Appendix B

General PCB Interpolation Methods Applied in the Preliminary Screening of Alternatives for the Lower Duwamish Waterway

B.1 Overview and Purpose

This appendix documents the methods used to create and evaluate surface sediment base maps for total polychlorinated biphenyls (PCBs) in the Lower Duwamish Waterway (LDW) in the *Preliminary Screening of Alternatives Memorandum* (PSA). Inverse Distance Weighting (IDW) was used to create the bed maps; methods and data generally followed those outlined in the technical memorandum *GIS Interpolation of Total PCBs in LDW Surface Sediment* (Windward 2006a). However, because the PSA interpolations and analyses were completed prior to finalizing the baseline surface sediment dataset and interpolation methods for the Phase 2 remedial investigation (RI) and risk assessments, methods in the PSA differ slightly from those in the latter technical memorandum.

The intent of this appendix is to document the methods used in the PSA to interpolate total PCB concentrations in surface sediments, and to estimate remedial areas, sediment volumes, and the post-remedial spatially-weighted average concentration (SWAC) of total PCBs. Furthermore, this appendix compares the findings of the PSA, with regard to changes in the total PCB SWAC with increasingly stringent levels of potential remedial action levels (RALs), with the changes in the total PCB SWAC that would be estimated using the more recent baseline surface sediment dataset and interpolation methods (Windward 2006a,b) that were used in support of the Phase 2 risk assessments.

The final baseline surface sediment dataset will be used in the feasibility study (FS). Furthermore, the mapping methods and parameterization will be re-evaluated after completion of, and inclusion of, the Round 3 surface sediment sampling. However, the PSA will not be modified beyond the comparisons provided in this appendix. The primary changes from the evaluation presented in the PSA to that carried forward to the FS are a greater number of acres estimated for the total PCB concentration range between 6 and 12 mg/kg OC and a higher estimated SWAC for baseline conditions than estimated in the PSA.

B.2 Data

The baseline surface sediment chemistry dataset used for the PSA is similar to the dataset described in the technical memorandum *Criteria for Defining the Baseline Surface Sediment Dataset for Use in the Lower Duwamish Waterway Phase 2 RI/FS* (Windward, 2006b). However, because finalization of that dataset was still in progress during development of the PSA, a preliminary baseline surface sediment dataset that was compiled by Windward in December 2005 was used for the calculations in the PSA.

For a comparison of differences in the interpolated total PCB concentrations using the different datasets and interpolation methods, RETEC was provided a copy of the total PCB and total organic carbon (TOC) data from the final baseline surface sediment chemistry dataset (Windward 2006b) in July 2006. Data used for interpolations with either dataset were surface sediment concentrations of total

PCBs and TOC from RM 0.0 to 5.0 of the LDW. Total PCBs represent the sum of the detected Aroclors, following the procedures of the Washington State Sediment Management Standards. When none of the Aroclors were reported as detected, one half of the highest detection limit for an individual Aroclor was used to represent the total PCB concentration for that sample. TOC dry weight data were converted to percent data for organic carbon (OC) normalization of the total PCB concentrations.

Three points relative to application of these data are important to emphasize:

1. The data used for the PSA, while intended to provide a view of "baseline" (i.e., pre-remedial actions) conditions, do not represent the baseline conditions used in the risk assessments. Both the human health and ecological risk assessments used the final baseline dataset (Windward 2006b).

2. The total PCB distribution maps presented in the PSA are not those that will be used in the FS, but the results of the interpolations are illustrative of the general spatial trends in total PCB concentrations.

3. Sediment chemistry data that will be used in the FS will include, in addition to the final baseline surface sediment dataset, both historical subsurface sediment data and the subsurface sediment data collected as part of the *Subsurface Sediment Sampling for Chemical Analyses* (Windward 2006c), as well as any additional surface sediment data that may be collected to complete the Phase 2 RI or the FS (e.g., Round 3 surface sediment data [Windward 2006d]).

B.3 General Interpolation Methods

The interpolation analyses were conducted using the ArcGIS 9.0 and the extensions Geostatistical Analyst and Spatial Analyst (ESRI®). IDW parameters used for the PSA are presented in Table B-1. An analysis of the statistical data distributions of the two parameters (TOC and total PCBs) necessary for calculating OC-normalized total PCB concentrations demonstrated that the two parameters vary independently. As a result of this, each parameter was interpolated separately. The OC-normalized total PCB concentration (mg/kg OC) for each grid cell was calculated by dividing the interpolated total PCB concentration (dry weight basis) by the interpolated TOC percentage expressed as a decimal fraction.

