal site. Nevertheless, pilot testing of several innovative in situ treatment technologies is currently planned, including testing of in situ Electro Chemical Remediation Technologies at a pilot test site in Bellingham Bay. Based on the results of these and other tests, it is possible that viable in situ technologies may be identified in the future. However, given the present lack of demonstrated performance, in situ technologies were not retained in this report.

7.2 SITE CONSTRAINTS AFFECTING CLEANUP FEASIBILITY

Three aspects of the site have been identified as influencing the feasibility of the cleanup: the long-term stability of the site, as affected by sedimentation and erosion; the known depth of contamination and constraints on excavation; and the potential for recontamination.

7.2.1 Site Sedimentation

Existing sediment grain sizes at the site vary from a relatively high percentage of fines (percent passing No. 200 sieve; silt and clay) within and adjacent to the navigation channel, to a somewhat lower percentage of fines closer to shore. This grain size pattern is consistent with normal tidal fluctuations and with wave and wake forces acting on relatively shallow sediments within the nearshore area (**Section 4.4.1.2**), and with the relatively higher current velocities in the upper water layer that occur during flood flows (Santos and Stoner 1972).

Prior to construction of the Duwamish Waterway in the early 1900s, the Duwamish/Diagonal site was located on an intertidal/shallow subtidal beach area. Dredging of the waterway increased the local water depth in this area.

Review of two condition surveys prior to the construction of the Duwamish Siphon, which occurred from approximately 1965 to 1967 (i.e., 1918 condition survey after initial construction of the Duwamish Waterway and 1931 condition survey), indicated that elevations in the Duwamish/Diagonal cleanup site had not noticeably changed during that timeframe. The 1931 condition survey also shows that elevations inside and for a short distance outside the navigation channel limits were as deep as -57 feet MLLW, with an average elevation of approximately -50 feet MLLW from the East Waterway to approximate Station 49+00 (**Figure 7-1**). Average channel elevations from Station 49+00 to 57+00 (i.e., adjacent to the Duwamish/Diagonal site) were -32 to -37 feet MLLW. In contrast, current mudline elevations in this area are approximately -30 feet MLLW or shallower, indicating that there is a potential for relatively thick historical (i.e., post-1931) sediment deposits and associated contamination within and adjacent to the channel areas.

A 1967 condition survey indicated elevations from -25 feet MLLW to -29 feet MLLW in a small shelf that had originally been at 0 to -3 feet MLLW based on the 1931 survey. The decrease in elevation probably was the result of private or USACE dredging, though records have not been located to confirm this. Construction of the Siphon, discussed in the following section, may also have been the cause for the deeper bathymetry. However, this is considered less likely since construction records do not indicate that material was disposed off site. Rather, the dredged material was likely sidecast and used to backfill the area dredged for the Siphon (personal correspondence with Pat Romberg). Results from the core samples taken during the site

assessment indicate that contamination extends to an approximate elevation of -30 feet MLLW near the navigation channel, and deeper in the areas potentially affected by Siphon construction.

Comparison of the navigation channel elevations between the 1967 condition survey and the 1931 survey, indicate that significant infill occurred from the East Waterway to approximately Station 49+00. During that period, the average elevation changed from approximately -50 feet MLLW to less than -40 feet MLLW. Elevations in the navigation channel from Stations 49+00 to 57+00 do not appear to have changed significantly.

For areas of common survey coverage, no significant changes in bathymetry appear to have occurred between the 1967 USACE survey and the 1994 David Evans and Associates (DEA) survey. However, a comparison of the 1994 DEA survey and the May 1997 Condition Survey performed by the USACE shows a generalized 1-foot deposition during this 3-year period (corrected for datum differences; personal correspondence with Alex Sumeri of USACE).

USACE dredging records indicate that very little maintenance dredging activity has been required for the navigation channel adjacent to the Duwamish/Diagonal site. The last recorded maintenance activity in the Duwamish/Diagonal area occurred in 1968 (approximate Stations 51+00 to 60+00) and removed approximately 7,000 cy of sediment (Appendix A of Duwamish/Diagonal Cleanup Study Workplan; EBDRP 1994b). Personal communication with the USACE indicated that there has also been some maintenance dredging in the vicinity of the Duwamish/Diagonal site in approximately 1984 with 2,000 cy to 3,000 cy of material dredged. From the 1997 USACE survey, it appears that a recent shoal has developed along the east limit of the navigation channel at the Duwamish/Diagonal site, though it is not clear whether this was caused by deposition or slope sloughing.

All information considered, the Duwamish/Diagonal site appears to be in a historical net sediment accumulation area, and there is evidence that net accumulation is still occurring, though likely at a lower rate compared with the historical record. A recent University of Washington study (Dail 1996) at the Duwamish/Diagonal cleanup site (approximate Duwamish River Stations 49+00 to 57+00) proved inconclusive as to whether the site is erosional or depositional. Similarly, a sediment trend analysis performed by GeoSea Consulting (1994) suggested that sediments in the Duwamish/Diagonal area are now in a dynamic equilibrium, characterized by variable deposition and erosion periods. The net transport of resuspended bed sediments through the Waterway appears to be oriented to the south, towards the turning basins, consistent with current observations reported by Santos and Stoner (1972).

7.2.2 Depth of Contamination

USACE post-dredge surveys from 1918 through 1997 were used to determine the deepest historical depths in the area. Surveys from 1918, 1925-1928, 1932, 1943, 1950, 1955, 1956, 1958, 1959, 1961, 1963, 1968, 1970, 1977, 1978, 1983, 1984, 1985, and 1997 were compared, and the deepest soundings in the areas under consideration for remediation were compiled into one map (**Figure 7-2**). Sediments below these depths were considered native sediments, and therefore have a limited potential to be contaminated.

Data from chemical analysis of sediment cores were compiled to determine the depth of contamination (relative to SQS criteria) in sediments deposited over time. Core data from the two phases of the Duwamish/Diagonal Cleanup study and from the EPA's Site Inspection Report for the Lower Duwamish were examined (**Chapter 4**). Not all the core analyses captured the depth of contamination, however.

Based on information gathered to date, it appears that the deepest sediment contamination at the Duwamish/Diagonal site is found in the area where the sewer Siphon crosses the Duwamish Waterway. Cores outside of the area potentially influenced by the Siphon construction indicate the bottom of contamination at approximately -30 feet MLLW while cores within the Siphon influenced area indicate contamination depths greater than -30 feet MLLW.

Metro constructed the sewer Siphon across the Duwamish Waterway between 1965 and 1967. This Siphon crosses the river generally east to west and passes through the cleanup site. According to a May 1967 as-built drawing included in the Duwamish/Diagonal Cleanup Study Workplan (EBDRP 1994b), the Siphon crosses the Duwamish Waterway at a slight angle relative to the navigation channel. The maximum depth of the invert of this Siphon was constructed at an elevation of -50 feet MLLW. There are two pipes that cross, one with a 21-inch diameter and the second pipe with a 42-inch diameter. The approximate top elevation of the Siphon is thus located at elevation -46.5 feet MLLW. Since the navigation channel has an authorized depth of -30 feet MLLW, there is approximately 16.5 feet of clearance from the top of the Siphon to the bottom of the navigation channel. The invert elevation of the Siphon at various points along its alignment are shown in Table 7.1.

Table 7.1 ELEVATIONS OF DUWAMISH SIPHON AT KEY LOCATIONS

Location	Distance along alignment	Invert Elevation (MLLW)
East end of Siphon	Station 0+13	-3.6
East channel R/W Line	Station 1+80	-50.0
East side of navigation channel	Station 3+45	-50.0
West side of navigation channel	Station 5+65	-50.0
West channel R/W Line	Station 7+32	-50.0
West end of Siphon	Station 8+52	-5.5

The Siphon remains at an invert elevation of -50 feet MLLW for approximately 165 feet on either side of the navigation channel along its alignment. This is approximately halfway between the navigational channel to the eastern shoreline. Bottom sediment (mudline) elevations vary from -34 feet MLLW to -14 feet MLLW over this length and decrease to approximately -4 feet MLLW at the east end of the Siphon, according to the 1997 USACE bathymetry survey of the area.

As-built drawings are not available regarding the post-Siphon construction side slopes. It appears that the trench was laid back at an approximate 3H:1V slope, which is typical for construction of this type. Allowing for an 11-foot wide trench, the width of disturbed sediment during the construction of the Siphon would vary from approximately 110 to 200 feet wide between Station 3+45 and Station 1+80 and from 200 feet to 20 feet wide between Station 1+80 and Station 0+13 (**Figure 7-3**). This assumes that the bathymetry depicted in the 1997 USACE survey existed at the time of construction.

As discussed above, it is likely that the material dredged for the Siphon trench was sidecast along the alignment and later backfilled after construction (personal correspondence with Pat Romberg, KCDNR). This would account for the contaminant detections at depths greater than would be expected based on private dredging or USACE maintenance dredging activity, especially at Station DUD253. The depth of contamination near the Siphon makes the option of dredging all of the contaminated material infeasible due to the need to dredge below the invert elevation of the Siphon. Removal of sediment to near the top of the Siphon would run the risk of damaging the Siphon. Further, surveys of the exact location of the Siphon would likely be required prior to performing remedial design.

7.2.3 Recontamination

As described in **Section 5.4**, the two chemical groups of greatest interest for potential recontamination at Duwamish/Diagonal are phthalates and PCBs. As discussed in **Section 3.4.2**, butyl benzyl phthalate and bis(2-ethylhexyl) phthalate recontamination are expected, even after source control. The discussions showed the source of bis (2-ethylhexyl) phthalate was from both the discharge and surrounding sediment, while the source of PCBs was limited to surrounding sediment. When additional factors were considered, it was determined that the removal of PCBs from the cleanup site provided a large enough environmental benefit to outweigh the concern about recontamination of the site by bis(2-ethylhexyl) phthalate.

Reduction of PCB concentrations is a recognized goal for the Duwamish River; therefore, an additional evaluation was performed to determine the amount of PCB recontamination that would occur at the cleanup site from an upstream PCB hot spot, which will need to be removed in the future. For the purposes of this report, and to support planning-level evaluations of possible sequencing of cleanup actions at the upstream PCB hot spot, a screening-level, semi-quantitative PCB recontamination analysis was performed utilizing existing USACE models and available data. This analysis of PCB recontamination and natural recovery is described in the following section.

7.3 NATURAL RECOVERY AND RECONTAMINATION MODELING

Sediment recovery and recontamination of the Duwamish/Diagonal site was modeled under a range of possible scenarios:

1. No action
2. Site remediated, no action in adjacent, prospective PCB cleanup areas
3. Site remediated, adjacent, prospective PCB cleanup areas remediated two years later
4. Site remediated, adjacent, prospective PCB cleanup areas remediated five years later

A screening-level, semi-qualitative analysis utilizing existing models, site data, and conservative assumptions regarding river hydrodynamics, sedimentation/settling rates, contaminant concentrations, and potential dredging actions was performed to determine the degree to which natural recovery and/or recontamination by adjacent sites could occur.

7.3.1 Screening-Level Recontamination/Recovery Model for PCBs

Natural recovery was defined for the purpose of this report as the improvement of sediment quality over time with or without active remediation of the sediments, and following the implementation of upland source controls. Recontamination was defined as the deterioration of sediment quality following completion of a cleanup action, and may occur in those situations where contaminated sediments remain at locations proximal to the site. The recovery or recontamination period (depending on the scenario evaluated) begins after sediment remedial actions are completed.

The natural recovery/recontamination model used for the Duwamish/Diagonal evaluation is the diagenetic model written by Dr. Bernard Boudreau of Dalhousie University (Boudreau 1997). Among other attributes, such as its relatively simple computational structure, the Boudreau model allows the user to represent important sediment bioturbation and resultant mixing of surface sediments with a Gaussian distribution (i.e., more mixing occurs at the surface than at the bottom of the representative surface mixed layer). More active mixing occurs at the surface and the amount of mixing decreases progressively with depth. Relative to other available recovery/recontamination models (e.g., SEDCAM), this depth-varying model for mixing is more representative of actual mixing characteristics generated by biological activity. This model has been used in other natural recovery evaluations in Puget Sound estuarine sites (Hylebos Cleanup Committee 1999; Anchor and Foster Wheeler 2001). The Boudreau numerical model is written in FORTRAN and uses a variable coefficient ordinary differential equation solver that is part of the ODEPACK algorithms (Hindmarsh 1983).

7.3.1.1 Advection, Diffusion, and Bioturbation of Sediment

The list of potentially relevant processes that control mixing in the sediment surface generally includes the following:

- Burrowing of organisms
- Sedimentation
- Incoming concentrations
- Lateral movement of sediment
- Resuspension
- Organic biodegradation or decay

All of these processes have been determined to be quantitatively important in modeling sediment mixing and natural recovery. For this evaluation, all of the above-listed mechanisms have been included in the model, though the magnitude of certain processes such as biodegradation were conservatively set equal to zero in this application (**Appendix P**). Lateral movement and resuspension have been included and integrated into the net sedimentation rate term applied in the model. To evaluate the potential for natural recovery and recontamination, key model input parameters were obtained from data collected at the Duwamish/Diagonal site and from similar studies in other Puget Sound estuarine waterways.

A detailed description of the Boudreau (1997) model and parameter derivation used in this application is presented in **Appendix P**.

7.3.1.2 Natural Recovery/Recontamination Model Results for PCBs

Figures 7-4, **7-5**, and **7-6** summarize the results of the screening-level natural recovery/recontamination modeling. **Figure 7-5** shows the area away from the outfalls and **Figure 7-6** shows the area near the outfalls, presented as projected surface sediment PCB concentrations at the site over 10 years given different modeling scenarios. Two separate figures were used to summarize the modeling results because different factors affect the inshore and offshore parts of the site. Natural recovery rates for PCBs are expected to be faster in the inshore area due to low PCB sediments discharged out the Diagonal Way CSO/SD outfall.

In **Figure 7-5**, natural recovery is shown as the "no action" line, indicated by triangles. No action starts at a concentration of 30 mg/kg OC and drops to a value of 28 mg/kg OC after 10 years. If the site is remediated, the area away from the outfalls will gradually recontaminate to 23 mg/kg OC after 10 years (indicated by the line with Xs), unless the hot spot is also remediated. If the hot spot is removed 2 years after the site cleanup (squares in the upper graph), the area away from the outfalls spikes up to 34 mg/kg and settles down to 14mg/kg OC 10 years after Duwamish/Diagonal remediation. If the hot spot is removed 5 years after the site cleanup (squares in the lower graph), the area away from the outfalls spikes up to 40 mg/kg and settles down to 19 mg/kg OC 10 years after Duwamish/Diagonal remediation.

Figure 7-6 shows the inshore conditions, where average surface sediment concentration is about 11 mg/kg OC (downstream of the outfall). In this area, some sediment core samples show there is a 2 to 3 foot thick layer of the lower concentrations of PCB sediments (3 to 45 mg/kg OC) covering higher concentration PCB sediments at depth (100 to 240 mg/kg OC). In **Figure 7-6**, natural recovery is shown as the "no action" line, indicated by triangles. No action starts at a concentration of 11 mg/kg OC and drops to a value of 7 mg/kg OC after 10 years. If the site is remediated, the area near the outfalls will gradually recontaminate to 7 mg/kg OC after 10 years (indicated by the line with Xs), unless the hot spot is also remediated. If the hot spot is removed 2 years after the site cleanup (squares in the upper graph), the area near the outfalls spikes up to 26 mg/kg and settles down to 7 mg/kg OC 10 years after Duwamish/Diagonal remediation. If the hot spot is removed 5 years after the site cleanup (squares in the lower graph), the area near the outfalls spikes up to 28 mg/kg and settles down to 10 mg/kg OC 10 years after Duwamish/Diagonal remediation.

The model results can be summarized as follows:

- Natural recovery alone (i.e., no action beyond upland source control) is not expected to reduce sediment PCB concentrations below the SQS in the off shore part of the Duwamish/Diagonal site within a 10-year time frame.
- PCB concentrations within the half of the cleanup site away from the outfalls are predicted to recontaminate to a concentration above the SQS if adjacent sediments are not also remediated a year after completion of the Duwamish/Diagonal cleanup action (**Figure 7-5**).

- The half of the site near the outfalls may recontaminate above PCB cleanup standards when adjacent areas are remediated but values will decrease at a faster rate inshore due to input of sediment from discharge (**Figure 7-6**).
- When the upstream hot spot is remediated, the model indicates the surface sediment concentration of PCBs on the 4.8-acre cleanup site will increase by at least 20 mg/kg OC (for a total concentration of 35 or 40 mg/kg OC), far exceeding the SQS. After this spike, the model indicates that it will take 10 years for the concentration to approach the SQS for PCBs. Natural recovery rates would be faster after the hot spot cleanup than without the hot spot cleanup, given the reduction in incoming PCBs. This is illustrated by the steeper curve of the post-hot spot remediation concentrations on the graph.

The results of the natural recovery/recontamination modeling were used in the development of remedial alternatives for the Duwamish/Diagonal site, as described in the sections below.

7.4 IDENTIFICATION/SELECTION OF TECHNOLOGIES AND PROCESS OPTIONS

A wide range of remedial technologies are available that could potentially be considered for application to the Duwamish/Diagonal site. However, in order to efficiently evaluate the available technologies and focus on those that are most viable for application at the Duwamish/Diagonal site, those options with a relatively low potential for application were identified early in the evaluation and screened from further analysis. Only those more promising options were retained for detailed evaluation. Consistent with CERCLA and MTCA guidance, the key criteria used in this initial technology screening were:

- Technical effectiveness. Has the technology been demonstrated to effectively remediate similar sites?
- Implementability. Is the option clearly permittable? Does the site have significant logistical problems for construction?
- Cost effective. What is the relative cost of each technology option? Between options that are similarly effective, permanent (as defined under MTCA), and implementable, those with relatively high costs may be eliminated from further consideration.
- Adverse impacts. Options that may cause significant (i.e., not easily mitigated) short- or long-term environmental or other adverse impacts may also be screened out at this early stage.

7.4.1 No Action

Under this option, no remedial action would be conducted and no institutional controls or long-term monitoring would be performed. The No Action option is not an effective technology for cleaning up the site. This option is low cost, since no actions would be performed at the site. This option is carried forward to provide a baseline for comparison.

7.4.2 Natural Recovery

This option is discussed in more detail in **Section 7.3**. Under this option, upland source controls would be implemented, but no in-water cleanup actions would be performed. Institutional controls would be implemented and long-term monitoring performed as an element of this alternative.

The screening-level natural recovery modeling performed for this report (**Section 7.3** and **Appendix P**) predicted that natural recovery alone would not be effective as a remedial action for the site. However, this process option may be effective in addressing recontamination that may occur during remedial activities occurring on adjacent sites, and thus may be appropriate as a component of a more active remedial option (e.g., capping or dredging). Because of its limited effectiveness, and also because this option is unlikely to comply with MTCA cleanup standards, natural recovery as a sole process option was eliminated as a remedial technology for the Duwamish/Diagonal site. However, as noted above, natural recovery may be appropriate for consideration as a component of a more active cleanup remedy.

7.4.3 Excavation Options

Sampling results indicate that the potential bottom elevation of sediment contamination at the Duwamish/Diagonal site is approximately -50 feet MLLW at the Siphon crossing. It appears infeasible to dredge and completely remove all contaminated sediment from the site, since the existing Siphon would need to be demolished and reconstructed in order to accomplish such an action. This would significantly affect the sanitary sewer system that serves West Seattle; therefore, total removal was not considered further in this evaluation.

Contaminated sediment may be removed (excavated) using either mechanical (e.g., clamshell) or hydraulic (e.g., cutterhead) technologies. Applying the screening criteria to excavation options yields the following results:

Dredging (mechanical). Mechanical dredging used in conjunction with capping (i.e., to contain subsurface sediments at the Siphon crossing) may be an effective remedial technology for this site. This option is proven and routinely applied at other similar sediment cleanup sites, and permitting has been accomplished with water quality and fisheries conditions acceptable to a range of applicants. Even though dredging could result in temporary releases of contaminated sediments to adjacent areas, the longer-term recontamination risk posed by such an action is mitigated by the ensuing acceleration of natural recovery rates (**Section 7.3**). To reduce loss of dredged material, the contractor will institute various best management practices (BMPs). These BMPs may include reducing the cycle time (relative to maintenance dredging cycle rates) so that the bucket is raised at a slower rate through the water column, minimizing the number of bucket cycles by obtaining a full bucket of sediment during each cycle or not allowing the contractor to stockpile sediments under water before bringing the bucket to the surface for sediment placement on the barge. Water quality and sediment controls can also be implemented to further reduce short-term impacts during construction. Depending largely on final water quality and fisheries conditions, mechanical dredging can be cost effective. This option was carried forward for further analysis.

Dredging (hydraulic). Although hydraulic dredges (e.g., cutterheads) resuspend a somewhat lower quantity of sediments (typically by a factor of 3 or more) compared to mechanical dredges, due to the large amount of water entrained during the hydraulic dredging process (typically 80 to 90 percent water by weight), logistics are significantly more complex than for mechanical dredging. The design must account for handling and possibly treatment of the water that is entrained prior to its return to the receiving water. Hydraulic dredging is typically used to remove sediments and transport them directly to a nearby upland or nearshore fill disposal site.

