Appendix for Section 33

Alternative Cleanup Levels

AETs Developed Using Reference Sediment Quality Conditions

		Arsenic		Copper		Lead		Mercury		PPAH		PCB Congeners		TBT		Zinc
Units		ppm		ppm		ppm		ppm		ppb		ppb		ppb		ppm
AET Benthic																
BRI	>	27.2	>	1,880	>	482	>	3.92	>	29,071	>	5,635	>	2,800	>	1,200
Abundance	>	27.2	>	1,880	>	482	>	3.92	>	29,071	>	5,635	>	2,800	>	1,200
# Taxa	>	27.2	>	1,880	>	482	>	3.92	>	29,071	>	5,635	>	2,800	>	1,200
SWI	>	27.2		1,030		248	>	3.92	>	29,071	>	5,635		1,900	>	1,200
AET Toxicity																
Amphipod	>	27.2	>	1,880	>	482	>	3.92	>	29,071	>	5,635	>	2,800	>	1,200
Bivalve	>	27.2	>	1,880	>	482	>	3.92	>	29,071	>	5,635	>	2,800	>	1,200
Echinoderm	>	27.2	>	1,880	>	482	>	3.92	>	29,071	>	5,635	>	2,800	>	1,200
Low AET	>	27.2		1,030		248	>	3.92	>	29,071	>	5,635		1,900	>	1,200
Exponent LAET		27		1000		250		3.2		na		3000		1900		1200

> = No hit sample exceeds this value

Outlier Removed from Data Set		Yes		No		No		No		No		No		No		Yes
Concentration deemed as an outlier		95.5														4,600

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POST-CLEANUP PCB CANCER AND NONCANCER RISKS TO RECREATIONAL & SUBSISTENCE ANGLERS

Recreational Angler (fillet):	C (1) mg/kg	IR g/day	ED years	BW kg	AT years	BSAF (2) unitless	FL (3) unitless	UCF g/kg	RfD (mg/kg-day)	CPF (mg/kg-day)-1	Cancer Risk	Noncancer Risk
Total PCB Congeners	0.217	21	30	70	70	1.65	0.003	1000	0.00002	2	2.76E-07	1.61E-02

Subsistence Angler (whole body):	C (1) mg/kg	IR g/day	ED years	BW kg	AT years	BSAF(2) unitless	FL (3) unitless	UCF g/kg	RfD (mg/kg-day)	CPF (mg/kg-day)-1	Cancer Risk	Noncancer Risk
Total PCB Congeners	0.217	161	30	70	70	1.84	0.0174	1000	0.00002	2	1.37E-05	7.99E-01

(1) From NOAA June 2, 2005 MacDonald email to Carlisle. "Post-Remediation Area Weighted Averages"

(2) From "Site-specific BSAFs for primary organic contaminants in sand bass fillets" table in Appendix for Finding 34 and Carlsbad Fish and Wildlife Office Technical Memorandum CFWO-EC-TM-04-01 in Appendix for Finding 33.

(3) From Lipid table to right using data from Exponent, 2003a.

Lipid (FL)	SB Whole	SB Fillet
	3.2	0.19
	1.4	0.41
	0.9	0.26
	1.8	0.44
	1.4	0.2
Ave (%)	1.74	0.3
Ave (dec)	0.0174	0.003

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From: "Donald Macdonald" <Donald.Macdonald@noaa.gov>
To: Craig Carlisle <CCarlisle@waterboards.ca.gov>
Date: 6/2/2005 9:34:59 AM
Subject: Post-Remed Area Wt Averages

Craig,

The attached table contains the post-remediation area weighted averages for 5 organics and 9 metals for three different scenarios. I chose to do multple scenarios because the post-remediation area weighted averages are highly dependent on the concentrations remaining in the remediated SMUs. The basic approach for calculating the area weighted average was:

1. Determine the average concentration in each SMU;
2. Multiply the average concentration for each SMU by the its respected areal fraction;
   (Avg Conc SMU) X (Area SMU/Total Area) = Areal fraction concentration
3. Sum up the resulting values for all SMUs.

All three scenarios use the proposed dredge area of Scenario A5X from NOAA's memo dated 2/23/05. The scenarios differ in the determination of the post-remediation average concentration in the remediated SMUs. The 5X Criteria scenario assigned the 5X baseline criteria as the post-remediation average concentration in the remediated SMUs. The 5X Average scenario assigned either the 5X baseline criteria or the pre-remediation average concentration, whichever was lower, as the post-remediation average concentration in the remediated SMUs. The 5X Baseline scenario assigned the baseline criteria as the post-remediation average concentration in the remediated SMUs. In all scenarios the pre-remediation average concentration was used for all unremediated SMUs.