Table B-1 IDW Parameters Used in the PSA

Parameter	Section	Power	Radius/Angle	Search Radius Shape	Number of Samples/ Use at Least	Interpolated Log of Data?
PCB dw	North	5	150 x 75, 334	cross	15/1	Yes
PCB dw	Mid	5	75 x 75, 0	cross	15/2	Yes
PCB dw	South	5	75 x 75, 0	cross	15/3	Yes
TOC	North	5	150 x 150, 0	circle	15/1	No
TOC	Mid	5	150 x 150, 0	cross	15/2	No
TOC	South	5	75 x 75, 0	cross	15/3	No

The grid cell size was 10 ft by 10 ft. The interpolation was conducted separately in three sections of the LDW to account for differences in the shape of the waterway. The three LDW sections are: downstream (river mile [RM] 0 to 1.9), mid-LDW (RM 1.7 to 3.7), and upstream (RM 3.5 to 5.0). The three LDW sections were merged together in GIS with the interpolation for the mid-LDW section slightly overlapping the downstream and upstream areas.

The GIS technical memorandum (Windward 2006a) identified a final set of IDW parameters (Table B-2) that are different than those used in the PSA. As with the data, the principal reason for this difference is that the final parameterization was still in progress during the development of the PSA. The differences reflected in the power, search radius and type, as well as the number of samples used, is in part due to the fact that for the PSA, the parameterization was optimized using log-transformed total PCB data, whereas the final method identified for use in the Phase 2 RI and risk assessments were based on untransformed data. In addition, the PSA parameterization was also adjusted to minimize the number of total PCB station concentrations for both false positives and false negatives.[1] In theory, optimization of the parameters on the root mean square error should minimize false positives and negatives. In practice, some critical areas of the LDW had false negatives that required calibration adjustments in the PSA.

[1] A "false positive" in these maps occurs when the actual total PCB concentration at a specific sampling station is less than that predicted by the interpolation. For example, a station with a reported total PCB concentration of 8 mg/kg OC falling within the 12 mg/kg OC isopleth would be a "false positive". A "false negative" would be where an actual total PCB concentration of 12 mg/kg OC at a station falls within the 6 mg/kg OC isopleth.

Table B-2 IDW Parameters Identified in Windward (2006a)

Parameter	Section	Power	Radius/Angle	Search Radius Shape	Number of Samples/ Use at Least	Interpolated Log of Data?
PCB dw	North	1	150 x 75, 0	cross-axis quadrants	2/1	No
PCB dw	Mid	1	150 x 75, 300	axis quadrants	6/2	No
PCB dw	South	1	150 x 150, 300	axis quadrants	4/4	No
TOC	North	1	150 x 75, 345	axis quadrants	3/3	No
TOC	Mid	1	150 x 75, 325	axis quadrants	3/3	No
TOC	South	1	150 x 75, 315	cross-axis quadrants	1/4	No

Using the final baseline surface sediment dataset (Windward 2006b) and the same interpolation methods used by Windward (2006a), base maps of the LDW similar to those in the PSA were created using multiples of the Washington State Sediment Quality Standards (SQS) for total PCBs, which set the concentration isopleths (Figure B-1**)**. These included one-half, one, two, and three times the total PCB sediment quality standard (SQS) of 12 mg/kg OC and the cleanup screening level (CSL) of 65 mg/kg OC. This resulted in total PCB isopleth values of 6, 12, 24, 36, and 65 mg/kg OC.

B.4 Spatially-Weighted Average Concentrations

An important GIS-based task for the PSA was to determine the SWAC for total PCBs. In the interpolation, each of the 10 ft x 10 ft grid cells was assigned a total PCB concentration based on the output of the interpolation algorithm. To calculate the SWAC, the total PCB concentration of each cell was multiplied by the area of that cell, those products were summed across all grid cells, and that sum was then divided by the total area represented by all of the grid cells. The SWACs calculated using the final baseline surface sediment dataset (Windward 2006b) and Windward's (2006a) interpolation methods were then compared to those reported in the PSA.

B.5 Area and Volume Estimation

A second function of the PCB bed maps was to calculate areas within a defined remedial boundary and/or within total PCB isopleths from which estimates of the volume of sediments that may potentially require remediation could be calculated. To estimate areas within an isopleth, the assigned-grid cell total PCB concentrations were binned by multiples of the SQS for total PCBs (i.e., >6 to 12 mg/kg OC, >12 to 24 mg/kg OC, etc.), and then the area within each bin was

calculated. For example, to estimate the total area in the >6 to 12 mg/kg OC total PCB interval, all grid cells assigned an interpolated value between 6 and 12 mg/kg OC were counted and the total area calculated (number of grid cells counted times 100 ft^2). Volumes of sediment that may potentially require remediation were then estimated by multiplying the calculated surface area by the assumed depth of contaminated sediments.