The availability of nearby disposal sites, however, is questionable, as discussed in **Section 7.4.5**. Further, because prospective sediment disposal volumes at the Duwamish/Diagonal site (approximately 81,000 cy) are relatively small by normal hydraulic dredging standards, this option would likely be associated with relatively large setup costs for the pipeline and water treatment facility. These factors render this option considerably less promising than mechanical dredging. As there is considerable uncertainty associated with a hydraulic dredging option at this site, and because there is a more proven and likely more cost-effective option available (mechanical dredging), hydraulic dredging was eliminated from further consideration.

7.4.4 Treatment Options

Contaminated sediment treatment has received increasing attention and evaluation over the last several years, at both the federal and state levels. For example, the WDNR recently issued a report assessing several sediment treatment alternatives that could potentially be implemented as part of a multi-user facility servicing the Puget Sound region (Hart Crowser 2001). Seven vendors with five different treatment technologies were addressed in a preliminary engineering and economic analysis. These technologies evaluated by WDNR included:

- Biological Treatment
- Soil Washing
- Lightweight Aggregate
- Plasma Arc
- Stabilization

Based on WDNR's analyses, several of these technologies were identified as potentially viable for application at a Sediment Multi-User Remediation Facility (SMURF) at an offsite location. However, there is no existing SMURF in the Puget Sound area, and the prospective viability and availability of such a facility is uncertain. The WDNR focused their prospective SMURF evaluation towards a hypothetical site located in Everett, Washington, though the analysis could be generally applicable to other potential SMURF sites with similar attributes. WDNR's preliminary analysis concluded that if a SMURF were to be owned, constructed, permitted, and operated by a third party entity (i.e., separate from the WDNR and the owner/generator of the sediments), it may be reasonable to expect tipping fees for treatment/disposal of contaminated sediments that would be cost-competitive with current upland disposal estimates. However, WDNR's preliminary tipping fee analysis was sensitive to a range of cost assumptions, and so is associated with considerable uncertainty. Nevertheless, because of the stated MTCA and CERCLA preference for permanent treatment remedies, and also because WDNR's estimated costs of a SMURF may be competitive with other off-site disposal options (see below), this option was carried forward in the evaluation of the alternatives. In this case, treatment in a hypothetical SMURF was retained as one of a range of potential offsite treatment and/or disposal process options. Should the offsite treatment and/or disposal option be selected by the EBDRP Panel as part of an overall cleanup remedy for the Duwamish/Diagonal site, the availability and cost of using such a facility would need to be assessed during remedial design of the Duwamish/Diagonal cleanup project.

7.4.5 In-Water Containment Options

Contaminated sediment may be effectively contained and isolated from potential biological exposure using a range of engineered cap and confined facility technologies. Application of the screening criteria to in-water containment options is described below.

In Situ Capping (Thick-Layer). This option involves placing a cap, typically composed of a 3-foot-thick layer of clean sand, over the contaminated footprint within the project site. This cap is used to isolate the contaminated sediment from the water column and from the biologically active zone of the sediments. Capping is typically used in relatively low energy aquatic sites, and may also be covered with a protective armor layer in more dynamic systems. As detailed in EPA and USACE guidance documents (Palermo et al. 1998), a cap would be engineered to ensure its effectiveness based on detailed analyses of site hydrodynamics, slope and seismic stability, chemical migration potential, and other factors. These detailed analyses would normally be performed as a component of remedial design. In addition to stability, habitat concerns would also be considered when choosing cap materials.

The available data suggest that prospective capping systems would be stable and effective at the Duwamish/Diagonal site. For example, field observations collected near the site to calibrate the King County hydrodynamic model (King County 1999) revealed maximum near-bottom water velocities of up to approximately 60 cm/s. Based on typical shear strength relationships, a fine sand cap would resist erosion by currents of this magnitude. Potential propeller wash currents must also be considered in cap design. Remedial design studies performed in the Thea Foss Waterway in Tacoma, which has similar water depths and vessel traffic operations as the Lower Duwamish Waterway, indicated that maximum bottom-water velocities resulting from reasonable worst-case vessel operations in that waterway ranged up to approximately 150 cm/s (PIE 1998). At that site, a sediment cap constructed of medium sand particles (more than 30 percent of material larger than 1 mm diameter) would resist erosion, with predicted maximum scour depths of less than 0.1 feet. Similar results are expected at the Duwamish/Diagonal site, and would be verified during remedial design. Clean sand materials (i.e., with chemical concentrations below SQS and Trustee restoration goals) meeting these general grain size specifications are routinely available from maintenance dredging of the upper turning basin of the Duwamish Waterway. Other prospective capping sources are also available.

Due to the presence of the Siphon and with potential subsurface sediment contamination extending to elevation -50 feet MLLW in this area, capping portions of the site may be the only feasible solution to isolate contaminants in certain locations. Capping in the federal navigational channel would be subject to the depth constraints necessary to maintain the authorized channel depths. Details of placing a cap near the navigation channel would be worked out in coordination with USACE. Thick-layer capping, which may also be used in conjunction with excavation, was retained for further analysis in this evaluation.

In Situ Capping (Thin-Layer). This option, which is also referred to as enhanced natural recovery, consists of placing a relatively thin cap, typically composed of clean sand 4 to 8 inches thick, over the contaminated footprint within the project site. In contrast to the complete isolation function of the thick-layer cap discussed above, the thin-layer cap is normally intended to partially mix with the underlying surface sediments, and has been demonstrated at certain sites to be sufficient to achieve cleanup levels throughout the biologically active zone. To the extent

that bioturbation processes extend below the bottom of the thin-layer cap, such processes will result in mixing of the clean upper sediments with underlying contaminated sediments. During remedial design, the thickness of the cap is engineered to ensure that cleanup levels are met throughout the biologically active zone, based on site-specific chemical distributions and bioturbation characteristics.

One of the benefits of a thin-layer cap relative to the thick-layer cap discussed above is that there is significantly less short-term loss of existing benthic infauna during construction, as cap placement rates are typically slow enough to allow existing infauna to migrate into and recolonize the new cap surface. Another benefit of thin-layer capping is that it results in less change to existing grades, and thus limits corresponding changes to habitat functions and navigation uses. As above, details of placing a cap near the navigation channel would be worked out in coordination with USACE. The thin-layer cap option has been shown to be effective in achieving cleanup levels at several Puget Sound sites (e.g. Pier 54/55 in Elliott Bay and West Eagle Harbor), particularly in areas where the sediment chemical concentrations are only marginally above cleanup standards. However, thin-layer capping may not be appropriate for prospective navigation or berthing areas, as it provides little or no surface buffer to protect the site from future disturbances associated with maintenance dredging operations. Given that the Duwamish/Diagonal site is located immediately adjacent to a federal navigation channel, and that much of the site area has historically been used for berthing, the thin-layer cap option was not retained for detailed analysis in this evaluation. Nevertheless, if the final remedy for the site were to include sufficient institutional controls for parts of the site to prevent future disturbances, thin-layer capping could potentially be an appropriate process option, and in such a case would be evaluated in more detail during remedial design.

In Situ Capping (Inverted). Inverted capping involves removing the top layer of contaminated sediment and stockpiling on site, then removing enough clean underlying material to be able to place the contaminated material into this deeper excavated area. After the contaminated material is backfilled, the clean sediment is placed on top as a cap. While this process option has been used at certain sites in the United States, it is rarely utilized in the Northwest. At the Duwamish/Diagonal site, this process option is likely to be impracticable, due in part to the necessary multiple handling of sediment, and the relatively thick deposits of contaminated subsurface sediments that underlie the site, particularly near the Siphon. Logistics during construction for this option are significantly more difficult than other capping options due to the dredging and stockpiling component. Therefore, this process option was eliminated from further consideration in this evaluation.

Confined Aquatic Disposal. Confined aquatic disposal (CAD) places dredged contaminated sediment in a submerged location and caps (covers) it with clean material. CADs are designed and placed in locations where they will always be completely underwater. The thickness of the cap and the grain size of the clean sediment are designed to prevent contaminants from migrating back into the aquatic environment. The CAD surface can either be completed as shallow water or deep water habitat, depending on site conditions.

Within the Elliott Bay/Duwamish region, the USACE previously (1984) constructed an experimental 1,000-cy CAD facility within the West Waterway (-40 to -50 feet MLLW), and this site has continued to perform effectively (Sumeri 1996). The U.S. Navy recently completed

construction of a somewhat shallower CAD in Sinclair Inlet for containment of contaminated sediment. The USACE has also identified several possible other deep-water CAD locations in the region, including a possible site in the East Waterway, though none of these sites has been formally proposed for construction (Port of Seattle 2000). No prospective CAD location has been identified to date within the immediate vicinity of the Duwamish/Diagonal site. As such, an on-site CAD process option was eliminated from further consideration in this evaluation. However, an off-site CAD could potentially become available in the future, and in such an event would likely be owned, permitted, constructed and operated by an independent third party. Because a prospective future off-site CAD may be cost-competitive with other off-site disposal options, it was retained as one of a range of potential off-site treatment and/or disposal process options. Should the off-site CAD option be selected by the EBDRP Panel as part of an overall cleanup remedy for the Duwamish/Diagonal site, the availability and cost of using such a facility would need to be assessed during remedial design.

Nearshore Confined Disposal (NCD). This option, otherwise known as a Nearshore Fill, is a type of landfill constructed underwater along the shoreline. A berm is constructed of clean material near the shoreline. The lower layer of the area between the berm and the shoreline is filled with the dredged contaminated sediment. The upper layer is covered with clean sediment or fill material until it is above tidal level. Nearshore fills create new land that can be used for public shoreline access or for businesses that depend on being near water. Since they convert submerged land to dry land, NCDs eliminate aquatic habitat.

NCDs have been constructed and used to contain contaminated sediments at several sites in the Puget Sound region (e.g., Terminal 91 in Seattle, West Eagle Harbor, Milwaukee Waterway in Tacoma), and have continued to perform effectively. Potential NCDs are also being considered for other areas, including two additional sites in Tacoma (Blair Slip 1 and St. Paul Waterway), as well as prospective sites near Harbor Island. Based on an initial screening, there does not appear to be a suitable location on site at which to construct a NCD. As such, an on-site NCD process option was eliminated from further consideration in this evaluation of alternatives. However, an off-site NCD could potentially become available in the future, and in such an event would likely be owned, permitted, constructed and operated by an independent third party. Because a prospective future off-site NCD may be cost-competitive with other off-site disposal options, it was retained as one of a range of potential off-site treatment and/or disposal process options. Should the off-site NCD option be selected by the EBDRP Panel as part of an overall cleanup remedy for the Duwamish/Diagonal site, the availability and cost of using such a facility would need to be assessed during remedial design.

7.4.6 Upland Disposal

Under this option, contaminated sediments would be dredged and placed in a specially designed landfill that is on dry land, away from surface water. The landfill would include liners and surface water controls to minimize infiltration. A special water collection system would likely also be required so that water draining through the landfill (leachate) does not escape and contaminate local groundwater.

Upland landfill disposal has been used for contaminated sediment remediation at a range of different sites in Puget Sound, including the Panel's Norfolk site remediation and the Port of

Seattle/USACE Stage I East Waterway cleanup. All of these projects have utilized existing off-site RCRA Subtitle D landfill facilities (e.g., Roosevelt Landfill) that are owned, constructed, permitted, and operated by an independent third party. No upland disposal site or facility has been identified within the immediate vicinity of the Duwamish/Diagonal site.

RCRA Subtitle D Landfills. As discussed above, off-site upland disposal at existing RCRA Subtitle D landfill facilities is a proven technology and relatively straightforward to permit. Depending on disposal quantities, Puget Sound region-specific costs for transport to and disposal at these off-site Subtitle D facilities currently (2001) range from approximately $40 to $55/cy, which are generally comparable to estimated costs associated with some of the other engineered containment options outlined above such as CADs, NCDs, and SMURF treatment.

The Duwamish/Diagonal contaminated sediment has been tested for waste characteristics (**Section 4.7.2**). The testing indicates that all of the sediment is non-hazardous and suitable for disposal at a Subtitle D landfill. Two projects implemented in November and December 2001 loaded sediments directly into containers for shipping and offloading at a landfill with a moisture deficit. It is expected that this option is available for Duwamish/Diagonal sediments also. Even were the project subject to a dewatering requirement, the costs associated with dewatering are normally minor in comparison to the stated tipping fees. Based on these considerations, off-site upland disposal is a currently available and likely practicable sediment disposal option. Thus, this option was carried forward.

Construction Reuse/Backfill. A potential alternative to a landfill is to reuse the sediment material as construction backfill, possibly after stabilization of the material to improve its structural qualities. However, substantial evaluation and/or engineering design would likely be required to assure that disposal procedures are safe and that the disposal/reuse site would be effective in containing the contaminated sediment. Concentrations of chemicals may also need to be below relevant MTCA cleanup levels to allow disposal without institutional controls. A preliminary review of the available site characterization data for the Duwamish/Diagonal site indicates that bulk sediment concentrations at the site are greater than those allowable for unrestricted land uses, but may be acceptable at certain controlled industrial site locations. However, this option would likely be relatively difficult to permit and implement (e.g., addressing potential indemnification issues), and may not be substantially more cost-effective than off-site upland disposal. Based on the above reasons, this option was eliminated from further consideration.

7.4.7 Summary of Retained Technologies and Process Options

A summary of the screening of technologies and process options is presented in Table 7.2. Where practicable, a permanent cleanup remedy is clearly preferred under both MTCA and CERCLA, and the inclusion of a range of removal and treatment/disposal process options in this evaluation of alternatives would be consistent with the intent of these regulations.

There are several reasons why permanent solutions, as defined under the MTCA and CERCLA regulations, may not be practicable for application throughout the Duwamish/Diagonal site. For example, previous construction of the sewer Siphon required excavation of a trench through the center of the site to an elevation of at least -50 feet MLLW. The area affected by trench

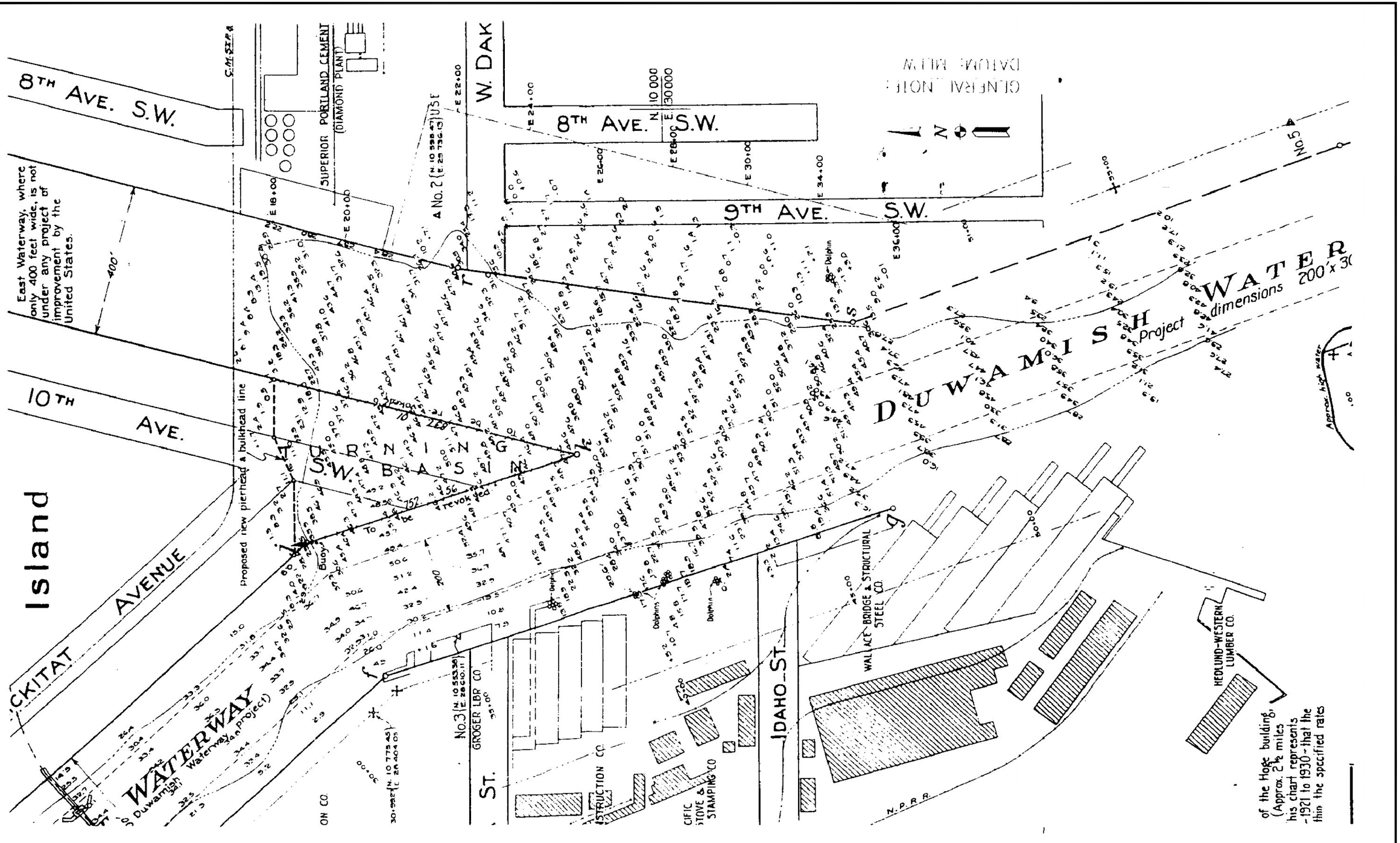
excavation was backfilled, resulting in potential contamination to the bottom of the trench. Also, cores collected and analyzed during the site assessment, particularly those located near shore, indicated contamination (exceedance of SQS chemical criteria) extending at least 6 feet below the existing surface elevations. It is not known how deep contamination extends in these areas. Extended depths of dredging near shore may also cause significant slope failure along the riprapped shoreline slopes. Because of the above reasons, complete removal of all contaminated sediment is probably not achievable. Some areas within the site potentially can be excavated to remove all contaminated sediment while other areas will require capping to isolate the contaminated sediment.

All disposal options that have been retained as a result of the initial screening process involve off-site facilities that would be constructed by other parties. The Duwamish/Diagonal sediment would be taken to one of these facilities and a tipping fee would be paid to an independent vendor to handle the sediments, potentially also including an indemnification provided by the vendor accepting future liability associated with these materials. No permitting or construction of the disposal site would be required by the Duwamish/Diagonal project. Each of the retained off-site disposal options, (CAD, NCD, upland landfill, and SMURF) have costs that have been estimated by various parties such as WDNR and USACE as within the same general range (within the uncertainties about the specific site or location). Therefore, for the remainder of this report, all disposal options will be considered as similar and will be represented by disposal at a Subtitle D landfill (e.g., Rabanco's Roosevelt Landfill in Klickitat County, Washington), in part because this technology is the only option that is currently available, and thus has more certainty than the other disposal process options. However, should the off-site disposal or treatment option be selected by the EBDRP Panel as part of an overall cleanup remedy for the Duwamish/Diagonal site, the availability and cost of using alternative, prospective CAD, NCD, upland landfill, or SMURF facilities would need to be reassessed during remedial design.