Because in many cases contaminant concentrations increase with depth the post-remediation average concnetration could actually be higher for some contaminants in some SMUs and this could result in an increase or no change in the area weighted average concentration for some contaminants following remediation. This is demonstrated by the 5X Criteria scenario where post-remediation area weighted averages showing an increase are highlighted in red on the table while those remaining unchanged are highlighted in blue.

By having the post-remediation averages in the remediated SMUs meeting the baseline criteria, as in the 5X Baseline scenario, the post-remediation area weighted averages may either approach or meet (green highlight) the baseline criteria. In other words the baseline criteria could be said to have been achieved without dredging the entire study area.

Remember ALL numbers are only estimates based on specific assumptions stated here and in the previous NOAA memos.

Don

CC: Tom Alo <TAlo@waterboards.ca.gov>, Denise Klimas <Denise.Klimas@noaa.gov>, Benjamin Shorr <Benjamin.Shorr@noaa.gov>

	Study Area				Inside Leaseholds				Outside Leaseholds				Reference Values		
Analyte	Before Remediation	5x Criteria	5X Average	5X Baseline	Before Remediation	5x Criteria	5X Average	5X Baseline	Before Remediation	5x Criteria	5X Average	5X Baseline	Baseline	ERL	ERM
TBT	150	85	76	28	270	110	110	24	70	70	56	31	22		
HPAH	2600	2500	1900	710	4100	3300	2500	690	1600	1900	1400	730	673	1700	9600
PPAH	4200	4500	3200	1300	6600	6100	4500	1300	2600	3400	2400	1300	1234	4022	44792
BAP	540	720	460	200	870	1000	660	210	340	550	330	190	202	430	1600
PCB	310	310	220	97	430	420	300	86	240	250	170	100	84	23	180
Arsenic	9.3	9.0	8.4	7.3	11	10	9.3	7.5	8.1	8.3	7.8	7.2	7.5	8.2	70
Cadmium	0.29	0.71	0.28	0.28	0.37	0.98	0.36	0.33	0.25	0.54	0.23	0.25	0.33	1.20	9.6
Chromium	51	67	51	52	59	81	59	57	46	59	46	48	57	81	370
Copper	190	180	160	120	250	200	180	120	150	160	140	130	121	34	270
Lead	74	78	70	55	91	90	82	53	64	72	62	55	53	47	218
Mercury	0.75	0.64	0.59	0.56	0.82	0.70	0.61	0.57	0.71	0.61	0.58	0.55	0.57	0.15	0.71
Nickel	15	17	13	13	16	20	16	15	14	15	12	13	15	21	51.6
Silver	0.94	1.3	0.93	0.99	1.1	1.5	1.1	1.1	0.85	1.1	0.83	0.93	1.10	1.00	3.7
Zinc	260	260	230	190	330	300	270	190	210	240	200	190	192	150	410

Red indicates an increase in area weighted average

Blue indicates no change in area weighted average

Green indicates an area weighted average equal to or less than baseline

These area weighted averages are based on the A5X scenario (see NOAA Memo 2/23/05) designated dredge area based on the footprint derived from the exceedance of the 5X baseline criteria for PCB, TBT, PPPAH and HMWPAH (accompaning Dredge Map) and were calculated based on the average concentration in each SMU before and after remeditation.

The 5X Criteria values were calculated by assigning the appropriate 5X baseline criteria as the average SMU concentration post-remediation for all SMUs remediated under the scenario; SMUs not remediated retained their pre-remediation average concentration.

The 5X Average values were calculated by assigning either the appropriate 5X baseline criteria or the pre-remediation average, which ever was lower, as the average SMU concentration post-remediation for all SMUs remediated under the scenario; SMUs not remediated retained their pre-remediation average concentration.

The 5X Baseline values were calculated by assigning the appropriate baseline criteria as the average SMU concentration post-remediation for all SMUs remediated under the scenario; SMUs not remediated retained their pre-remediation average concentration.