B.6 Post-Remedial Bed Maps and SWAC Estimates

GIS was also used in the PSA to estimate changes in the site-wide SWAC of total PCBs after implementing remediation at the sponsored Early Action Areas (EAAs), the Potential Priority Areas (PPAs), and in the Areas of Interest (AOIs). To evaluate the changes in total PCB concentrations after removals at the sponsored EAAs, the boundaries of the sponsored EAAs were first plotted onto the baseline total PCB distribution maps. To calculate the post-EAA condition, the total PCB values for all grid cells within the sponsored EAA boundaries were replaced with a total PCB concentration of 5 mg/kg OC (see PSA Section 3.2.2 for justification of the 5 mg/kg OC value). The interpolation for the entire LDW was then re-calculated using the methods described above in Section B.3. To calculate the post-PPA conditions, the grids produced from the post-EAA condition were used as the base condition, and the same procedures (i.e., replacement of all total PCB concentrations for grid cells falling within the PPA boundaries with a value of 5 mg/kg OC) were repeated for estimating the post-PPA conditions. Post-remedial SWACs and remedial volumes were then calculated as described previously.

For the AOIs, a simpler estimation method was used to calculate post-remedial conditions. For a given hypothetical RAL, all of the grid cells falling within that specific isopleth were assigned a total PCB concentration of 5 mg/kg OC, and the SWAC was recalculated as described above.

B.6 Comparison of Results

Table B-3 compares the SWAC and area estimates from PSA Table 5-1 with the results of re-interpolation using the final baseline surface sediment dataset (Windward 2006b) and Windward's (2006a) IDW parameterization. The areas of the sponsored EAAs and PPAs are the same because they were not set by the total PCB interpolation. There are only minor differences in the areas calculated for the AOIs having the four highest concentrations (i.e., >65, >36 to 65, >24 to 36, and >12 to 24 mg/kg OC). There are two major differences between the results using the different datasets and interpolation methods:

- The area of the AOI with the lowest total PCB concentrations ($\leq$12 and >6 mg/kg OC) was substantially greater using the final baseline surface sediment dataset and interpolation methods (164 acres) than in the PSA (103 acres). Consequently, the total number of acres that

exceed 6 mg/kg OC was substantially greater using the final dataset (260 acres vs. 200 acres in the PSA).

- The baseline total PCB SWAC was 20 mg/kg OC vs. 13 mg/kg OC in the PSA.

Estimation of the baseline SWAC is likely different between the two methods due to the log-transformation of the total PCB data for the PSA, without application of an appropriate bias correction for transformed data. The estimate using untransformed data is likely closer to the true LDW SWAC. The relative changes between each of the potential RALs shows that a greater drop in the overall SWAC is achieved with remediation of the sponsored EAAs and PPAs: from 13 to 7 mg/kg OC for the PSA vs. from 20 to 10 mg/kg OC using the final baseline surface sediment dataset and IDW parameterization. Regardless of the dataset used, the greatest improvement in the SWAC is achieved after remediation of the sponsored EAAs and PPAs.

B.7 References

Windward 2006a. *Technical memorandum: Technical Memorandum: GIS Interpolation of Total PCBs in LDW Surface Sediment. Lower Duwamish Waterway Remedial Investigation.* Prepared for the Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA. April 21, 2006.

Windward 2006b. *Technical Memorandum: Criteria for Defining the Baseline Surface Sediment Dataset for Use in the Lower Duwamish Waterway Phase 2 RI/FS. Final. Lower Duwamish Waterway Remedial Investigation* Prepared for the Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA. April 5, 2006.

Windward 2006c. *Quality Assurance Project Plan: Subsurface Sediment Sampling for Chemical Analyses. Final.* Lower Duwamish Waterway Remedial Investigation. Prepared for the Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA. February 3, 2006.

Windward 2006d. *Quality Assurance Project Plan: Surface Sediment Sampling for Chemical Analyses in the Lower Duwamish Waterway. Round 3 Addendum. Draft.* Prepared for the Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA. August 8, 2006.

Table B-3 Comparison of Areas and SWACs Calculated Using the Final Baseline Surface Sediment Dataset and IDW Parameterization vs. those in the PSA

Remedial Areas	PSA Interpolation Methods and December 2005 Dataset			Windward 2006 Interpolation Methods and Final Baseline Surface Sediment Dataset		
	Acres per Area [3]	Cumulative Total Acres [4]	SWAC Reduction[1] Post-Remedial total PCB SWAC [5] (mg/kg OC)	Acres per Area	Cumulative Total Acres [4]	SWAC Reduction[1] Post-Remedial Total PCB SWAC [5] (mg/kg OC)
Baseline Conditions (> 6 mg/kg oc total PCBs)	200	—	13	260	—	20
Sponsored EAAs	31	31	8	31	31	12
PPAs [2]	19	51	7	19	50	10
AOIs						
> 65 (CSL)	2	53	6	3	53	8
≤ 65 and >36	3	56	6	4	57	8
≤ 36 and >24	9	65	6	5	62	7
≤ 24 and >12 (SQS)	32	97	5	34	96	6
≤ 12 and > 6	103	200	4	164	260	5

Notes:

[1] Estimates do not account for long-term reduction in concentrations associated with MNR.