Table 7.2 SUMMARY OF SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS

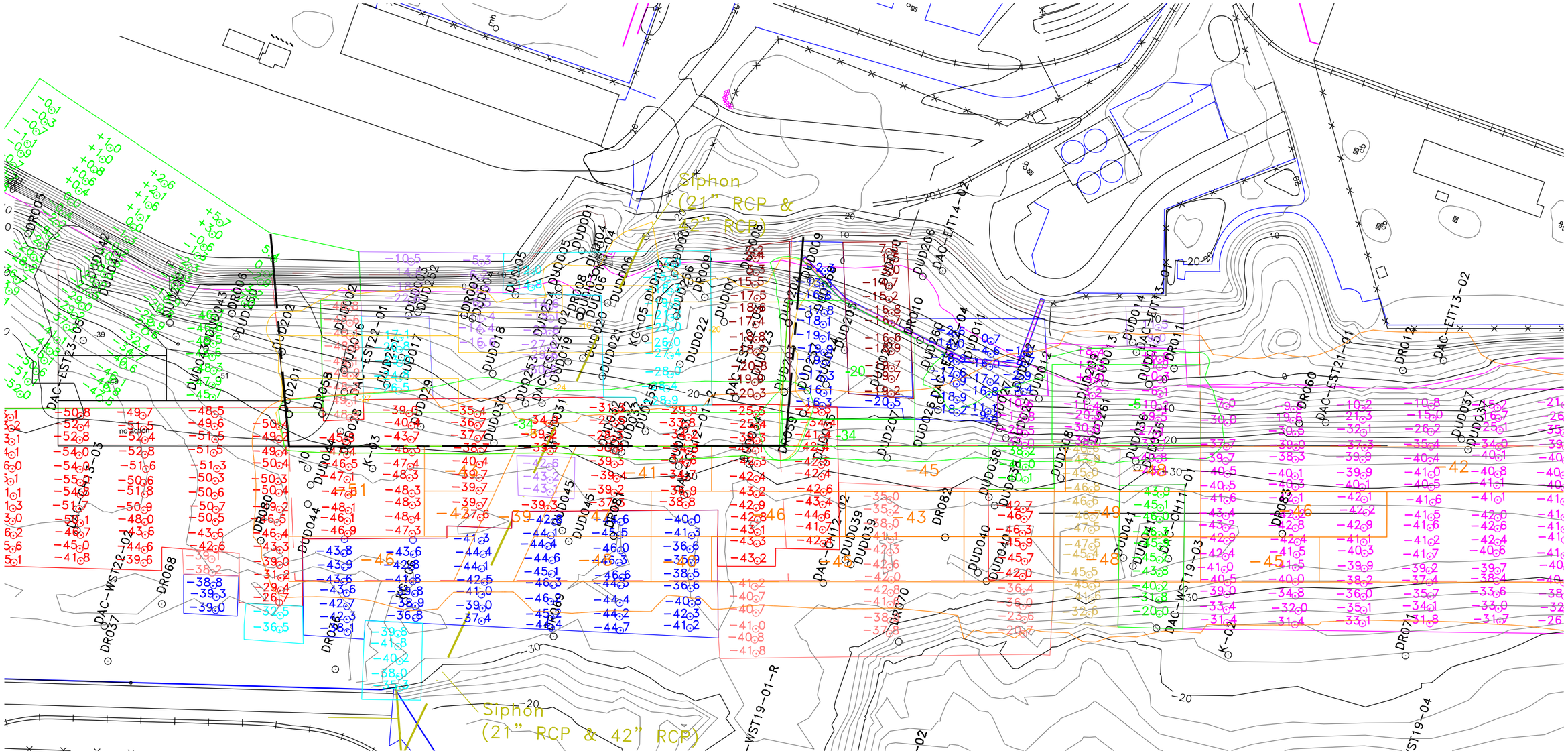
Options	Technical Effectiveness (Does the option appear to have merit?)	Implementability (Is the option feasible?)		Relative Cost (low, medium, high)	Adverse Impacts (Does the option have significant adverse impacts?)	Comments	Carried Forward
		Logistics	Regulatory				
No action	No	Yes	No	Low	Not beyond current levels.	This option is carried forward as a basis for alternatives comparison	Yes
Natural Recovery	No	Yes	No	Low	Not beyond current levels.	Eliminated as remedial option.	No
Mechanical Dredging	Yes. Proven technology.	Yes. Dredging would probably be barge based.	Yes. Proven technology.	Medium	No. Dredging will suspend some sediment in the water column, but this is short term and limited.	Due to contamination associated with the sewer Siphon that cannot be removed easily, this option is combined with capping.	Yes
Hydraulic dredging	Yes. Proven technology, small volumes result in higher unit costs.	Only if dewatering with direct discharge is allowable.	Yes. Proven technology.	Medium	No. Dredging will suspend some sediment in the water column, but this is short term and limited.	Hydraulic dredging has higher costs and is more complicated to plan and permit than mechanical dredging; therefore it is eliminated.	No
SMURF	Yes, if one were available.	Yes, if a facility is set up by other entities at offsite location.	Would be handled by facility sponsors.	Medium	None at D/D site	No facility currently available.	Yes, if a facility is developed
In situ thick-layer cap	Yes	Yes, if in conjunction with excavation in area adjacent to navigational channel.	Yes, if in conjunction with excavation in area adjacent to navigational channel.	Medium	No	If not done in conjunction with excavation, there may be conflicts with navigational and fishing rights.	Yes

Options	Technical Effectiveness (Does the option appear to have merit?)	Implementability (Is the option feasible?)		Relative Cost (low, medium, high)	Adverse Impacts (Does the option have significant adverse impacts?)	Comments	Carried Forward
		Logistics	Regulatory				
In situ thin-layer cap	No, due to near- by navigational uses.	Yes	Unknown. Concerns about effectiveness	Low	No	Eliminated	No
In situ inverted cap	Not for this site.	Impractical due to the great depth to clean sediment and the presence of the Siphon	Unknown. Little track record in region.	High	No	Eliminated	No
Confined Aquatic Disposal	Yes, if available.	No locations readily available.	No. CAD sites in Elliott Bay are difficult to permit.	High	None at D/D site	No facility currently available.	Yes, if a facility is developed
Nearshore Confined Disposal	Yes, if available.	Only if a nearshore developmen t project is available in the necessary time frame.	Would be handled by development sponsors.	Medium	None at D/D site. Disposal site would have issues of nearshore habitat and fishing.	No facility currently available.	Yes, if a facility is developed
RCRA Subtitle D Landfill	Yes	Yes	Yes, the material has been tested and found to be non-hazardous.	Medium	No	Would be required to pass paint filter test at point of loading.	Yes
Miscellaneous Upland Disposal Locations	Unknown	No	No	Unknown (project specific)	Unknown (project specific)	No sites are currently identified. Eliminated due to unknowns.	No
Construction Backfill	Yes, provided site specific criteria are met.	No, project specific analyses required.	No, process would be difficult.	Unknown (project specific)	Unknown (project specific)	No sites are currently identified. Eliminated due to unknowns.	No



Sep 20, 2005 1:29pm cdavidson K:\Jobs\020067-KING_CO_SED_MANAG\02006701\02006701-63.dwg Fig 7-1

EcoChem Team	Duwamish/Diagonal Sediment Remediation Project	Figure 7-1
	1931 Condition Survey USACE	



Historic Dredge Dates	
-43.3	1925
-41.6	1928
-43.8	1932
-40.6	1943
-41.0	1950
-43.2	1968
-28.9	1970
-17.5	1978
-17.2	1984

Notes:
1. Topography/Basemap provided by the Port of Seattle (1994). This data is to be used for visual reference only.
2. Bathymetric contours created by Anchor Environmental from COE 1997 survey referenced to MLLW (NOS).

0 150
Scale in Feet

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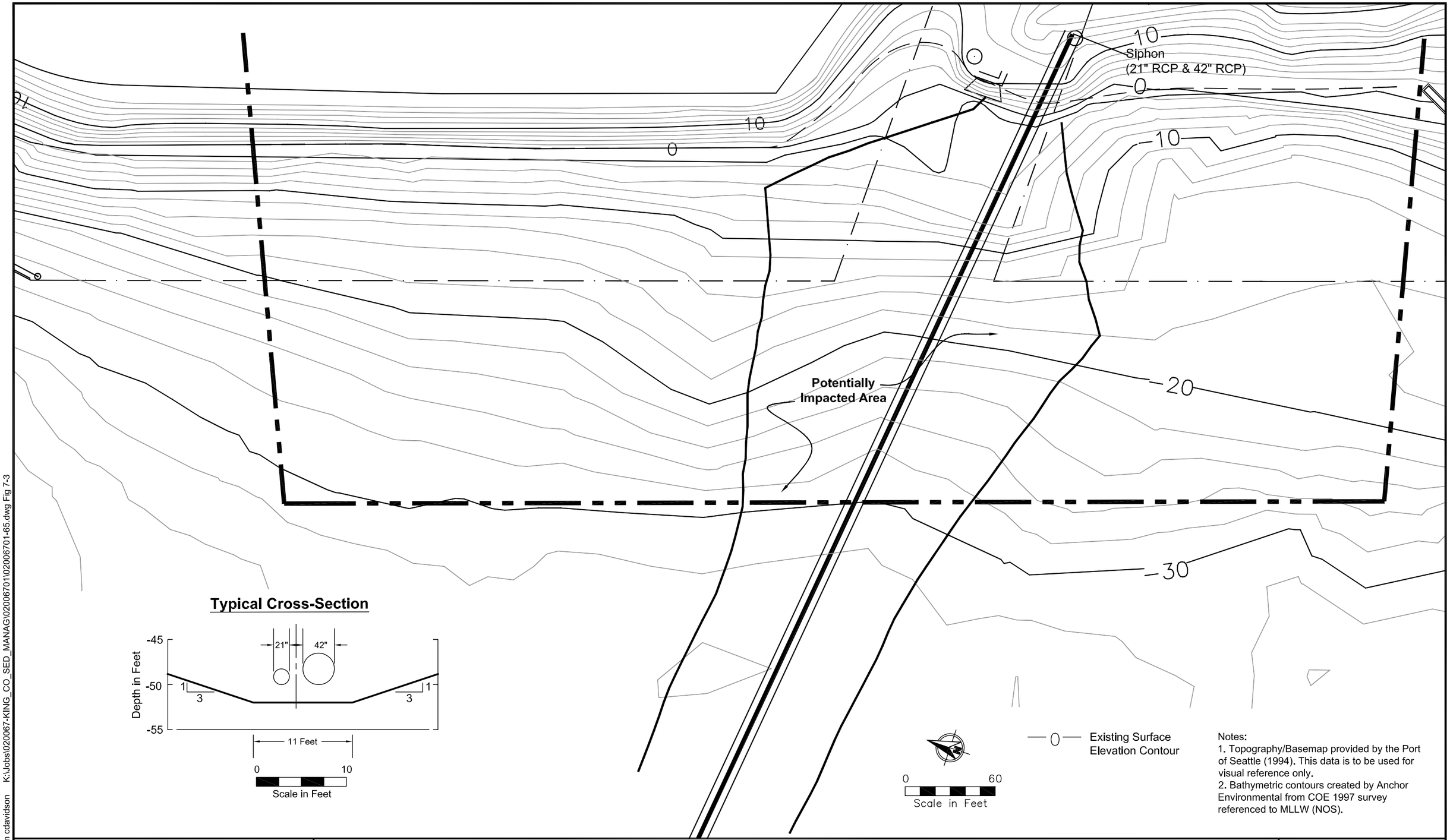
Duwamish/Diagonal Sediment Remediation Project

Deepest Historical Dredge Depths

Figure 7-2

Sep 20, 2005 1:32pm cdavidson K:\Jobs\020067-KING_CO_SED_MANAG\02006701\02006701-64.dwg Fig 7-2



Notes:
1. Topography/Basemap provided by the Port of Seattle (1994). This data is to be used for visual reference only.
2. Bathymetric contours created by Anchor Environmental from COE 1997 survey referenced to MLLW (NOS).

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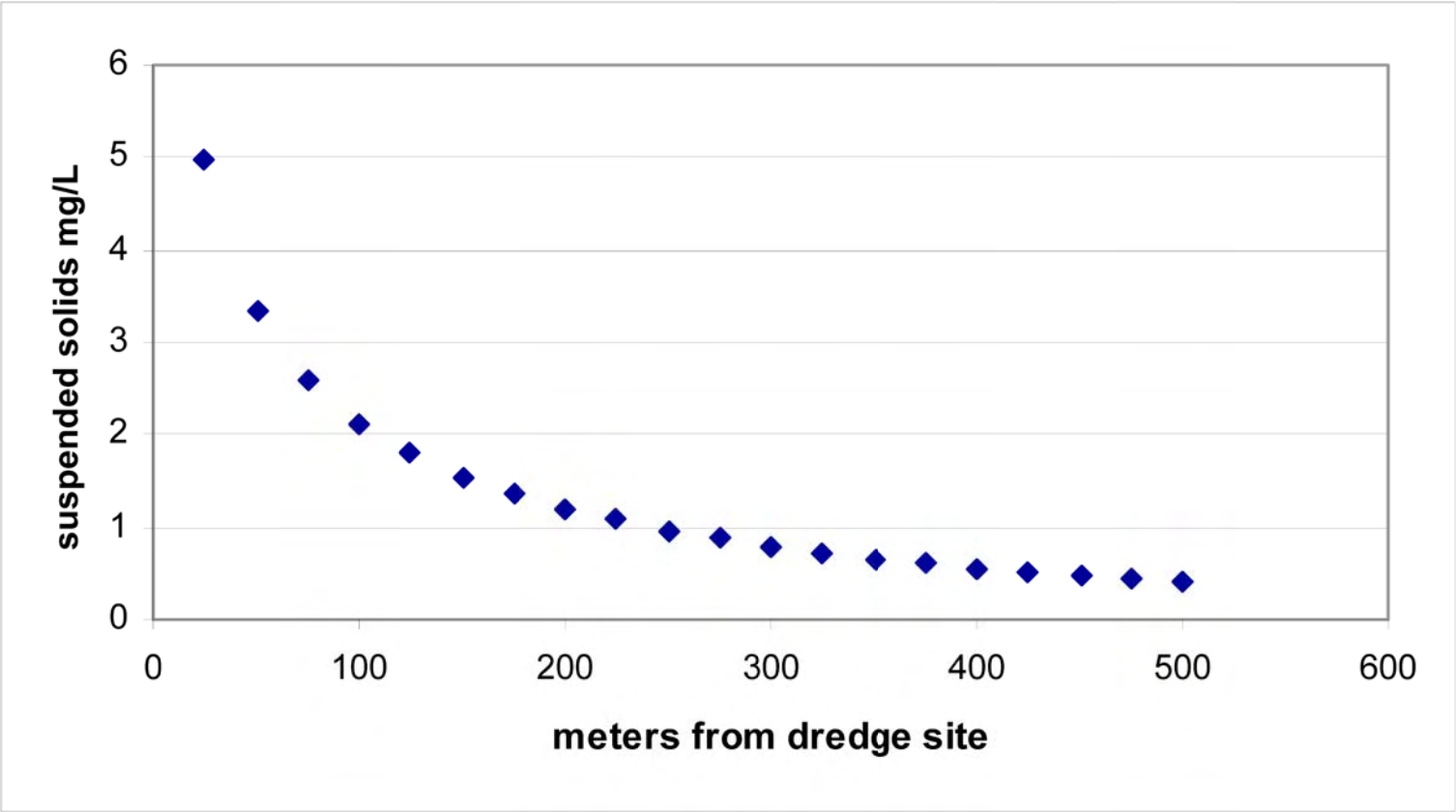
Duwamish/Diagonal Sediment Remediation Project

Estimated Disturbed Sediment Boundary during Construction of Siphon

Figure 7-3

Sep 20, 2005 1:34pm cdavidson K:\Jobs\020067-KING_CO_SED_MANAG\02006701\02006701-65.dwg Fig 7-3



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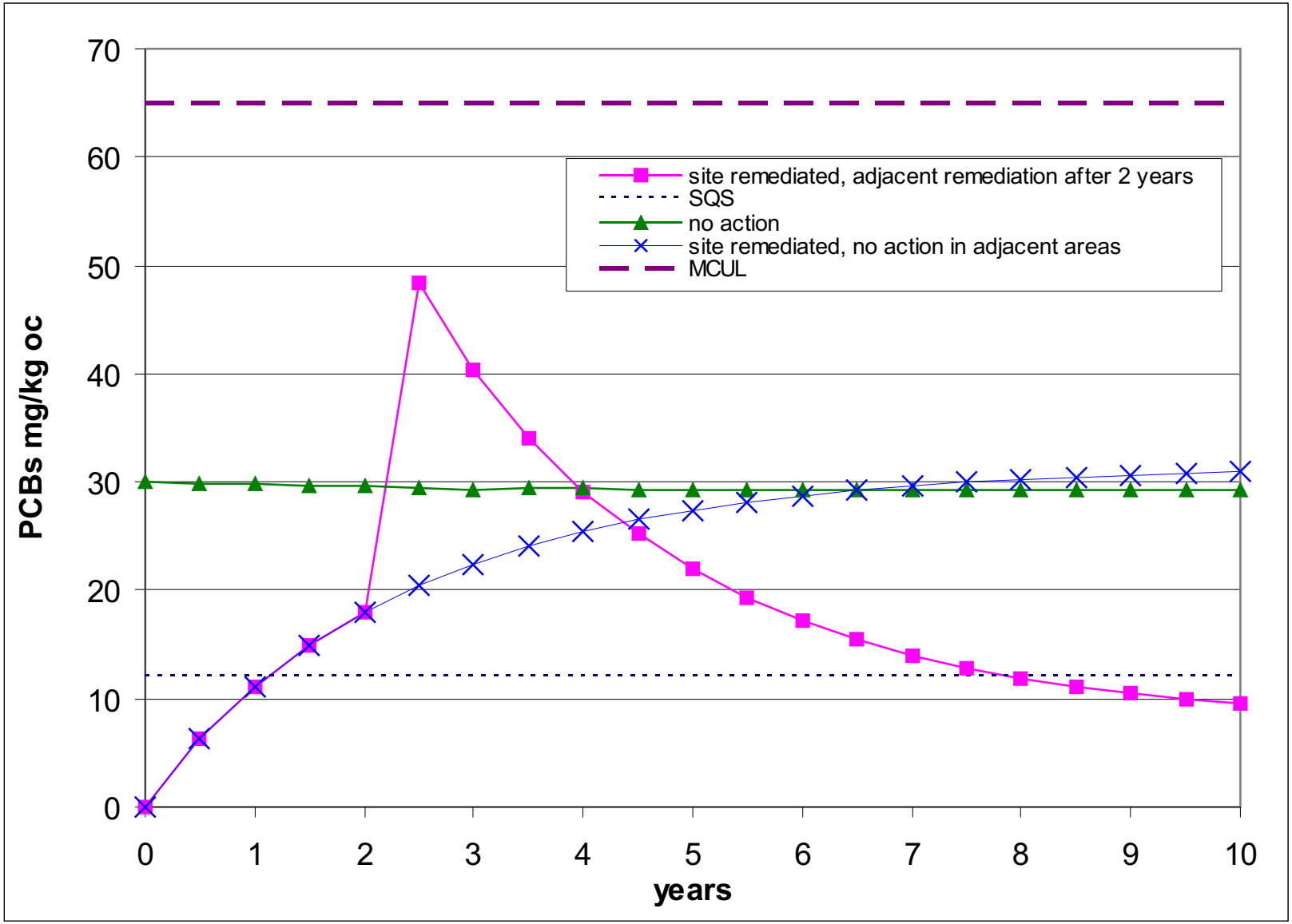
Duwamish/Diagonal Sediment Remediation Project

Suspended Sediments Predicted by DREDGE at
8m Below the Water Surface

Figure 7-4

Sep 28, 2005 3:26pm cdavidson K:\Jobs\020067-KING_CO_SED_MANAG\02006701\02006701-66.dwg Fig 7-4



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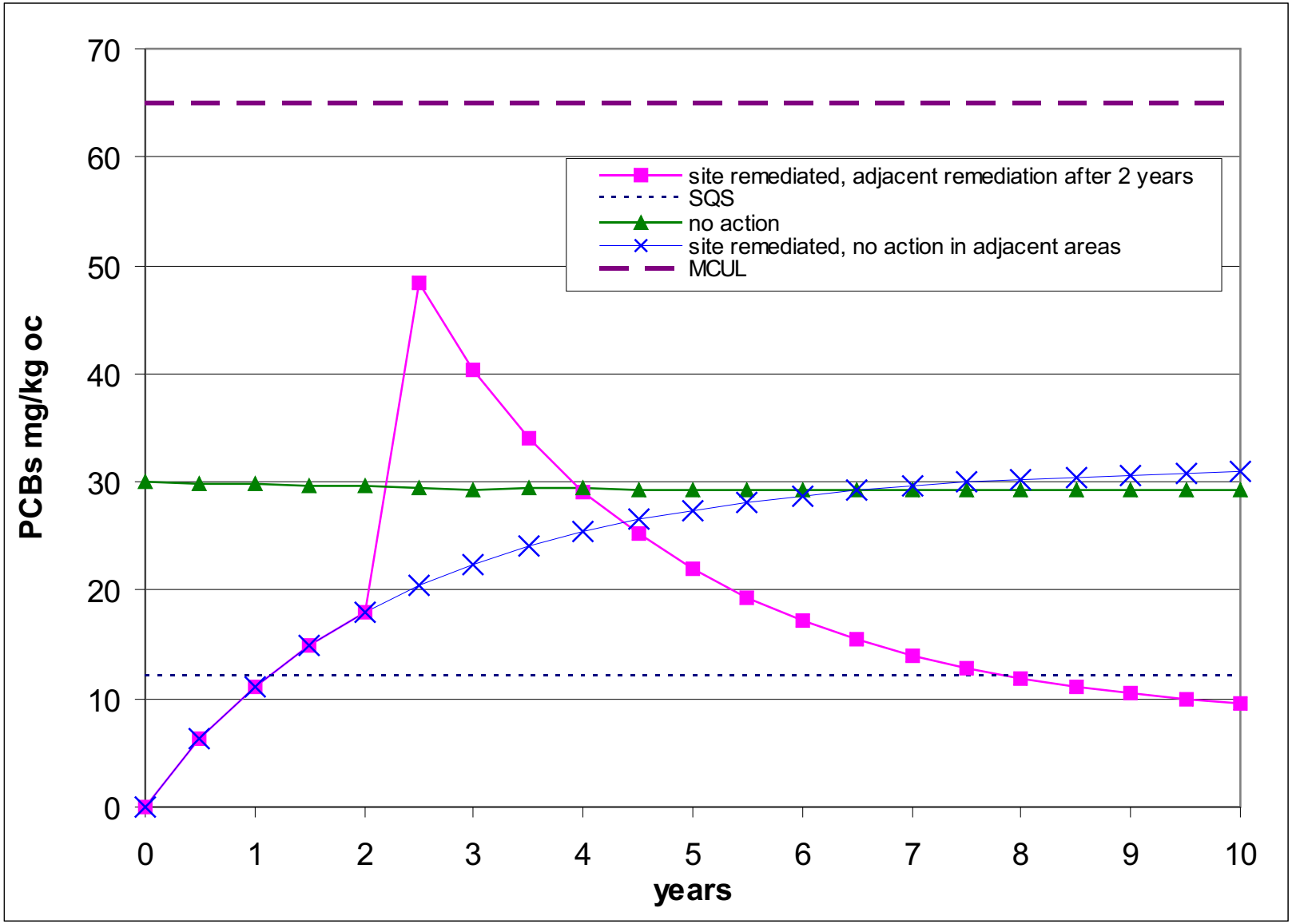
Duwamish/Diagonal Sediment Remediation Project

Natural Recovery Model Results for the Area Away from the Outfalls

Figure 7-5

9/28/05 K:Jobs\020067-King_CO_SED_MANGA\02006701\FIG 7-5_7-6.cdr



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Duwamish/Diagonal Sediment Remediation Project

Natural Recovery Model Results for the Area Near the Outfalls

Figure 7-6

9/28/05 K:Jobs\020067-King_CO_SED_MANGA\02006701\FIG 7-5_7-6.cdr

8 SCREENING AND DEVELOPMENT OF ALTERNATIVES

Following initial screening, the technology types and process options retained for screening and development of alternatives are:

- No Action
- Excavation
    - Mechanical Dredging
- In-Water Containment
    - Thick-Layer In Situ Capping
- Off-site Disposal (representative of a range of off-site disposal and treatment options)

The objective of this chapter is to assemble, screen, and develop alternatives that will undergo more detailed evaluation in a subsequent section of this report. These alternatives were assembled from potential combinations of the technologies and process options that were retained following the initial screening in **Chapter 7**. After the alternatives were assembled, a secondary screening was applied based on further considerations of technical effectiveness, implementability, cost, and adverse impacts. A conceptual design of each alternative was then developed, and served as the basis for the more detailed evaluation presented in **Chapter 9**.