[2] Four surface samples (CH0014, SD-DUW60, WES238, SD-DUW87) on boundary of Boeing Plant 2 EAA included within the EAA removal areas

[3] Total acres in this evaluation include sponsored EAAs, PPAs, and the AOIs where surface sediments are > 6 total PCB mg/kg OC.

[4] Cumulative total acres includes the sponsored EAAs, PPAs, and the interval in the AOIs that exceeds the specified total PCB concentration.

[5] SWAC calculated by replacing all remedial areas with 5 mg/kg OC. Any value <6 mg/kg OC is retained in the SWAC calculation.

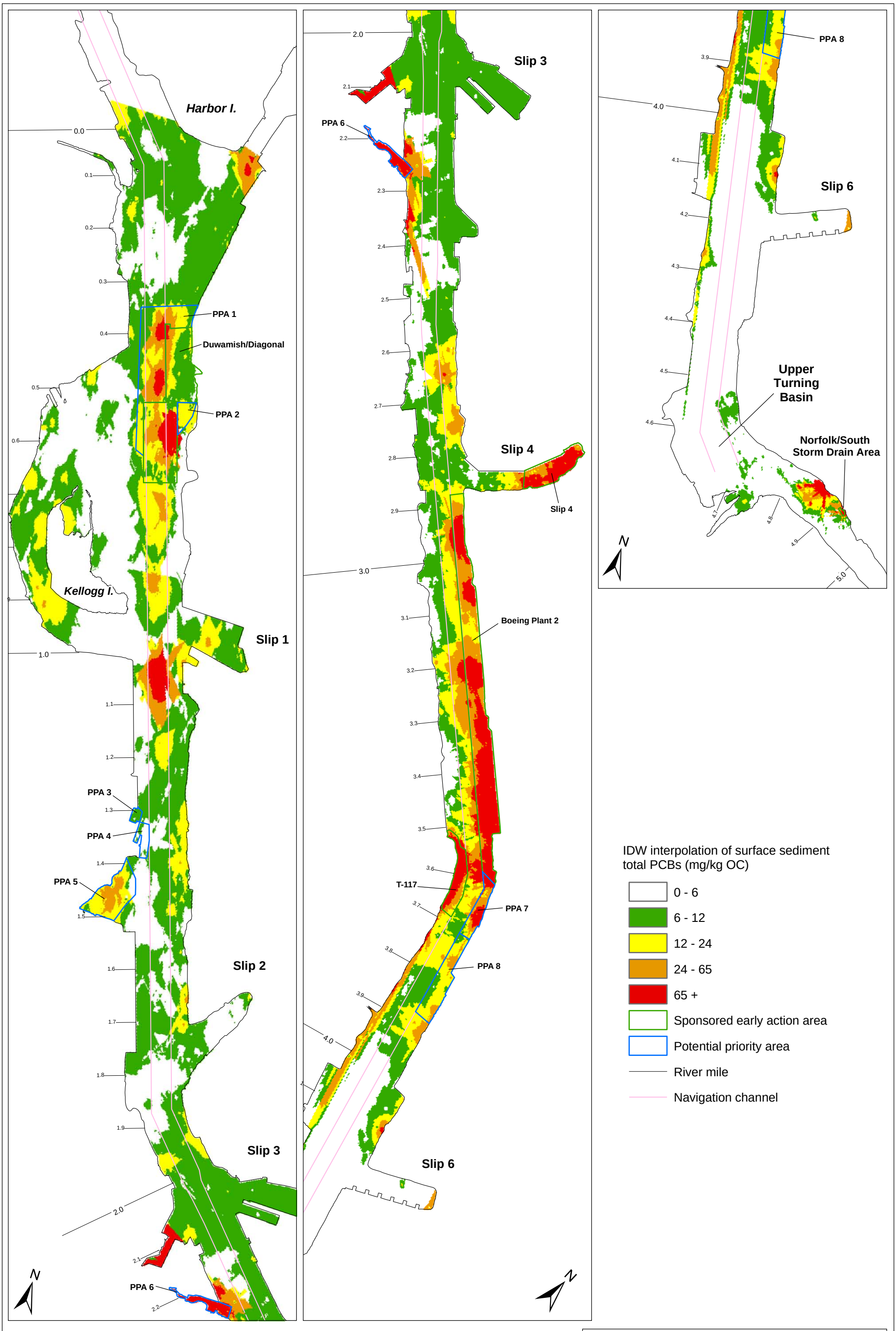

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Figure B-1 **Baseline Total PCB IDW Interpolation**

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