8.1 ASSEMBLY OF ALTERNATIVES

Utilizing the above technology and process options, the following preliminary alternatives were assembled to represent a broad range of potential response actions at the Duwamish/Diagonal site:

- Alternative 1: No Action. This alternative, which would entail leaving the site as-is with no further action, is carried forward as a baseline for comparison with the other alternatives.

- Alternative 2: Maximum Practicable Containment. The overall objective of this alternative is to achieve SQS chemical criteria throughout the cleanup site while maintaining existing navigation channels and shoreline structures, and minimizing dredging and disposal of contaminated sediment. The focus of this alternative is minimizing dredging and disposal volumes. This alternative does not accommodate the objectives of maintaining existing habitat elevations and removing possible future encumbrances to navigation deepening of the federal waterway and adjacent berthing areas. Alternative 2 would combine minimal dredging near the navigation channel and near certain shoreline structures (to accommodate cap backfill), off-site disposal of all dredged materials, and capping the entire site with a clean sand cap designed and constructed in accordance with EPA and USACE standards, in order to ensure its long-term integrity and performance. Upland source controls such as pipe cleaning would be completed as a separate action prior to initiation of this remedial action.

- Alternative 3: Capping with No Change in Existing Elevations. The overall objective of this alternative is to achieve SQS chemical criteria throughout the cleanup site while maintaining existing depths and elevations throughout the site, concurrently minimizing dredging and disposal of contaminated sediment to the extent practicable. In this alternative, maintaining existing habitat elevations predominates over competing objectives of minimizing dredging and disposal volumes and removing possible future encumbrances to navigation deepening of the federal waterway and adjacent berthing areas. Alternative 3 would achieve this objective through a combination of dredging of a surface layer throughout the site (approximately 3 feet) to accommodate cap backfill, off-site disposal of all dredged materials, and capping the entire site with a clean sand cap designed and constructed in accordance with EPA and USACE standards, in order to ensure its long-term integrity and performance. Upland source controls such as pipe cleaning would be completed as a separate action prior to initiation of this remedial action.

- Alternative 4: Maximum Practicable Removal of Contaminants. The overall objective of this alternative is to achieve SQS chemical criteria throughout the cleanup site while allowing for maximum practicable flexibility in future deepening of the navigation channels, without the risk of exposing or excavating contaminated sediments in the future. In this alternative, removing possible future encumbrances to navigation deepening of the federal waterway and adjacent berthing areas predominates over a competing objective of minimizing dredging and disposal volumes. In addition, the objective of maintaining existing habitat elevations could be achieved by backfilling the excavations with clean material. Alternative 4 would be implemented through a combination of dredging sediments to the maximum practicable extent (excluding within the siphon area), off-site disposal of all dredged materials, capping relatively limited areas of the site such as the Siphon where subsurface contaminated sediments will remain in place, and backfilling as necessary. As in Alternatives 2 and 3, upland source controls such as pipe cleaning would be completed as a separate action prior to initiation of this remedial action.

8.2 SCREENING OF ALTERNATIVES

The individual handling, treatment, and disposal options components were screened in **Section 7.4** in order to eliminate those technologies and/or process options not considered feasible. The next step is to evaluate the assembled alternatives against each other with respect to the screening criteria below:

- Technical effectiveness
- Implementability
- Cost effectiveness
- Adverse impacts

8.2.1 Alternative 1: No Action

Alternative 1 would not implement any remedial actions. The site would remain as is and no institutional controls would be implemented. As discussed above, this alternative was carried forward as a basis for comparison.

8.2.2 Alternative 2: Maximum Practicable Containment

This alternative would clean up the site by placing a thick cap of clean material over the contaminants and isolating them from the environment. Dredging is required in the areas 1) near the navigation channel to ensure that the cap does not encroach on the channel and reduce the minimum authorized water depths; and 2) in front of the outfall so the cap does not impede discharge flows.

Thick layer capping is an effective technology that is proven and has been accepted on several projects in Puget Sound and Elliott Bay. Permitting for this alternative is relatively straightforward and similar to the other cleanup alternatives. Institutional controls to prevent disturbance to the cap would be negotiated with the Port of Seattle and other landowners; these controls would include anchoring, dragging, digging, and pile driving without proper conditions. However, there are two issues that might slow the permitting process. First, the potential tribal fishing issues and alteration of habitat type might raise concerns. Second, the level of detail required by the agencies for review may be greater than for dredging options due to concerns of cap stability.

Evaluation of site characteristics, including flow velocity and existing sediment grain size, will need to be taken into consideration in design of a cap to ensure its stability. In addition to stability, habitat concerns would also be considered when choosing cap materials.

Disposal of excavated material is a significant cost, so minimization of dredged volumes that this alternative offers also minimizes the overall cost of cleanup. The cost of disposal at an upland Subtitle D landfill has been declining over the last several years at the major regional landfills such as Roosevelt Landfill in Klickitat County, Washington and Columbia Ridge Landfill in Arlington, Oregon. Currently, the general quoted cost range is between $28 to $34 per ton (equivalent to approximately $40 to $55 per cy, including transportation) depending on the quantity required. The sediments would need to be rehandled out of the haul barge and placed at an upland rehandling site where they would be loaded into trucks or rail cars for transport to the disposal facility.

The project site is located outside of the USACE navigation channel limits and there are no present navigation requirements within the site. However, the Port of Seattle (the current site owner) may in the future identify navigational requirements at the site, which could potentially conflict with a cap. In addition, a 3-foot-thick cap in the area in front of the E-shaped pier could impact navigational access to this pier. The mudline elevation in this area is currently at approximately -20 feet MLLW. A study of potential navigational needs of E-shaped pier users was not performed as a part of this report. Placing a 3-foot cap over the site would also reduce water depths and potentially the width of the channel, which could have an impact on tribal fishing activities, and would also alter the quality and function of existing habitat (converting some subtidal habitat to intertidal habitat).

However, since these potential impacts are not atypical of other sediment capping projects implemented in the Puget Sound region, this alternative was carried forward for detailed evaluation.

8.2.3 Alternative 3: Capping with No Change in Existing Elevations

This alternative would clean up the site by removing a layer of contaminated material throughout the site and capping the remaining surface with clean material to return the site nominally to existing elevations. The cap would be designed to isolate the remaining subsurface sediment contamination from the environment. Similar to Alternative 2, Alternative 3 employs proven and accepted remedial technologies. Permitting for this alternative is also relatively straightforward and similar to the other cleanup alternatives. Institutional controls to prevent disturbance to the cap would be negotiated with the Port of Seattle and other landowners; these controls would include anchoring, dragging, digging, and pile driving without proper conditions. Evaluation of site characteristics, including flow velocity and existing sediment grain size, will need to be taken into consideration in the design of a cap, as discussed under Alternative 2.

Since a cap probably would be placed using mechanical equipment, the dredging equipment could be utilized for construction of a cap, thereby saving mobilization costs. Disposal costs are discussed under Alternative 2. Again, since potential impacts associated with implementation of Alternative 3 are not atypical of other sediment cleanup projects implemented in the Puget Sound region, this alternative was carried forward for detailed evaluation.

8.2.4 Alternative 4: Maximum Practicable Removal of Contaminants

This alternative includes the maximum practicable removal of contaminated sediments by dredging and off-site disposal. For the purpose of development of this alternative, the vertical extent of sediment contamination was defined based on the deepest historical dredge depths recorded by the USACE in this area. Maximum practicable removal would allow the site to be used for a wider range of potential future uses, while minimizing future encumbrances. The sediments would likely be dredged with a mechanical clamshell dredge, loaded into a haul barge, and taken to an approved disposal site. Disposal sites are discussed in Alternative 2. Dredging activities in the vicinity of the two buried Siphon lines would have to be carefully designed to ensure that the Siphons are not damaged. The site would then be backfilled as necessary with clean sand to restore existing aquatic habitat elevations. In the vicinity of the Siphons, this backfill will be an environmental cap that would include appropriate design (e.g., grain size specification) to ensure its long-term integrity and performance. There would be no future use limitations or institutional controls placed on the majority of the site, since all contaminants would be removed – with the exception of those associated with the area over the Siphon.

Alternative 4 employs proven and accepted technologies. Permitting for this alternative would be relatively straightforward and similar to the other cleanup alternatives. Again, since potential impacts associated with implementation of Alternative 4 are not atypical

of other sediment cleanup projects implemented in the Puget Sound region, this alternative was carried forward for detailed evaluation.

8.3 DEVELOPMENT OF ALTERNATIVES

Based on the above analysis, Alternatives 1, 2, 3, and 4 are carried forward for further detailed evaluation. Alternative 1 (No Action) is carried forward only for the purpose of providing a baseline comparison.

To prepare a detailed evaluation, it was first necessary to provide a conceptual design for purposes of evaluation and comparison against other alternatives. In the absence of sufficient design-level information and data, the conceptual design must necessarily rely on assumptions for certain parameters. Key areas requiring assumptions included: 1) the assumed location of an upland staging area(s); 2) source of cap and backfill materials; 3) agency agreement on cleanup levels (**Section 6.2**) and future recontamination risks (**Section 7.3**); and 4) specific permitting requirements applied to the cleanup actions (**Section 6.1**). For this analysis, we have assumed the following:

- Upland sites within the Duwamish Waterway will be available for use as staging areas and rehandling areas. Dredged material typically is placed into haul barges, which require an upland transfer site to offload either into trucks or rail cars for transport to the final disposal location. The former LaFarge property, located adjacent to the site at Terminal 108, is currently vacant and is advertised for lease by the Port of Seattle. This property is 7.2 acres in size, including 5.1 acres of uplands and 2.1 acres of submerged property. An existing rail spur is at the site, though it is unclear if there is sufficient room to queue or load rail cars for transporting to the landfill, or dewatering activities, if required. The E-shaped pier has electrical power and was previously used with a conveyor system to transfer cement from barges to the LaFarge facility. This conveyor system is no longer present, but a similar system could be installed. Rabanco utilizes the former Crowley dock facility on Harbor Island to offload barges and load their rail cars for transport to their landfill in Roosevelt, Washington. This property is also owned by the Port and is expected to be available. For this analysis, it was assumed that the former LaFarge property would not be used (because it may not be available) and that the Crowley facilities would be utilized to offload the barges.
- Availability of sufficient quantity of clean capping material. The traditional source of capping material in the Duwamish River and Elliott Bay areas has been sands from the bi-annual dredging of the turning basin at the southern end of the Duwamish Waterway. Typically, the USACE dredges 100,000 cy of material during each of these events. Demand for these sands is increasing as more projects are proposed; however, a substantial proportion of these materials is still available even for the upcoming (2001/2002) dredging project (H. Arden, USACE, personal communication). However, it is not certain that a sufficient quantity of sands with the necessary specifications (grain size and chemical quality) would be available from the turning basin at the time the project is undertaken. Therefore, cost estimates developed for this evaluation used the

conservative assumption that capping material would be purchased and delivered from an upland quarry. It is possible, and even likely, that suitable capping material would be available from the turning basin and the total cost would be reduced appropriately.

- Cleanup standards and recontamination risk. We have assumed that the prospective cleanup standards for this remedial action are the SQS chemical criteria, and that the future risk of site recontamination can be acceptably managed through the implementation of upland source controls and appropriate coordination with cleanup of the adjacent waterway. Based on the preliminary recontamination modeling presented in **Section 7.3** and **Appendix P**, if cleanup of adjacent sediment areas is accomplished with approximately 5 years following the Duwamish/Diagonal remedial action, the risk of recontamination may be acceptably small.
- Future development actions may affect the site. For example, potential future redevelopment activities by the Port of Seattle or channel widening and deepening projects by the USACE, could require additional cleanup and remediation in the future.

8.3.1 Alternative 1: No Action

Under this alternative, no remedial action would occur. The site would remain as is. No institutional controls would be implemented and no long-term monitoring would occur. Monitoring of the Diagonal Way CSO/SD outfall as required for NPDES permits or other programs would occur as normal. This alternative is carried forward for comparative purposes.

8.3.2 Alternative 2: Maximum Practicable Containment

Capping is typically accomplished using mechanical methods. For marine aquatic sites, a typical method is to position a bottom dump barge loaded with capping material (i.e., typically sand) over the site and then slowly open the barge doors as the barge is towed across a portion of the site to deposit the cap material with minimum disturbance. The falling material covers the site at that location and the barge is repositioned during the next discharge activity. If greater control during cap placement is required, the capping material can be offloaded from a flat deck or haul barge with dozer or front end loader, or rehandled onto the site directly by crane with a bucket. Another mechanical option includes using a conveyor system to transport the capping material to the site. It is anticipated that capping equipment will be located on the water due to limited access to the site from the shore. Because of the nearshore slopes at the site, it is also anticipated that any capping activity on the nearshore slope would be performed using a crane and bucket to rehandle the capping material from a floating barge directly onto the site. Rehandling the material increases the construction cost but provides tighter control of the cap depth and extent.

Capping material can be obtained from USACE maintenance dredging activities in the turning basin of the Duwamish River or other Puget Sound regions, or material potentially could be imported from an upland sand and gravel facility. Obtaining capping

material from other dredging projects would require logistical coordination between projects. Capping on the existing slope will require that the post-construction cap slope be no steeper than approximately 3H:1V due to the angle of natural repose of the capping material (**Figures 8-1** and **8-2**). Cap material on the existing intertidal slope would probably consist of a select mix of sand and gravel, and, if determined necessary during the design phase of this project, cobble sized material for cap stability and slope stability issues. Because existing sediment classification ranges from sandy silts to silty sands with more sand towards the shore, a select mixture with coarser material will protect against cap erosion better than using similarly graded material as in situ. The preliminary volume of capping material needed for Alternative 2 is 22,000 cy (33,000 tons), based on a minimum 3-foot cap with 3H:1V nearshore slope.

Estuarine caps are subjected to dynamic forces and can potentially shift to a more stable configuration. The cap design would anticipate this condition. Future monitoring including condition surveys would be performed to verify the long-term stability and integrity of the cap and whether any maintenance of the cap would be necessary.

A thick-layer cap would isolate any contamination from the environment and would generally raise the elevation of the site under this alternative by 3 feet, thereby increasing the area of shallow subtidal, low intertidal, and high intertidal habitat zones.

The area immediately adjacent to the navigation channel would need to be dredged so that there would be minimal encumbrances on future USACE maintenance needs. The navigation channel has an authorized depth of -30 feet MLLW. Sediments would be removed to an elevation of -35 feet, resulting in approximately 9,000 cy (13,500 tons) of dredged material. Then a 3-foot cap would be placed over this area and the entire site. This will allow the normal 2-foot tolerance (i.e., overdepth allowance and/or advance maintenance depth) between the authorized depth of the navigation channel and the top of the environmental cap. Similarly, approximately 500 cy would be removed near the outfalls to allow a 3-foot cap that would not interfere with discharge flows. The existing riprapped bank would have a dressing of armor stone and fish mix placed on it (approximately 1,700 cy [2,500 tons]).

The sediments would likely be dredged with an 8-to-12-cy mechanical clamshell dredge bucket, loaded into a haul barge, and taken to an offloading and rehandling site. As discussed earlier, Rabanco's Roosevelt Landfill is used as a representative disposal facility for this evaluation. The haul barge would be moved using a tugboat. The dredged material could be dewatered directly on the barge or dewatering could occur on the upland site, if necessary. Rabanco would offload the sediments at the Crowley dock on Harbor Island, place them in a lined container and transport them to the landfill.

As Rabanco's landfill has a moisture deficit, dewatering is not anticipated. If dewatering were required, it could occur on the barge or at an upland facility. If dewatering were to occur on the barge only, free water would be discharged through a filter system to reduce or eliminate suspended solids. If more extensive dewatering were necessary, an upland dewatering area could be constructed. This area typically includes construction of a diked area, with retaining berms or other structures to prevent the loss of contaminated

sediment off site. The area may need to be lined to address groundwater contamination concerns. Since there is a relatively high percentage of coarse sediment (i.e., sand) within the dredge area, more complicated and expensive dewatering methods (e.g., presses and centrifuges) are not expected to be required.

The construction monitoring plan for dredging would include impacts to water quality and tribal fishing.

Based on the recontamination modeling performed on the Duwamish outfall and discussed in **Section 8.4**, it appears that the cap could become recontaminated by phthalates in the vicinity of the Duwamish/Diagonal outfalls if upland source controls are not implemented prior to initiation of this remedial action. In the absence of complete source control, it is possible that a sediment impact zone, as allowed for under the SMS, would be required. The size and duration of the impact zone would be determined during the design phase of the project using the methods described in WAC 173-204-590.

The recontamination analysis for dredging adjacent locations, discussed in **Section 7.3**, indicated that adjacent sites may recontaminate the Duwamish/Diagonal site with PCBs to a level greater than the SQS (but less than the MCUL), if cleanup of these areas is not appropriately coordinated. If this recontamination occurs, one mitigation measure that could be required by the regulatory agencies would be for the sponsor of the adjacent project to place an additional thin-cap layer (e.g., 0.5 feet thick) over the Duwamish/Diagonal site to reduce contaminant levels at the site to below the SQS. Alternative approaches may also be appropriate.

Institutional controls would also need to be included with this alternative to ensure the future integrity of the cap (e.g., limitations on anchoring, dredging, and construction).

8.3.3 Alternative 3: Capping with No Change in Existing Elevations

This alternative includes dredging a minimal amount of contaminated material and capping the site back to existing elevations with clean sands and other materials required to ensure stability (**Figures 8-3** and **8-4**). This would allow for all existing site uses to continue or any future site uses to be performed under the current conditions. In addition, all the existing habitat elevations would remain intact. The sediments would likely be dredged with a mechanical clamshell dredge (8 to 12 cy bucket), loaded into a haul barge and taken to an approved disposal site. Disposal sites are discussed in Alternative 2. The precise design of the isolation cap will be determined during the design phase of the project, but it is expected that it will be a minimum of approximately 3 feet thick. The minimum 3-foot cut in this area is estimated to be approximately 42,500 cy (63,750 tons). Due to construction limitations of working on a slope, this translates to an average cut of 5.3 feet across the site. As in Alternative 2, this alternative includes advance maintenance dredging at the channel boundary to allow the cap to remain 2 feet below the USACE 30-foot channel depth. Institutional controls would be included with this alternative to ensure the future integrity of the cap.

Mechanical dredging would be accomplished using a clamshell dredge from a floating barge. Dredging can also take place using a crane with clamshell from the shore if the

crane has sufficient reach to dredge the sediment. For this site, the area to be dredged is located on the east side of the Duwamish River, and has limited access from shore. Therefore, dredging would be most effective from a floating barge. A haul barge would be tied up next to the mechanical dredge barge and will be used to transport the dredged material to the upland rehandling site, as discussed in **Section 8.3.2**.

The toe of dredging near the shoreline will be set back sufficient distance to avoid undermining the existing slope. A slope of 3H:1V has been used for external side slopes and 2H:1V for internal slopes, due to the depth of the cuts (**Figure 8-4**). The minimum 3-foot cut in this area is estimated to be approximately 42,500 cy (63,750 tons) of dredged material. **Section 8.3.2** discusses the thick-layer cap technology including material type, sources, and techniques for placement. The preliminary volume of capping material needed to return the site to original grade is approximately 42,500 cy (63,750 tons). The existing riprapped bank would have a dressing of armor stone with fish mix placed on it (approximately 1,700 cy [2,500 tons]) to ensure the long-term stability of the slope and create a more fish-friendly slope.

Sediment recontamination risks and contingency measures would be as generally described for Alternative 2.

8.3.4 Alternative 4: Maximum Practicable Removal of Contaminants

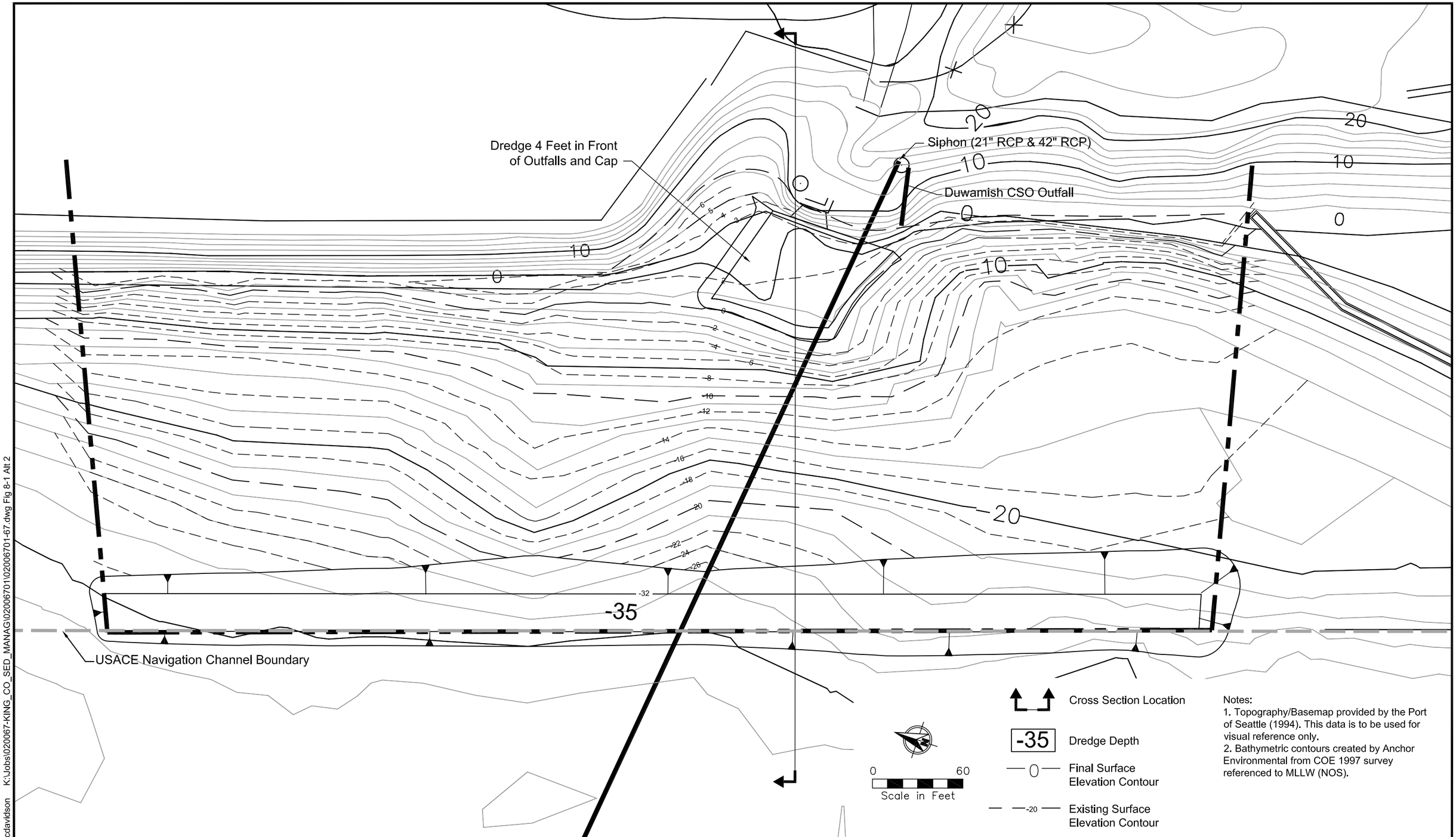
This alternative includes removal of the maximum amount of contaminated sediments practicable by dredging to historical dredge depths (**Figures 8-5** and **8-6**). Not all contaminated sediments can be removed in the vicinity of the Siphons. This will allow the site to be used for any future use with minimal future encumbrances. This alternative will likely involve the removal of approximately 82,000 cy (123,000 tons) of contaminated sediments. The sediments would likely be dredged with a mechanical clamshell dredge (8-to-12-cy bucket), loaded into a haul barge, and taken to an approved disposal site. Disposal sites are discussed in Alternative 2 (**Section 8.3.2**).

Dredging activities in the vicinity of the two buried Siphon lines would be carefully designed to ensure that the Siphons are not damaged. The site would then be backfilled with clean sand to restore the elevations for valuable habitat. However, in the vicinity of the Siphons this backfill will be an environmental cap and would need to include appropriate grain size to prevent erosion. By leaving a minimum of 5 feet of cover over the Siphons during dredging activities and capping with clean material back to existing grade, the Siphons will have a 10- to 15-foot-thick clean cap (15 to 20 feet total) over it. **Section 8.3.2** discusses the thick layer cap technology including material type, sources, and techniques for placement. The preliminary volume of capping and backfill material needed to return the site to original grade is approximately 82,000 cy (123,000 tons). The existing riprapped bank would have a dressing of armor stone and fish mix placed on it (approximately 1,700 cy [2,500 tons]). There would be no future use limitations or institutional controls placed on the site except in the vicinity of the Siphons, since all contaminants would be removed.

The toe of dredging near the shoreline will be set back sufficient distance to avoid undermining the existing slope. A slope of 3H:1V has been used for external side slopes

and a slope of 2H:1V has been used for internal slopes due to the depth of the cuts (**Figure 8-6**).

Sediment recontamination risks and contingency measures would be as generally described for Alternative 2.



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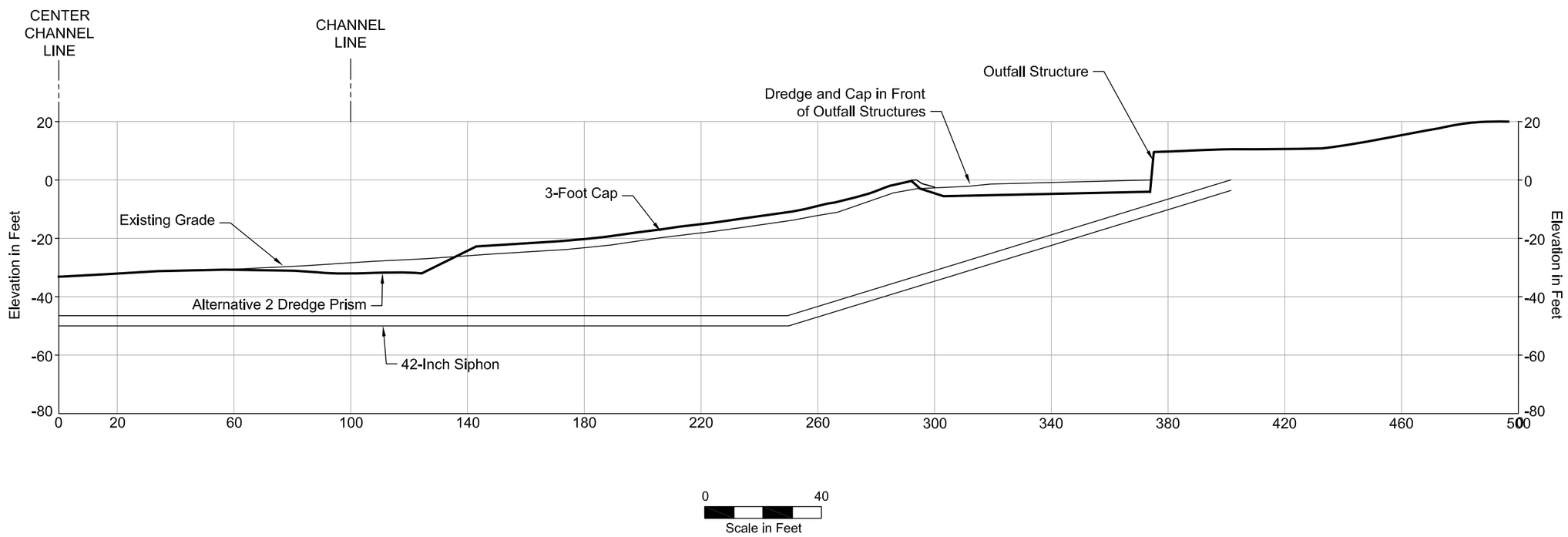
Duwamish/Diagonal Sediment Remediation Project

Alternative 2: Maximum Practicable Containment (Plan View)

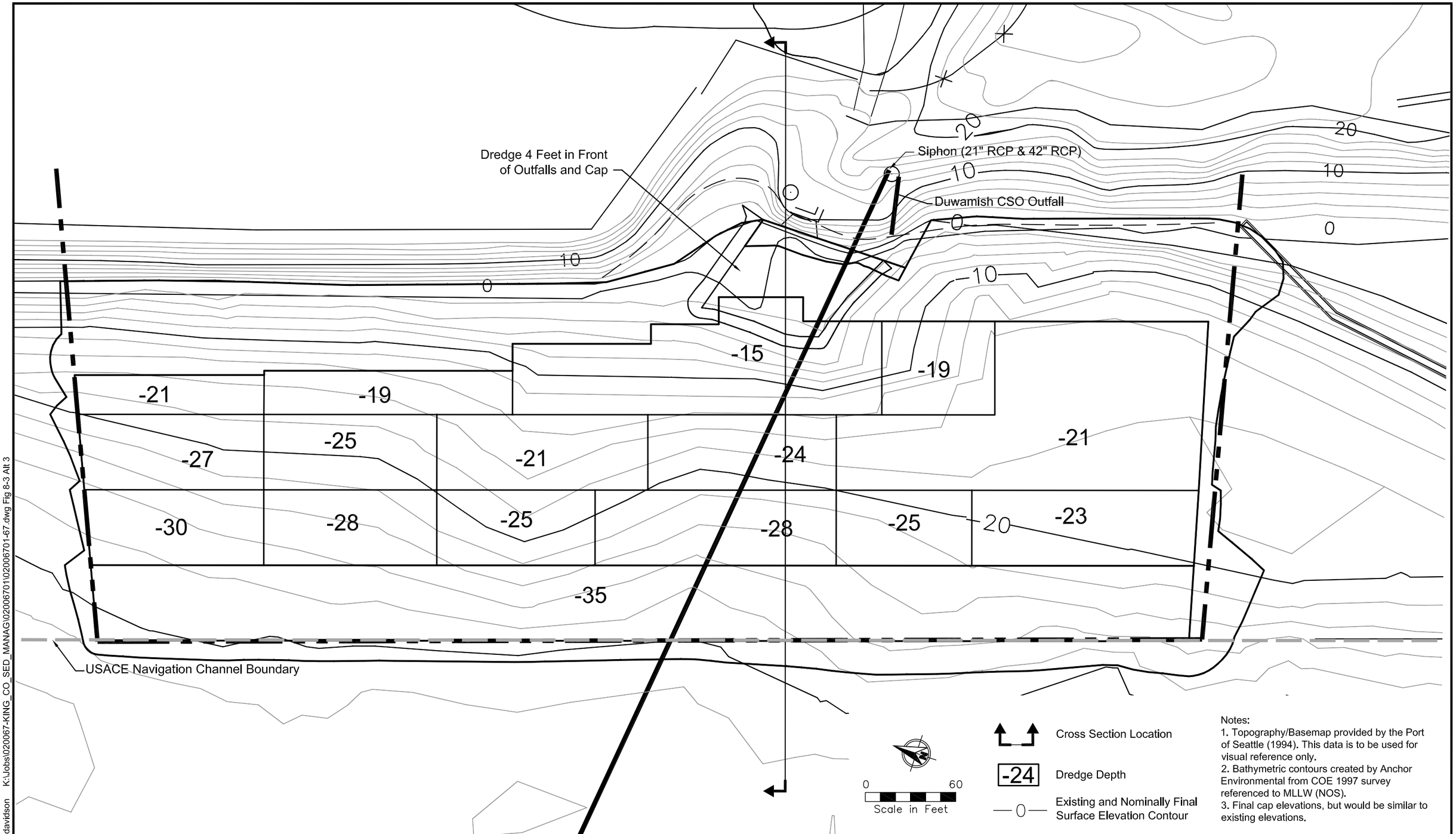
Figure 8-1

Sep 20, 2005 1:41pm cdavidson K:\Jobs\020067-KING_CO_SED_MANAG\02006701\02006701-67.dwg Fig 8-1 Alt 2



Sep 08, 2005 1:53pm cdavidson K:\Jobs\020067-KING_CO_SED_MANAG\02006701\02006701-45.dwg Alt 2 Figure 8-2

EcoChem Team	Duwamish/Diagonal Sediment Remediation Project	Figure 8-2
	Altternative 2: Cross Section	



Notes:
1. Topography/Basemap provided by the Port of Seattle (1994). This data is to be used for visual reference only.
2. Bathymetric contours created by Anchor Environmental from COE 1997 survey referenced to MLLW (NOS).
3. Final cap elevations, but would be similar to existing elevations.

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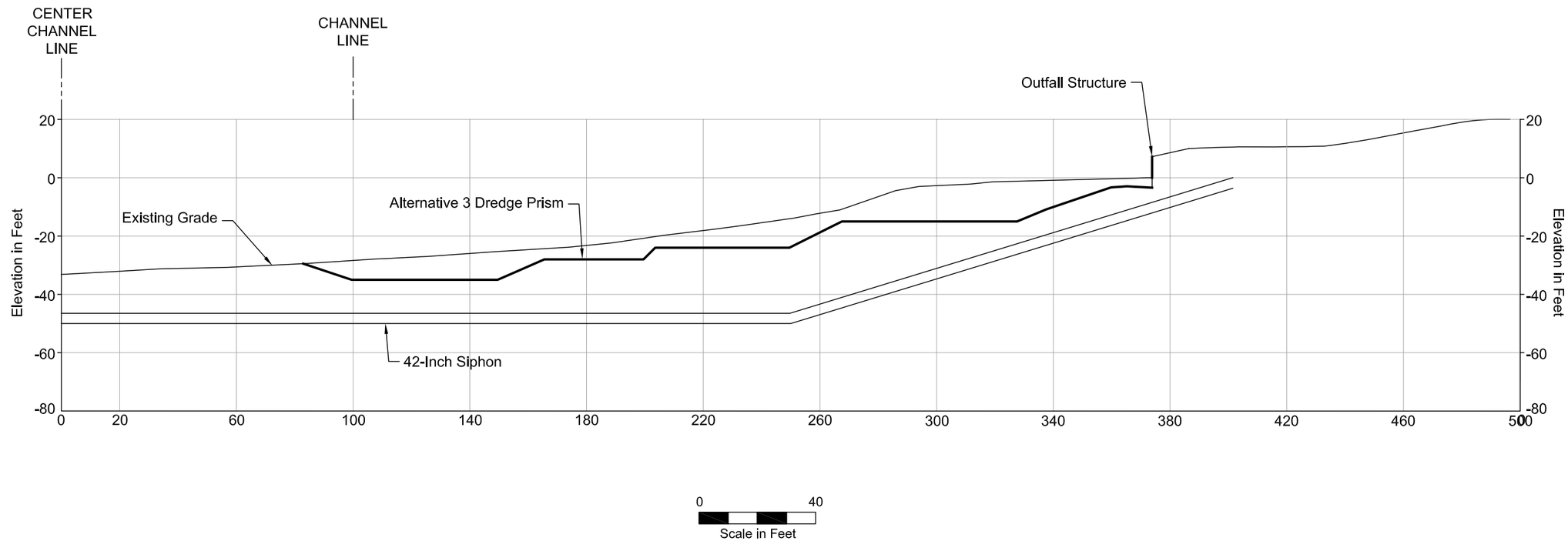
Duwamish/Diagonal Sediment Remediation Project

Alternative 3: Capping with No Change in Existing Elevations, Dredge Layout (Plan View)

Figure 8-3

Sep 20, 2005 1:42pm cdavidson K:\Jobs\020067-KING_CO_SED_MANAG\02006701\02006701-67.dwg Fig 8-3 Alt 3



Sep 08, 2005 1:53pm cdavidson K:\Jobs\020067-KING_CO_SED_MANAG\02006701\02006701-45.dwg Alt 3 Figure 8-4

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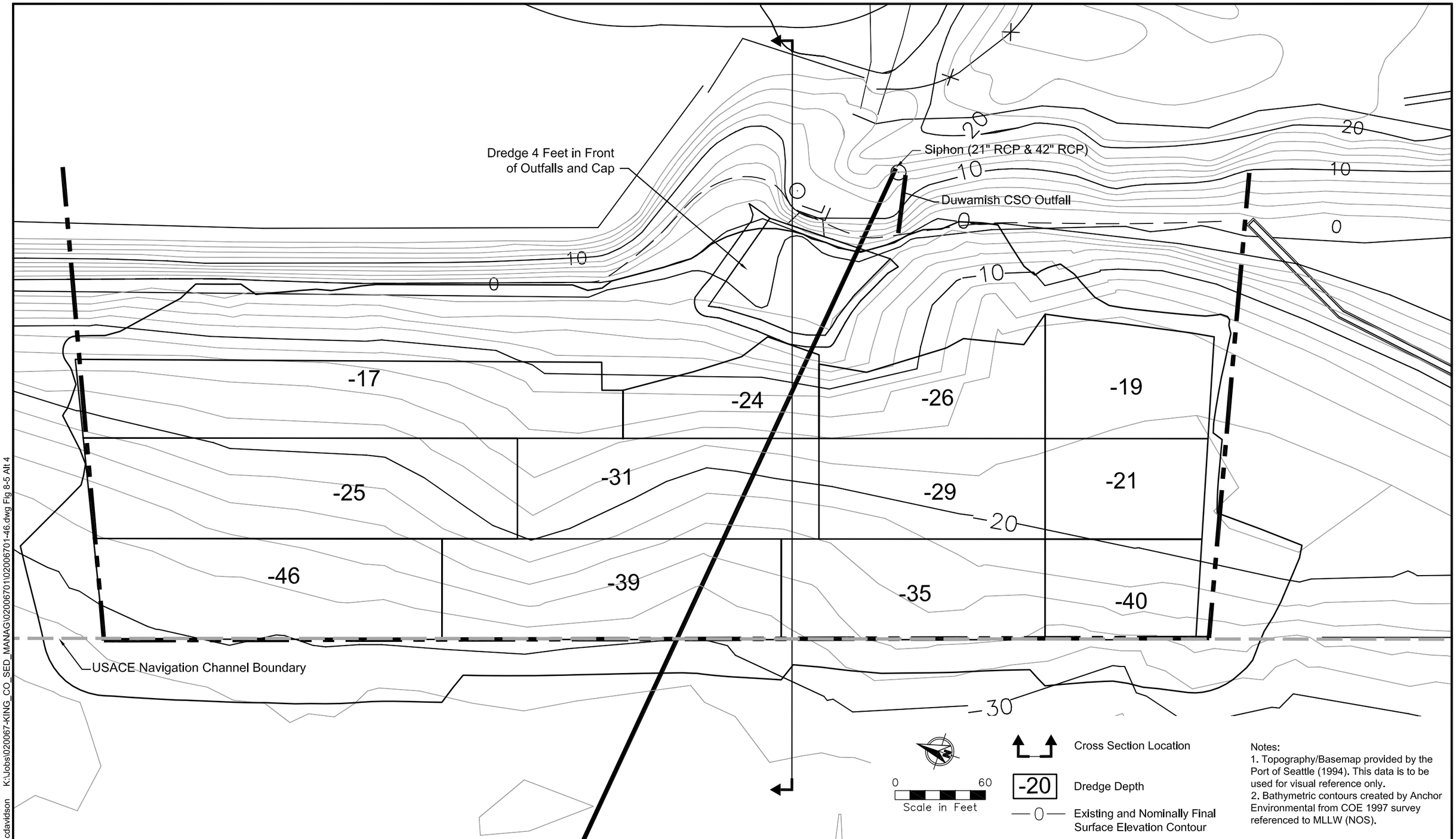
Duwamish/Diagonal Sediment Remediation Project

Altternative 3: Cross Section

Figure 8-4



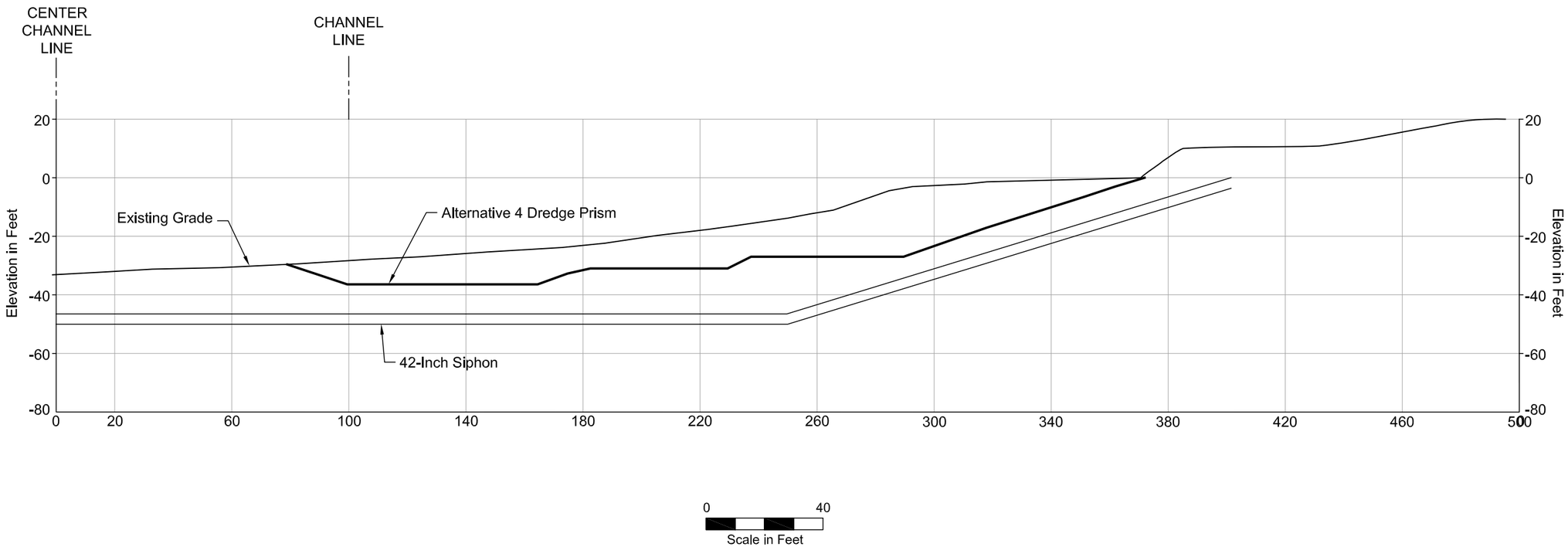
EcoChem Team

Duwamish/Diagonal Sediment Remediation Project

Alternative 4: Maximum Practicable Removal of Contanimants, Dredge Layout (Plan View)

Figure 8-5

Sep 07, 2005 2:30pm cdavidson K:\Jobs\020067-KING_CO_SED_MANAG\02006701\02006701-46.dwg Fig 8-5 Alt 4



Sep 28, 2005 3:32pm cdavidson K:\Jobs\020067-KING_CO_SED_MANAG\02006701\02006701-68.dwg FIG 8-6

EcoChem Team

Duwamish/Diagonal Sediment Remediation Project

Alternative 4: Cross Section

Figure 8-6

9 DETAILED EVALUATION OF ALTERNATIVES

In Chapter 8, technology and process options were assembled into alternatives and were screened using the threshold criteria of technical effectiveness, implementability, cost effectiveness, and adverse impacts. In this chapter, the alternatives are evaluated in detail against eight criteria presented in WAC 173-204-560(4)(f)(iii). These criteria include:

1. Overall protection of human health and the environment, time required to attain the cleanup standard(s), and on-site and off-site environmental impacts and risks to human health resulting from implementing the cleanup alternatives.
2. Compliance with cleanup standards and applicable federal, state, and local laws.
3. Short-term effectiveness, including protection of human health and the environment during construction and implementation of the alternative.
4. Long-term effectiveness, including degree of certainty that the alternative will be successful, long-term reliability, magnitude of residual biological and human health risk, effectiveness of controls for ongoing discharges, management of treatment residues, and disposal site risks.
5. The ability to be implemented including the potential for landowner cooperation, technical feasibility, availability of needed off-site facilities, services, and materials, administrative and regulatory requirements, scheduling, monitoring requirements, access for construction, operations and monitoring, and integration with existing operations and other current or potential cleanup actions.
6. Cost, including consideration of present and future direct and indirect capital, operation, and maintenance costs and other foreseeable costs.
7. The degree to which community concerns are addressed.
8. The degree to which recycling, reuse, and waste minimization are employed.

This chapter concludes with a comparison of the alternatives and the selection of the preferred alternative.

9.1 ALTERNATIVE 1: NO ACTION

The No Action alternative is included as a baseline alternative to which other alternatives can be compared. Under this alternative no remedial action or institutional controls would be implemented and nothing would be done to mitigate existing impacts to human health and the environment. Improvement in the level of contamination at the site resulting from degradation of contaminants by natural chemical, physical, and biological processes is unlikely.

9.1.1 Overall Protection of Human Health and the Environment

This alternative would not provide protection of human health and the environment because no remedial action would be performed.

9.1.2 Compliance with Cleanup Standards and Applicable Laws

This alternative does not comply with cleanup standards or applicable laws since phthalate, PCB, and mercury contamination would remain exposed on site at concentrations above the MCUL.

9.1.3 Short-Term Effectiveness

This alternative is not effective in the short term, but would also not result in any short-term increases in contaminant releases beyond existing conditions.

9.1.4 Long-Term Effectiveness

The long-term risk remains unchanged under this alternative.

9.1.5 Implementability

There are no actions to implement under this alternative.

9.1.6 Cost

There is no cost associated with this alternative.

9.1.7 Community Concerns

There would not be a public comment period, as there would be no action to trigger such comment. However, it is assumed that this alternative may not be acceptable to the public.

9.1.8 Employment of Recycling, Reuse, and Waste Minimization

There are no recycling, reuse, or waste minimization procedures associated with this alternative.

9.2 ALTERNATIVE 2: MAXIMUM PRACTICABLE CONTAINMENT

This alternative would place a thick cap (3 feet) of clean sand or other appropriate grain size to avoid erosion over the site to contain the contaminated sediments. This would isolate contamination from the environment and would generally raise the elevation of the site by 3 feet, thereby increasing the area of shallow subtidal and low intertidal habitat zones. The area immediately adjacent to the navigation channel would have to be dredged to minimize encumbrances on future maintenance needs. The area in front of the outfall would also have to be dredged, so the cap would not impede discharge flows.

9.2.1 Overall Protection of Human Health and the Environment

This alternative will provide protection of human health and the environment by isolating contaminated materials. Engineering controls would be instituted during dredging, dewatering, and capping operations to ensure that dredged material and water are properly contained and disposed of and the potential for resuspension of contaminants is minimized during dredging and capping operations. Any dredged sediment would be disposed of in an approved disposal facility. Cleanup standards would be met once the cap is entirely in place. Placing a thick-layer cap would likely smother the existing benthic community. Similarly, dredging of contaminated sediments will temporarily

disrupt and/or destroy the existing benthic community. Recolonization would be expected to occur within a year of the remedial action. Placing a thick-layer cap over the existing sediments will increase the elevation of those sediments. Approximately two-thirds of the site is located below -13 feet MLLW; therefore, placing a 3-foot thick cap over the site may not materially affect the habitat type in this portion of the site. However, areas located above -13 feet MLLW may change from deep subtidal zone to shallow subtidal zone, shallow subtidal zone to low intertidal zone, or low intertidal zone to high intertidal zone. Generally, the low intertidal zone (-4 to +4 feet MLLW) is considered to have a greater habitat value for salmonids. This thick layer cap would increase the amount of low intertidal habitat by approximately 0.19 acres.

9.2.2 Compliance with Cleanup Standards and Applicable Laws

This alternative would comply with cleanup standards and all applicable laws. All required permits would be obtained prior to performing the remedial activities. Water quality permits would be obtained and implemented to ensure that water quality is not degraded during dredging and capping. The dredged materials would be placed in a fully permitted disposal facility.

9.2.3 Short-Term Effectiveness

Dredging and capping could create limited adverse water quality impacts at the site resulting from sediment suspension in the water column. Resuspension could cause turbidity and migration of sediments. If turbidity is anticipated to reach levels of concern, silt curtains could be used to limit migration. Work would not be performed during the time that juvenile salmonids migrate through the area. Engineering controls would be required to prevent or contain spillage during transfer operations from the haul barge to the upland rehandling site.

9.2.4 Long-Term Effectiveness

This alternative is effective in the long term because it isolates all contaminated materials either in approved disposal facilities or under a thick-layer cap.

To ensure the long-term effectiveness of this alternative, the area immediately adjacent to the navigation channel would have to be dredged so that future maintenance actions undertaken within the navigation channel would not affect the integrity of the cap. Institutional controls to prevent disturbance to the cap would be negotiated with the Port of Seattle and other landowners; these controls would include no anchoring, dragging, digging, and pile driving without proper conditions.

As the project proponent, King County may request that a sediment impact zone (SIZ) in compliance with WAC 173-204-590 be approved by Ecology. King County and Ecology will continue to discuss whether or not analysis of a SIZ for this project is appropriate.

The PCB modeling performed in **Section 7.4** predicts that the final surface would temporarily recontaminate to levels greater than the SQS but significantly below the MCUL due to the general flux of PCB within the waterway. As additional cleanup projects are performed under the MTCA and CERCLA programs, this background level

will be reduced and it is anticipated that PCB concentrations will eventually be reduced to levels below the SQS.

9.2.5 Implementability

This alternative is technically implementable. Dredging and capping are reliable, proven technologies. No difficulty in obtaining right-of-entry and access agreements for construction is anticipated. The equipment is available locally. However, there are three possible difficulties with implementation of this alternative. First it has the potential to impact Tribal Treaty fishing by altering the bathymetry. Second, the Port of Seattle owns the adjacent properties and would likely resist any alternative that would limit their current uses of the site, including the reduced water depths in the vicinity of the E-shaped pier. Finally, the National Marine Fisheries Service (NMFS) and USFWS may resist the filling of the site due to a net loss of shallow subtidal habitat.

The offloading and rehandling site at the former Crowley dock at Harbor Island (which is owned by the Port of Seattle) is expected to be available for use. If for some reason it were not available, Rabanco has agreements with the Port of Seattle to utilize other similar facilities. If dewatering were required prior to loading the sediments into the railcars, a dewatering facility would be constructed at the offloading site.

9.2.6 Cost

The estimated cost for this alternative is $2,390,000. The preliminary cost estimate is detailed in **Table 9.1**.

9.2.7 Community Concerns

It is not possible to evaluate the community's concerns regarding this alternative until after the public comment period. The public comment period will extend for a 30-day period during which the public will be asked to provide their evaluation, advice, and any concerns they have regarding all potential alternatives.

9.2.8 Employment of Recycling, Reuse, and Waste Minimization

There are no recycling, reuse, or waste minimization procedures associated with this alternative.

9.3 ALTERNATIVE 3: CAPPING WITH NO CHANGE IN EXISTING ELEVATIONS

This alternative includes dredging sufficient contaminated material to allow placement of a thick-layer cap and retention of existing elevations. This would allow existing site uses to continue and future site uses to be performed under the current conditions. The existing habitat elevations would remain.

Table 9-1
Cost Estimate for Alternative 2: Maximum Practicable Containment

Item	Quantity	Unit	Unit Cost	Cost	Notes
Preconstruction					
Mobilization/Demobilization	1	EA	$ 60,000	$ 60,000	1, 2
Pre- and Post-Dredge Surveys	4	EA	$ 10,000	$ 40,000	
Dredge and Transport	9,500	CY	$ 10.00	$ 95,000	3, 4, 5, 6, 7
Rehandle to Rail Cars	10,450	CY	$ 2.00	$ 20,900	8, 9
Upland Disposal	15,675	Ton	$ 26.00	$ 407,550	10, 11
Thick Cap					
Purchase and Deliver	33,000	Ton	$ 8.25	$ 272,250	11, 12
Place	33,000	Ton	$ 6.25	$ 206,250	
Armor Shore Protection					
Purchase and Deliver	2,500	Ton	$ 13.00	$ 32,500	11, 13
Place	2,500	Ton	$ 8.50	$ 21,250	
Habitat Mitigation	1	LS	TBD	$ -	14
Subtotal				$ 1,155,700	
Tax		Percent	8.61%	$ 99,506	
Bond		Percent	1%	$ 11,557	
Profit		Percent	10%	$ 115,570	
Total Construction Cost				$ 1,382,333	
Engineering Design		Percent	8%	$ 110,587	
Construction Monitoring/Mgmt.		Percent	5%	$ 69,117	
Legal/ Administrative	3	FTE	$ 90,000	$ 243,000	
Permits, Fees, Misc. Expenses	1	EA	$ 25,000	$ 25,000	
Long Term Monitoring	1	LS	$ 165,000	$ 165,000	15
Total Project Cost				$ 1,995,036	
Contingency		Percent	20%	$ 399,007	
TOTAL (Rounded to $10,000)				$ 2,390,000	

Notes:

1 No demolition of structures required.
2 Coordination with the Port of Seattle not included.
3 No costs for land rental or lease for dewatering facility included.
4 Mechanical dredging with an 8 cy digging bucket
5 Two 1,500 cy haul barges used.
6 One tug boat dedicated to project.
7 Minimal debris will be encountered.
8 Ten percent bulking factor included for rehandling
9 Rail car will be adjacent to the wharf.
10 Disposal cost based on Quote from Rabanco, November 15, 2001. Includes off load from barge, placement into lined container, haul to landfill and tipping fee at landfill. Variation between Alternatives due to quantities.
11 One cubic yard assumed to equal 1.5 tons (or one ton equals 0.67 cubic yard)
12 Prices for sand, gravel, and armor stone from LoneStar Industries. (Could be obtained for minimal cost from Turning Basin.)
13 Shore protection included for dressing up the bank, includes 2-foot thick layer.
14 Habitat Mitigation costs are To Be Determined (TBD)
15 Long -Term Monitoring based on $20,000/yr for 10 yrs; discount=7%, Inflation=3%

9.3.1 Overall Protection of Human Health and the Environment

This alternative will provide protection of human health and the environment by isolating contaminated materials. Engineering controls would be instituted during dredging and dewatering operations to ensure that dredged material and water are properly contained and disposed of and the potential for resuspension of contaminants is minimized during capping operations. Any dredged sediment would be disposed of in an approved disposal facility. Cleanup standards would be met once the cap is entirely in place. Dredging of contaminated sediments will temporarily destroy the existing benthic community. The site would be capped immediately after dredging operations, providing a clean surface for the benthic organisms. Recolonization would be expected to occur within a year of the remedial action. There would be no significant change in the areas of habitat zones under this alternative.

9.3.2 Compliance with Cleanup Standards and Applicable Laws

This alternative would comply with cleanup standards and all applicable laws. All required permits would be obtained prior to performing the remedial activities. Water quality permits would be obtained and control measures would be implemented to ensure that water quality is not degraded during dredging and capping. The dredged materials would be placed in a fully permitted disposal facility.

9.3.3 Short-Term Effectiveness

Dredging and capping could create limited adverse water quality impacts at the site resulting from sediment suspension in the water column. Resuspension could cause turbidity and migration of sediments. If turbidity is anticipated to reach levels of concern, silt curtains could be used to limit migration. In-water work would not be performed during the time that juvenile salmonids migrate through the area. Engineering controls would be required to prevent or contain spillage during transfer operations from the haul barge to the upland rehandling site.

9.3.4 Long-Term Effectiveness

This alternative is effective in the long term because it removes contaminants to an approved disposal facility and isolates remaining contaminated materials under a thick-layer cap.

To ensure the long-term effectiveness of this alternative, the area immediately adjacent to the navigation channel would to be dredged so that future maintenance actions undertaken within the navigation channel would not affect the integrity of the cap. Institutional controls to prevent disturbance to the cap would be negotiated with the Port of Seattle and other landowners; these controls would include no anchoring, dragging, digging, and pile driving without proper conditions.

As the project proponent, King County may request that a SIZ in compliance with WAC 173-204-590 be approved by Ecology. King County and Ecology will continue to discuss whether or not analysis of a SIZ for this project is appropriate.

The PCB modeling performed in **Section 7.4** predicts that the final surface would temporarily recontaminate to levels greater than the SQS but significantly below the MCUL due to the general flux of PCB within the waterway. As additional cleanup projects are performed under the MTCA and CERCLA programs, this background level will be reduced and it is anticipated that PCB concentrations will eventually be reduced to levels below the SQS.

9.3.5 Implementability

This alternative is technically implementable. Dredging and capping are reliable, proven technologies. The equipment is available locally and the site is accessible. No difficulty in obtaining right-of-entry and access agreements is anticipated. **Sections 8.3** and **9.2.5** discuss the assumptions and use of upland rehandling facilities.

9.3.6 Cost

The estimated cost for this alternative is $5,840,000. The preliminary cost estimate is detailed in **Table 9.2**.

9.3.7 Community Concerns

It is not possible to evaluate the community's concerns regarding this alternative until after the public comment period. The public comment period will extend for a 30-day period during which the public will be asked to provide their evaluation, advice, and any concerns they have regarding all potential alternatives.

9.3.8 Employment of Recycling, Reuse, and Waste Minimization

There are no recycling, reuse, or waste minimization procedures associated with this alternative.

9.4 ALTERNATIVE 4: MAXIMUM PRACTICABLE REMOVAL OF CONTAMINANTS

This alternative includes removal, to the maximum extent practicable, of all contaminated sediments by dredging to historical dredge depths. The site would then be backfilled, as necessary, with clean sand to restore it to current elevations. This would allow for all existing site uses to continue and future site uses to be performed under the current conditions. The existing habitat elevations would remain.

9.4.1 Overall Protection of Human Health and the Environment

This alternative will provide protection of human health and the environment by removing, to the maximum extent practicable, all contaminated materials and isolating them in an approved disposal facility. Engineering controls would be instituted during dredging and dewatering operations to ensure that dredged material and water are properly contained and disposed.

Table 9.2

Cost Estimate for Alternative 3: Capping with No Change in Existing Elevations for Area A

Item	Quantity	Unit	Unit Cost	Cost	Notes
Preconstruction					
Mobilization/Demobilization	1	EA	$ 60,000	$ 60,000	1, 2
Pre- and Post-Dredge Surveys	4	EA	$ 10,000	$ 40,000	
Dredge and Transport	42,500	CY	$ 10.00	$ 425,000	3, 4, 5, 6, 7
Rehandle to Rail Cars	46,750	CY	$ 2.00	$ 93,500	8, 9
Upland Disposal	70,125	Ton	$ 24.00	$ 1,683,000	10, 11
Thick Cap					
Purchase and Deliver	63,750	Ton	$ 8.25	$ 525,938	11, 12
Place	63,750	Ton	$ 6.25	$ 398,438	
Armor Shore Protection					
Purchase and Deliver	2,500	Ton	$ 13.00	$ 32,500	11, 13
Place	2,500	Ton	$ 8.50	$ 21,250	
Habitat Mitigation	1	LS	TBD	$ -	14
Subtotal				$ 3,279,625	
Tax		Percent	8.61%	$ 282,376	
Bond		Percent	1%	$ 32,796	
Profit		Percent	10%	$ 327,963	
Total Construction Cost				$ 3,922,759	
Engineering Design		Percent	8%	$ 313,821	
Construction Monitoring/Mgmt.		Percent	5%	$ 196,138	
Legal/ Administrative	3	FTE	$ 90,000	$ 243,000	
Permits, Fees, Misc. Expenses	1	EA	$ 25,000	$ 25,000	
Long Term Monitoring	1	LS	$ 165,000	$ 165,000	15
Total Project Cost				$ 4,865,718	
Contingency		Percent	20%	$ 973,144	
TOTAL (Rounded to $10,000)				$ 5,840,000	

Notes:

1 No demolition of structures required.
2 Coordination with the Port of Seattle not included.
3 No costs for land rental or lease for dewatering facility included.
4 Mechanical dredging with a 12 cy digging bucket
5 Two 1,500 cy haul barges used.
6 One tug boat dedicated to project.
7 Minimal debris will be encountered.
8 Ten percent bulking factor included for rehandling
9 Rail car will be adjacent to the wharf.
10 Disposal cost based on Quote from Rabanco, November 15, 2001. Includes off load from barge, placement into lined container, haul to landfill and tipping fee at landfill. Variation between Alternatives due to quantities.
11 One cubic yard assumed to equal 1.5 tons (or one ton equals 0.67 cubic yard)
12 Prices for sand, gravel, and armor stone from LoneStar Industries. (Could be obtained for minimal cost from Turning Basin.)
13 Shore protection included for dressing up the bank, includes 2-foot thick layer.
14 Habitat Mitigation costs are To Be Determined (TBD)
15 Long -Term Monitoring based on $20,000/yr for 10 yrs; discount=7%, Inflation=3%

9.4.2 Compliance with Cleanup Standards and Applicable Laws

This alternative would comply with cleanup standards and all applicable laws. All required permits would be obtained prior to performing the remedial activities. Water quality permits would be obtained and implemented to ensure that water quality is not degraded during dredging and capping. The dredged materials would be placed in a fully permitted disposal facility.

9.4.3 Short-Term Effectiveness

Dredging and capping could create limited adverse water quality impacts at the site resulting from sediment suspension in the water column. Resuspension could cause turbidity and migration of sediments. If turbidity is anticipated to reach levels of concern, silt curtains could be used to limit migration. Engineering controls would be required to prevent or contain spillage during transfer operations from the haul barge to the upland rehandling site.

9.4.4 Long-Term Effectiveness

This alternative is effective in the long term because it removes contaminants to an approved disposal facility and isolates remaining contaminated materials under a thick-layer cap.

To ensure the long-term effectiveness of this alternative, the area immediately adjacent to the navigation channel would be dredged so that future maintenance actions undertaken within the navigation channel would not affect the integrity of the cap. Institutional controls to prevent disturbance to the cap would be negotiated with the Port of Seattle and other landowners; these controls would include no anchoring, dragging, digging, and pile driving without proper conditions.

As the project proponent, King County may request that a SIZ in compliance with WAC 173-204-590 be approved by Ecology. King County and Ecology will continue to discuss whether or not analysis of a SIZ for this project is appropriate.

The PCB modeling performed in **Section 7.4** predicts that the final surface would temporarily recontaminate to levels greater than the SQS but significantly below the MCUL due to the general flux of PCB within the waterway. As additional cleanup projects are performed under the MTCA and CERCLA programs, this background level will be reduced and it is anticipated that PCB concentrations will eventually be reduced to levels below the SQS.

9.4.5 Implementability

This alternative is technically implementable. Dredging and capping are reliable, proven technologies. The equipment is available locally and the site is accessible. No difficulty in obtaining right-of-entry and access agreements is anticipated. **Sections 8.3** and **9.2.5** discuss the assumptions and use of upland rehandling facilities.

9.4.6 Cost

The estimated cost for this alternative is $10,550,000. The preliminary cost estimate is detailed in **Table 9.3**.

9.4.7 Community Concerns

It is not possible to evaluate the community's concerns regarding this alternative until after the public comment period. The public comment period will extend for a 30-day period during which the public will be asked to provide their evaluation, advice, and any concerns they have regarding all potential alternatives.

9.4.8 Employment of Recycling, Reuse, and Waste Minimization

There are no recycling, reuse, or waste minimization procedures associated with this alternative.

Table 9-3
Cost Estimate for Alternative 4: Maximum Practicable Removal of Contaminants

Item	Quantity	Unit	Unit Cost	Cost	Notes
Preconstruction					
Mobilization/Demobilization	1	EA	$ 60,000	$ 60,000	1, 2
Pre- and Post-Dredge Surveys	4	EA	$ 10,000	$ 40,000	
Dredge and Transport	82,000	CY	$ 10.00	$ 820,000	3, 4, 5, 6, 7
Rehandle to Rail Cars	90,200	CY	$ 2.00	$ 180,400	8, 9
Upland Disposal	135,300	Ton	$ 24.00	$ 3,247,200	10, 11
Thick Cap					
Purchase and Deliver	123,000	Ton	$ 8.25	$ 1,014,750	11, 12
Place	123,000	Ton	$ 6.25	$ 768,750	
Armor Shore Protection					
Purchase and Deliver	2,500	Ton	$ 13.00	$ 32,500	11, 13
Place	2,500	Ton	$ 8.50	$ 21,250	
Habitat Mitigation	1	LS	TBD	$ -	14
Subtotal				$ 6,184,850	
Tax		Percent	8.61%	$ 532,516	
Bond		Percent	1%	$ 61,849	
Profit		Percent	10%	$ 618,485	
Total Construction Cost				$ 7,397,699	
Engineering Design		Percent	8%	$ 591,816	
Construction Monitoring/Mgmt.		Percent	5%	$ 369,885	
Legal/ Administrative	3	FTE	$ 90,000	$ 243,000	
Permits, Fees, Misc. Expenses	1	EA	$ 25,000	$ 25,000	
Long Term Monitoring	1	LS	$ 165,000	$ 165,000	15
Total Project Cost				$ 8,792,400	
Contingency		Percent	20%	$ 1,758,480	
TOTAL (Rounded to $10,000)				$ 10,550,000	

Notes:

1 No demolition of structures required.
2 Coordination with the Port of Seattle not included.
3 No costs for land rental or lease for dewatering facility included.
4 Mechanical dredging with a 12 cy digging bucket.
5 Two 1,500 cy haul barges used.
6 One tug boat dedicated to project.
7 Minimal debris will be encountered.
8 Ten percent bulking factor included for rehandling.
9 Rail car will be adjacent to the wharf.
10 Disposal cost based on Quote from Rabanco, November 15, 2001. Includes off load from barge, placement into lined container, haul to landfill and tipping fee at landfill. Variation between Alternatives due to quantities.
11 One cubic yard assumed to equal 1.5 tons (or one ton equals 0.67 cubic yard)
12 Prices for sand, gravel, and armor stone from LoneStar Industries. (Could be obtained for minimal cost from Turning Basin.)
13 Shore protection included for dressing up the bank, includes 2-foot thick layer.
14 Habitat Mitigation costs are To Be Determined (TBD)
15 Long -Term Monitoring based on $20,000/yr for 10 yrs; discount=7%, Inflation=3%

9.5 COMPARISON OF REMEDIAL ALTERNATIVES

The alternatives are compared below to evaluate their relative performance in relation to each of the eight cleanup study criteria. The purpose of this comparison is to identify advantages and disadvantages of each alternative relative to the others. This will facilitate the selection process by identifying key tradeoffs. For each criterion, the alternatives are qualitatively ranked in order of desirability. **Table 9.4** presents a summary of the alternatives comparison.

Table 9.4 ALTERNATIVES COMPARISON

Criterion	Alternative 1: No Action	Alternative 2: Maximum Practicable Containment	Alternative 3: Capping with No Change in Existing Elevations	Alternative 4: Maximum Practicable Removal of Contaminants
Overall Protection of Human Health and the Environment	Continued environmental exposure. Potential for human exposure to contaminated sediments. Uptake of contaminants by organisms and subsequent ingestion is the primary human exposure pathway.	Isolation and removal of contaminated sediments would eliminate exposure pathways from site.	Removal and isolation of contaminated sediments would eliminate exposure pathways from site. Maintaining existing elevations improves cap stability.	Same as Alternative 3.
Compliance with Cleanup Standards and Applicable Laws	Does not comply.	Isolation and removal of contaminated sediments will comply with cleanup standards. All required permits would be obtained and complied with.	Same as Alternative 2.	Same as Alternative 2.
Short-Term Effectiveness	Not applicable.	Low risk to the public at dredge and handling sites. Workers required to use proper health and safety procedures. Potential water quality issues, which can be addressed.	Similar to Alternative 2, though more material is handled.	Similar to Alternatives 2 and 3, though more material is handled.
Long-Term Effectiveness	Not effective.	Effective as all contaminated sediments are removed or isolated under an engineered cap.	Similar to Alternative 2, though more material is removed.	Similar to Alternatives 2 and 3, though more material is removed.

Criterion	Alternative 1: No Action	Alternative 2: Maximum Practicable Containment	Alternative 3: Capping with No Change in Existing Elevations	Alternative 4: Maximum Practicable Removal of Contaminants
Implementability	No action to implement. Violates Consent Decree	Readily implemented provided navigational and fishing issues are worked out.	Readily implemented.	Same as Alternative 3.
Cost	No cost.	$2.39 million	$5.84 million	$10.55 million
Community Concerns	Assumed to be unacceptable.	Not possible to evaluate until after public comment period.	Same as Alternative 2.	Same as Alternative 2.
Employment of Recycling, Reuse, and Waste Minimization	None.	None.	None.	None.

9.5.1 Overall Protection of Human Health and the Environment

Alternative 1 would not provide any additional protection of human health and the environment. Alternatives 2, 3, and 4 isolate some or most the contaminants with a thick-layer cap, with increasing volumes of removal, respectively. The cap will be designed to be stable for the currents and wave conditions expected at the site. Alternative 2 would reduce the existing water depths by approximately 3 feet, which could increase the velocities in the area of the cap; however, this is not anticipated to be significant, as a 3-foot increase over this portion of the river would decrease the cross-section of the river by approximately 2 percent. Alternative 3 removes approximately 42,500 cy (63,750 tons) of sediment, which would no longer be available for potential release if the cap failed. Alternative 4 removes approximately 82,000 cy (123,000 tons) of sediment, which is all sediment that can be removed without risking potential damage to the siphons.

Overall Protection Ranking: Alternative 4=Alternative 3>Alternative 2>Alternative 1.

9.5.2 Compliance with Cleanup Standards and Applicable Laws

Alternative 1 would not comply with cleanup standards or applicable laws. Alternatives 2, 3, and 4 would isolate or remove all sediments with contaminant concentrations greater than the cleanup standards. Under Alternatives 2, 3, and 4, all applicable permits would be obtained and complied with. It may be easier to obtain permits for Alternatives 3 and 4 due to concerns over nearshore fill, habitat alteration, and tribal fishing rights in Alternative 2. Maintenance access for the navigational channel would be maintained under all of the alternatives. Dredged sediments would be placed in a fully permitted facility.

Overall Compliance Ranking: Alternative 4=Alternative 3>Alternative 2>Alternative 1.

9.5.3 Short-Term Effectiveness

This criterion is not applicable to Alternative 1. Alternatives 2, 3, and 4 employ dredging and capping which could create limited adverse water quality impacts at the dredging site. If resuspension is anticipated to occur at levels of concern, silt curtains could be use to limit migration of suspended sediments. However, silt curtains are not wholly effective in tidal environments. Moreover, the greater the amount of dredging the greater the potential risk for releases during dredging operations. Engineering controls would be required to prevent or contain spillage during transfer operations from the haul barge to the upland rehandling site.

Overall Ranking: Alternative 2>Alternative 3>Alternative 4.

9.5.4 Long-Term Effectiveness

Alternative 1 is not effective in the long-term. Alternatives 2, 3, and 4 are effective because they remove contaminants to an approved disposal facility and isolate remaining contaminated materials under a thick-layer cap. Because Alternative 4 removes more material than Alternative 3 (which removes more than Alternative 2) and places it in an engineered, fully monitored landfill, it is preferred.

All caps placed at the site will be designed to comply with EPA and USACE guidance so that they will be stable. As mentioned above, the 3-foot cap in Alternative 2 will extend above the channel bed will decrease the cross-sectional area of the river by approximately 2 percent. The resultant increase in water velocities is not anticipated to cause the cap to be scoured away (as it would be designed to withstand this), though there would be an increased risk of failure.

To ensure the long-term effectiveness of capping immediately adjacent to the navigation channel, a strip would be dredged to -35 feet MLLW and capped to -32 feet MLLW. This will allow future maintenance actions undertaken within the navigation channel (authorized to a depth of -30 feet MLLW) to avoid affecting the integrity of the cap.

A SIZ authorized by Ecology and in compliance with WAC 173-204-590 may be required for Alternatives 2, 3, and 4 in the vicinity of the Duwamish/Diagonal outfalls, if phthalate releases from the existing stormwater outfalls are not sufficiently controlled. These releases would likely be addressed in the future under the conditions of Ecology's authorization.

The PCB modeling performed in **Section 7.3** and **Appendix P** predicts that the final capped surface of Alternatives 2, 3, and 4 may temporarily recontaminate to levels greater than the SQS but significantly below the MCUL, due to the general flux of PCB within the waterway. As additional cleanup projects are performed under the MTCA and CERCLA programs, this background level will be reduced and it is anticipated that PCB concentrations will eventually be reduced to levels below the SQS.

Overall Ranking: Alternative 4>Alternative 3>Alternative 2>Alternative 1.

9.5.5 Implementability

Alternative 1 is easily implemented, since there is no action to perform; however, this alternative would not be administratively implementable as it would violate the Consent Decree (**Section 6.1.1.2**).

Alternatives 2, 3, and 4 are technically implementable. Dredging and capping equipment and experienced personnel are available locally. The technologies are reliable and proven. The actions taken in Alternatives 2, 3, and 4 are very similar, but the quantities involved differ. It may be easier to obtain permits for Alternatives 3 and 4 due to concerns over nearshore fill, habitat alteration, and tribal fishing rights in Alternative 2.

Overall Implementability Ranking: Alternative 3=Alternative 4>Alternative 2> Alternative 1.

9.5.6 Cost

The estimated total costs for each alternative are summarized below:

Alternative 1: $0
Alternative 2: $2,390,000
Alternative 3: $5,840,000
Alternative 4: $10,550,000

The cost estimates provided in **Tables 9.1** through **9.3** are feasibility study level estimates with an accuracy of -30 percent to +50 percent.

Overall Cost Ranking: Alternative 1>Alternative 2>Alternative 3>Alternative 4.

9.5.7 Community Concerns

It is not possible to compare this criterion for the various alternatives until after the public comment period. It is assumed at this point that action alternatives are preferred over the no action alternative.

9.5.8 Employment of Recycling, Reuse, and Waste Minimization

There are no recycling, reuse, or waste minimization procedures associated with any of the alternatives. The alternatives are equally ranked for this criterion.

9.6 PREFERRED ALTERNATIVE

The preferred alternative is Alternative 3: Capping with No Change in Existing Elevation. For ease of reference this alternative is described again here and a justification for the choice follows the description.

The overall objective of Alternative 3 is to achieve SQS chemical criteria throughout the 4.8-acre cleanup site by removing a layer of the contaminated sediment and installing an isolating cap of clean sediment that maintains existing water depths and river bottom elevations throughout the site. To the extent practicable, this alternative minimizes dredging depths; however, additional dredging is included along the east channel line to

remove possible future encumbrances to navigation deepening of the federal waterway and adjacent berthing areas.

The preferred alternative will achieve this objective by using a combination of proven and accepted remedial technologies. The surface layer throughout the site would be removed by mechanical dredging to accommodate cap backfill and all dredge materials would be disposed off-site. The cap would be designed and constructed in accordance with EPA and USACE standards, in order to ensure its long-term integrity and performance. Upland source controls such as pipe cleaning would be completed as a separate action prior to initiation of this remedial action. A SIZ authorized by Ecology and in compliance with WAC 173-204-590 may be required in the vicinity of the Duwamish/Diagonal outfalls if phthalate input from the Diagonal Way CSO/SD outfall outfall cannot be totally controlled.

Under this preferred alternative, an average of approximately 5 feet (minimum 3 feet) of contaminated sediment (42,500 cy) would be removed from the Duwamish/Diagonal site using a mechanical clamshell dredge. Additional dredging depth is included in a 50-foot wide stripe along the east channel line to ensure that after the cap is placed, the cap surface will be 2 feet below the USACE's 30-foot channel depth. Along the inshore boundary, the dredge cuts are set back so the existing riprap shoreline will not collapse. A slope of 3H:1V has been used for external side slopes and 2H:1V for internal slopes, due to the depth of the cuts (**Figure 8-4**). Dredged sediment will be loaded onto a haul barge for transport to an off-site disposal facility. The four potential off-site disposal facilities are either an upland landfill (as assumed in the cost estimates), a CAD, NCD, or SMURF. The EBDRP Panel will select from among these four prospective disposal/treatment options during remedial design, based on consideration of availability, cost, and other relevant factors. If sediment must be shipped to a disposal facility, an approved transfer operation will be used to offload and ship dredged sediment. (Note: the final disposal option was upland disposal at Rabanco's Roosevelt Regional Landfill.)

Following dredging, the remediation site will be capped with clean backfill material (42,500 cy) to isolate remaining sediment contamination from the environment. The exact thickness of the cap will be determined during design utilizing USACE and EPA guidance documents for designing isolation caps. For the purposes of this report it is assumed that the cap will be a minimum of 3 feet thick, but in many areas of the site the cap thickness will need to exceed 3 feet in order to return the site to existing elevations. Cap material would be chosen for stability and, to the extent possible, for habitat considerations. Although existing sediments are sandy-silt to silty-sands, the capping material selected for this project will probably contain coarser sediment materials to protect against erosion. Medium to coarse grained sand could be used to cap most of the site since this material has been successfully used in several other local capping projects. For the existing intertidal slope, the cap material would probably consist of a select mix of sand and gravel. Cobble-sized material would only be used if the design phase determined it was necessary to ensure stability of the cap and slope in certain areas. The existing riprapped bank would be given a dressing layer of armor stone and fish mix (approximately 1,700 cy [2,500 tons]) to ensure the long-term stability of the slope and create a more fish-friendly slope.

No in-water work would be performed during the time that juvenile salmonids migrate through the area. Institutional controls to ensure the ongoing integrity of the cap would be negotiated with the Port of Seattle and other landowners. These controls include no anchoring, dragging, digging, or pile driving without proper conditions.

Figures 5-2, 5-4, 5-6, and 5-8 have been modified for the *Duwamish/Diagonal Expanded Area Document* (**Appendix R**) to provide Ecology and EPA information they subsequently requested regarding the sediment quality of the material left in place under the cap. Because the dredge prism is located on a slope, a minimum 3 feet would be removed from the nine cores in Area A and five cores in Area B (by definition), and at least 6 feet would be removed at two Area B stations and 9 feet removed at one Area A station. These figures are also included as **Figures R-4** through **R-7** in **Appendix R**.

The following section summarizes the justification for selecting this alternative.

9.6.1 Justification of Preferred Alternative

Under CERCLA, MTCA, and SMS cleanup programs, potential remedial actions must be evaluated relative to a wide range of technical criteria, as presented above in **Chapter 9**. The selected remedy must meet certain threshold requirements, including protection of human health and the environment; compliance with cleanup standards; compliance with applicable state and federal laws; and provision for compliance monitoring. The preferred alternative meets these threshold criteria.

Compliance monitoring would be performed following the completion of the remedial action to ensure the continued effectiveness of the cleanup remedy (see **Appendix Q**). Though some recontamination is expected following construction of the cleanup action (**Section 7.3**), sediment PCB concentrations are not expected to exceed minor effects criteria (e.g., MCUL). However, as other locations within the Duwamish River are remediated, it is expected that PCB levels will be further reduced (**Figures 7-5** and **7-6**) and concentrations will approach no effects criteria (e.g., SQS). Considering potential time frames of two to five years for remediation of surrounding sediment cleanup site, the time frame for restoration of the Duwamish/Diagonal site is expected to be within 10 years.

The selected remedy approved under CERCLA, MTCA, and SMS must also meet other balancing and modifying criteria, including the requirement that the remedy use permanent solutions to the maximum extent practicable. Permanent solutions are defined in the regulations as those remedial actions that meet cleanup standards with a minimum of further action being required either at the site or at the disposal/treatment facility. The MTCA Cleanup Standard Regulation sets forth a process to identify the most permanent remedy from among a range of possible cleanup alternatives (WAC 173-340-360(3)). If all other factors were equal, the remedial alternative that utilizes the greatest degree of on-site or off-site disposal in an engineered, lined, and monitored facility would be ranked more permanent than alternatives with a greater reliance on on-site isolation or containment with attendant engineering controls. If this were the case (i.e., if no other evaluation criterion were to be applied), Alternative 4 – Maximum Practicable Removal of Contaminants would be the most permanent cleanup remedy.

However, MTCA, CERCLA, and SMS regulations also recognize that there may be other important factors, including cost, that need to be considered when determining whether a cleanup action uses permanent solutions to the maximum extent practicable. For example, the MTCA regulation sets forth a general test to determine whether the costs to implement a given cleanup remedy are disproportionate to the benefits achieved by that action. At the Duwamish/Diagonal site, Alternative 2 would be less costly than Alternative 3, which in turn would be less costly than Alternative 4. However, in determining whether the alternative uses permanent solutions to the maximum extent practicable, other balancing and modifying criteria are considered, including:

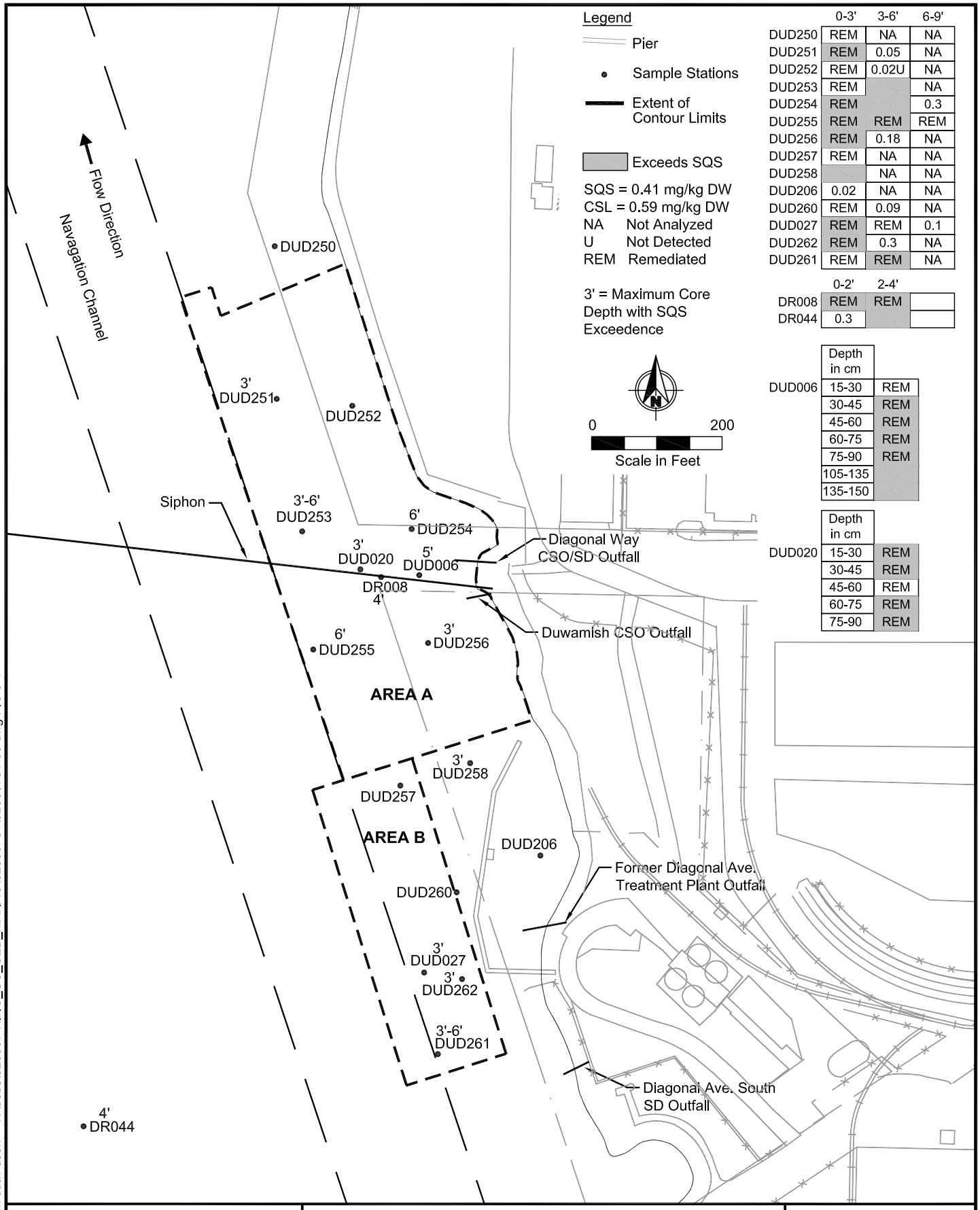
- Protectiveness (Alternatives 2 is ranked less protective than 3 and 4, which are equivalent; see **Table 9.4**)
- Employment of Recycling, Reuse, and Waste Minimization (Alternatives 2, 3, and 4 are equivalent; see **Table 9.4**)
- Effectiveness over the Long Term (because it utilizes the greatest degree of disposal in an engineered, lined, and monitored facility, Alternative 4 is ranked higher than Alternative 3, which is turn is ranked higher than Alternative 2; see **Table 9.4**)
- Management of Short-Term Risks (Alternative 2 is ranked higher than Alternative 3, which in turn is ranked higher than Alternative 4; see **Table 9.4**)
- Technical and Administrative Implementability (Alternatives 3 and 4 are ranked higher than Alternative 2; see **Table 9.4**; also see below)
- Consideration of public concerns (the public is given the opportunity to comment on the Cleanup Study prior to formal selection of the cleanup action).

Based on the preliminary rankings summarized above (i.e., prior to considering public input), Alternative 3: Capping with No Change in Existing Elevation provides the same overall benefits as Alternative 4, but at a significantly lower cost. Both Alternatives 3 and 4 provide greater benefits than Alternative 2. Thus, consistent with the MTCA/SMS evaluation procedure (WAC 173-340-360(3)), Alternative 3 has been preliminarily identified as the option that uses permanent solutions to the maximum extent practicable. This preliminary selection will be reevaluated following public comment.

It is also important to note that the EBDRP Panel currently has only a limited amount of funds available (approximately $8 million) in its Registry Account that can be utilized to implement the Duwamish/Diagonal cleanup action. The estimates presented in **Tables 9.2** and **9.3** indicate that Alternative 3 could be implemented at a total cost of less than $8 million, while the cost to implement Alternative 4 would substantially exceed the Panel's budget. Therefore, without supplemental funding from another entity(ies), Alternative 4 would be considerably more difficult to implement (administratively) than Alternative 3. These budgetary/implementability considerations provide further support for selection of Alternative 3 as the preferred cleanup remedy at the Duwamish/Diagonal Site.

The Cleanup Study Report detailing this preferred alternative was provided to the public for review. In addition, Ecology issued a Cleanup Action Decision document for this site that determines whether Ecology agrees that the proposed project meets the requirements of the SMS and other state laws. Both the Cleanup Action Decision document and the

SEPA checklist were made available for public comment along with the Cleanup Study Report. Public comments received modified the cleanup analysis and/or preferred alternative presented herein. Appendices R, S, and T of this final Cleanup Study Report address concerns brought up by the public and Ecology after the draft Cleanup Study Report was released.



	0-3'	3-6'	6-9'
DUD250	REM	NA	NA
DUD251	REM	0.05	NA
DUD252	REM	0.02U	NA
DUD253	REM		NA
DUD254	REM		0.3
DUD255	REM	REM	REM
DUD256	REM	0.18	NA
DUD257	REM	NA	NA
DUD258		NA	NA
DUD206	0.02	NA	NA
DUD260	REM	0.09	NA
DUD027	REM	REM	0.1
DUD262	REM	0.3	NA
DUD261	REM	REM	NA

	0-2'	2-4'
DR008	REM	REM
DR044	0.3	

	Depth in cm	
DUD006	15-30	REM
	30-45	REM
	45-60	REM
	60-75	REM
	75-90	REM
	105-135	
	135-150	

	Depth in cm	
DUD020	15-30	REM
	30-45	REM
	45-60	REM
	60-75	REM
	75-90	REM

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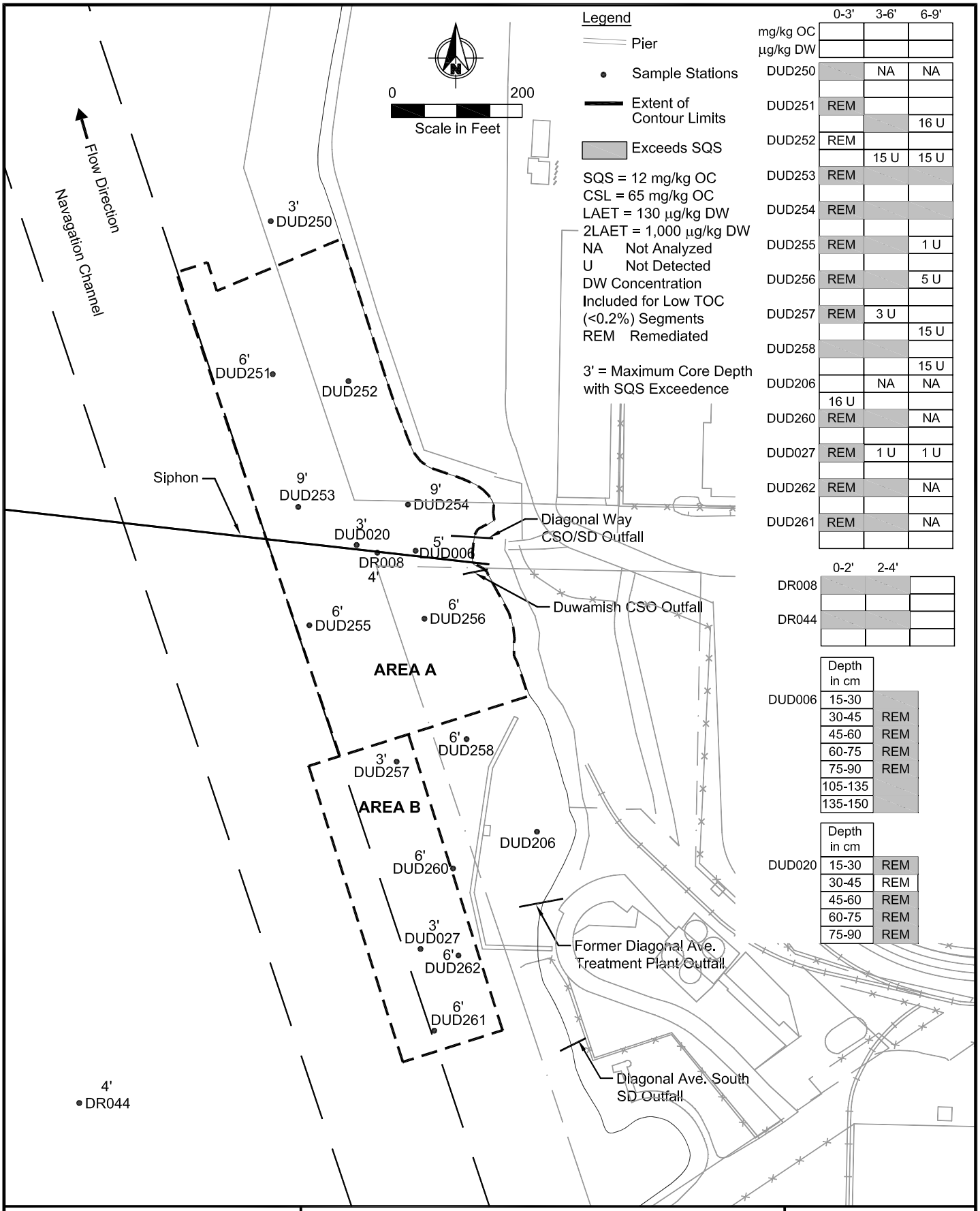
Duwamish/Diagonal Sediment Remediation Project

Mercury Concentrations in Subsurface Sediments

Figure 9-1

Sep 29, 2005 9:42am cdavidson K:\Jobs\020067-KING_CO_SED_MANAG\02006701\02006701-38.dwg FIG 9-1



	0-3'	3-6'	6-9'
mg/kg OC			
µg/kg DW			
DUD250		NA	NA
DUD251	REM		
			16 U
DUD252	REM		
		15 U	15 U
DUD253	REM		
DUD254	REM		
DUD255	REM		1 U
DUD256	REM		5 U
DUD257	REM	3 U	
			15 U
DUD258			
			15 U
DUD206		NA	NA
	16 U		
DUD260	REM		NA
DUD027	REM	1 U	1 U
DUD262	REM		NA
DUD261	REM		NA

	0-2'	2-4'	
DR008			
DR044			

	Depth in cm	
DUD006	15-30	
	30-45	REM
	45-60	REM
	60-75	REM
	75-90	REM
	105-135	
	135-150	

	Depth in cm	
DUD020	15-30	REM
	30-45	REM
	45-60	REM
	60-75	REM
	75-90	REM

Sep 29, 2005 9:45am cdavidson K:\Jobs\020067-KING_CO_SED_MANAG\02006701\02006701-39.dwg FIG 9-2

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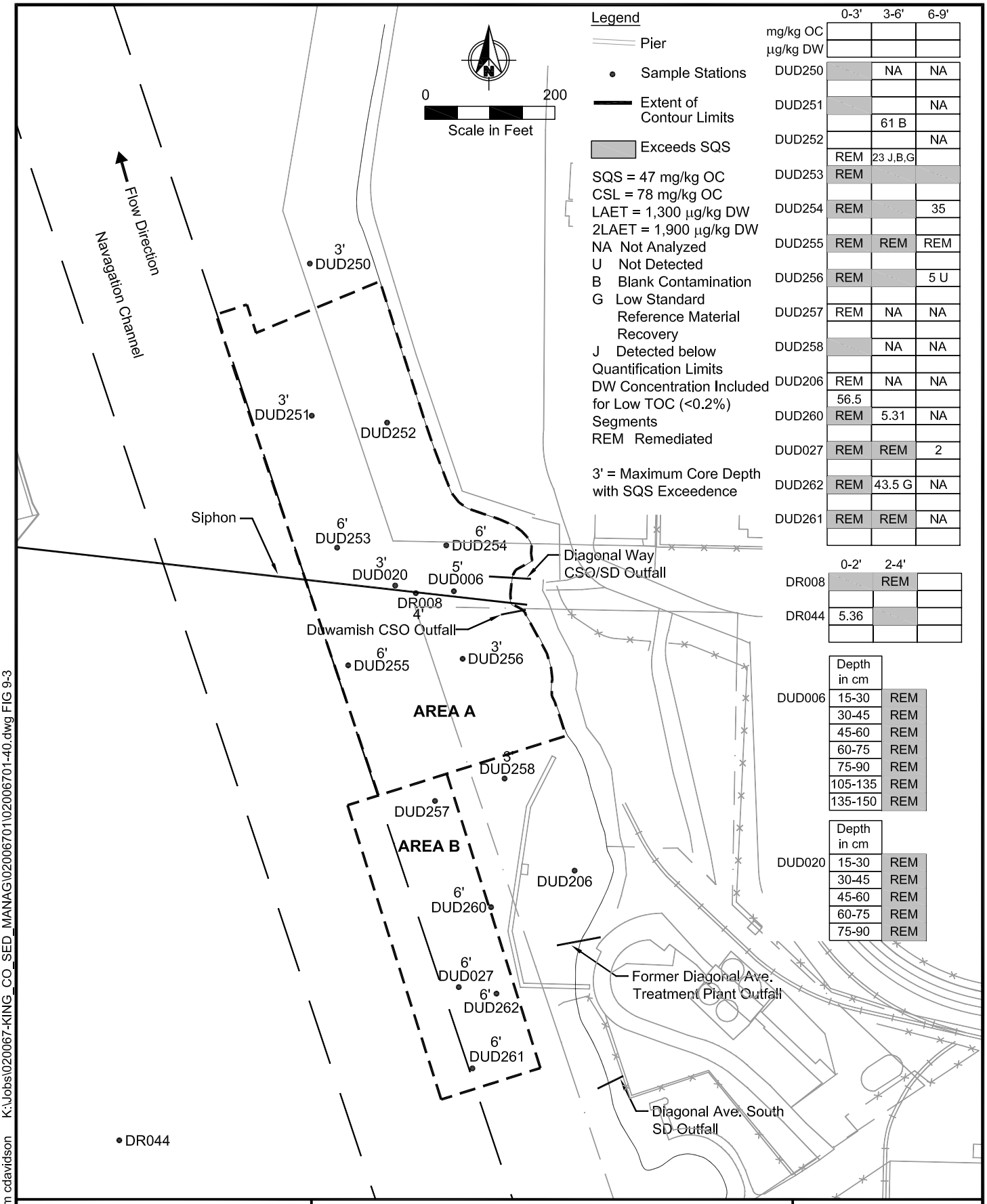
Duwamish/Diagonal Sediment Remediation Project

Total PCBs in Subsurface Sediments

Figure 9-2



	0-3'	3-6'	6-9'
mg/kg OC			
µg/kg DW			
DUD250		NA	NA
DUD251			NA
		61 B	
DUD252			NA
	REM	23 J,B,G	
DUD253	REM		
DUD254	REM		35
DUD255	REM	REM	REM
DUD256	REM		5 U
DUD257	REM	NA	NA
DUD258		NA	NA
DUD206	REM	NA	NA
	56.5		
DUD260	REM	5.31	NA
DUD027	REM	REM	2
DUD262	REM	43.5 G	NA
DUD261	REM	REM	NA

	0-2'	2-4'	
DR008		REM	
DR044	5.36		

	Depth in cm	
DUD006	15-30	REM
	30-45	REM
	45-60	REM
	60-75	REM
	75-90	REM
	105-135	REM
	135-150	REM

	Depth in cm	
DUD020	15-30	REM
	30-45	REM
	45-60	REM
	60-75	REM
	75-90	REM

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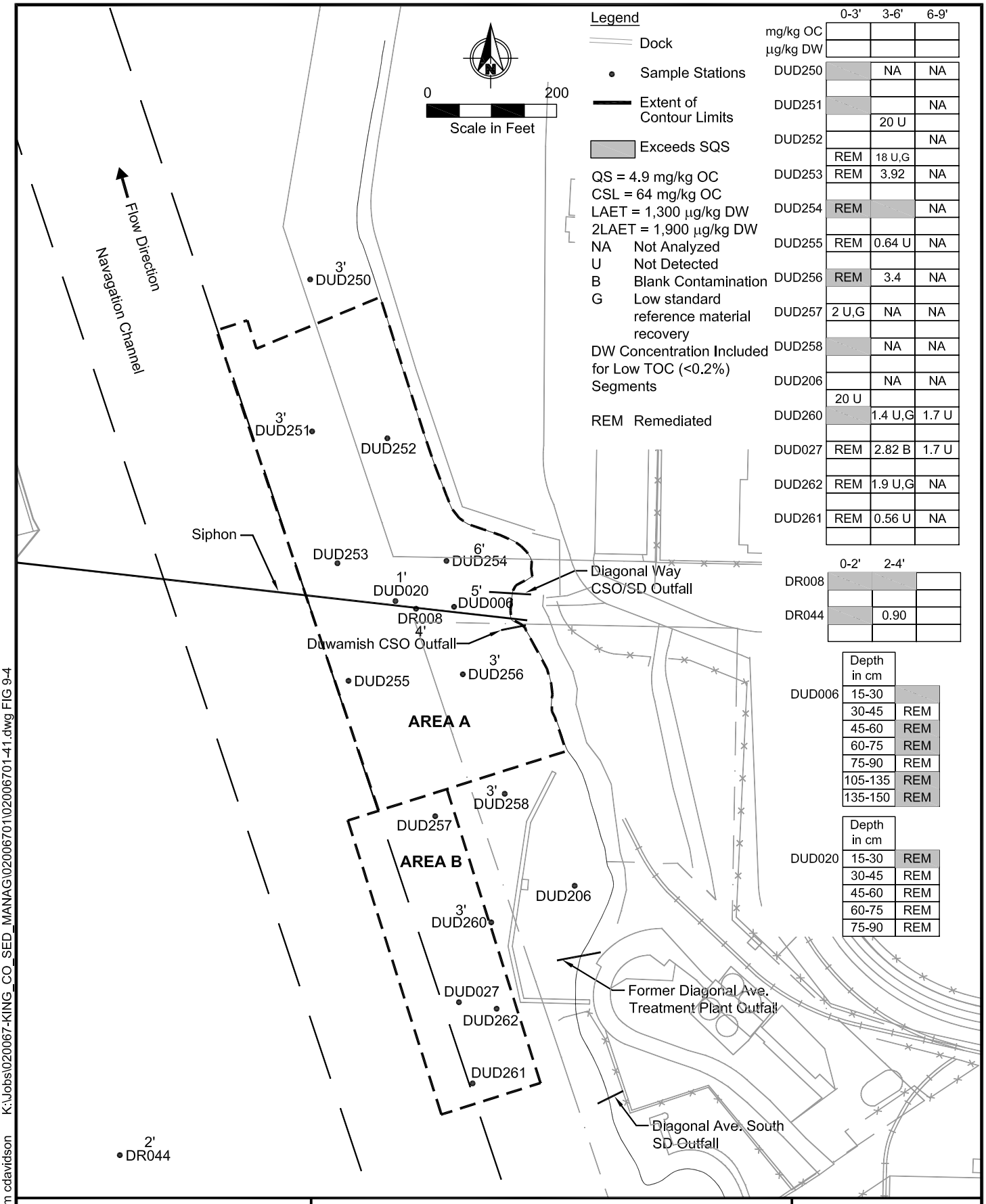
Duwamish/Diagonal Sediment Remediation Project

Bis(2-Ethylhexyl)Phthalate in Subsurface Sediments

Figure 9-3

Sep 29, 2005 9:47am cdavidson K:\Jobs\020067-KING_CO_SED_MANAG\02006701\02006701-40.dwg FIG 9-3



mg/kg OC / µg/kg DW	0-3'	3-6'	6-9'
DUD250		NA	NA
DUD251		20 U	NA
DUD252	REM	18 U,G	NA
DUD253	REM	3.92	NA
DUD254	REM		NA
DUD255	REM	0.64 U	NA
DUD256	REM	3.4	NA
DUD257	2 U,G	NA	NA
DUD258		NA	NA
DUD206	20 U	NA	NA
DUD260		1.4 U,G	1.7 U
DUD027	REM	2.82 B	1.7 U
DUD262	REM	1.9 U,G	NA
DUD261	REM	0.56 U	NA

	0-2'	2-4'
DR008		
DR044		0.90

	Depth in cm	
DUD006	15-30	
	30-45	REM
	45-60	REM
	60-75	REM
	75-90	REM
	105-135	REM
	135-150	REM

	Depth in cm	
DUD020	15-30	REM
	30-45	REM
	45-60	REM
	60-75	REM
	75-90	REM

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Duwamish/Diagonal Sediment Remediation Project

Butyl Benzyl Phthalate in Subsurface Sediments

Figure 9-4

Oct 05, 2005 9:47am cdavidson K:\Jobs\020067-KING_CO_SED_MANAG\02006701\02006701-41.dwg FIG 9-4

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