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Site-Specific BSAFs for PCBs in Sand Bass Fillet

Study Area	Total Solids	f-solids	Lipid wet	f-lipid dry	PCB Aroclors ppb wet	PCB Aroclors ppm dry	PCB Aroclors ppm/lipid	PCB Congeners ppb wet	PCB Congeners ppm dry	PCB Congeners ppm/lipid
Reference	20.1	0.201	0.3	0.0149	40	0.199004975	13.33333333	120	0.597014925	40
	19.9	0.199	0.2	0.0101				12	0.060301508	6
	20.5	0.205	0.4	0.0195	31	0.151219512	7.75	55	0.268292683	13.75
	20	0.2	0.27	0.0135	19	0.095	7.037037037	40	0.2	14.81481481
	20.8	0.208	0.48	0.0231	55	0.264423077	11.45833333	110	0.528846154	22.91666667
NASSCO 1	19.8	0.198	0.19	0.0096	27	0.136363636	14.21052632	27	0.136363636	14.21052632
	19.7	0.197	0.41	0.0208	34	0.172588832	8.292682927	46	0.233502538	11.2195122
	16.6	0.166	0.26	0.0157	38	0.228915663	14.61538462	68	0.409638554	26.15384615
	21.7	0.217	0.44	0.0203	46	0.211981567	10.45454545	64	0.294930876	14.54545455
	19.4	0.194	0.2	0.0103	18	0.092783505	9	17	0.087628866	8.5
NASSCO 2	20.7	0.207	0.46	0.0222	57	0.275362319	12.39130435	160	0.77294686	34.7826087
	20.1	0.201	0.19	0.0095	40	0.199004975	21.05263158	76	0.378109453	40
	20.1	0.201	0.11	0.0055	35	0.174129353	31.81818182	100	0.497512438	90.90909091
	19.3	0.193	0.39	0.0202	27	0.139896373	6.923076923	51	0.264248705	13.07692308
	19.7	0.197	0.28	0.0142	32	0.162436548	11.42857143	110	0.558375635	39.28571429
SWM 1	19.4	0.194	0.38	0.0196	27	0.139175258	7.105263158	50	0.257731959	13.15789474
	19.8	0.198	0.26	0.0131	190	0.95959596	73.07692308	270	1.363636364	103.8461538
	19.1	0.191	0.18	0.0094	69	0.361256545	38.33333333	55	0.287958115	30.55555556
	19.5	0.195	0.17	0.0087	400	2.051282051	235.2941176	370	1.897435897	217.6470588
	21.6	0.216	0.9	0.0417	140	0.648148148	15.55555556	220	1.018518519	24.44444444
SWM 2	18.3	0.183	0.15	0.0082	110	0.601092896	73.33333333	160	0.87431694	106.6666667
	19.3	0.193	0.37	0.0192	69	0.357512953	18.64864865	63	0.32642487	17.02702703
	18.7	0.187	0.25	0.0134	41	0.219251337	16.4	33	0.176470588	13.2
	20.3	0.203	0.2	0.0099	41	0.201970443	20.5	120	0.591133005	60
	19.7	0.197	0.27	0.0137	39	0.197969543	14.44444444	73	0.370558376	27.03703704
TISSUE										
NASSCO Mean (ppm/lipid dry)							14.01869054			29.26836762
SWM Mean (ppm/lipid dry)							51.26916192			61.35818381
SEDIMENT										
NASSCO Mean (ppm/toc dry)							26.123			15.348
SWM Mean (ppm/toc dry)							73.875			44.019
BSAF										
NASSCO Mean							0.536641677			1.906982514
SWM Mean							0.693998808			1.393902265
Shipyard Site Mean							0.615320243			1.650442389

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United States Department of the Interior

FISH AND WILDLIFE SERVICE
Ecological Services
Carlsbad Fish and Wildlife Office
6010 Hidden Valley Road
Carlsbad, California 92009

TECHNICAL MEMORANDUM

TO: Scott Sobiech, Chief, Environmental Contaminants Division

SUBJECT: Ecological Risk-Based Screening Levels for Contaminants in Sediments of San Diego Bay

FROM: Catherine Q. T. Zeeman, Ph.D., Environmental Contaminants Specialist

DATE: December 8, 2004

Attached is Technical Memorandum CFWO-EC-TM-04-01, Ecological Risk-Based Screening Levels for San Diego Bay Sediments. This Technical Memorandum presents results of initial efforts to develop wildlife risk-based screening levels for contaminants in sediments of San Diego Bay. These screening levels were developed to assist CFWO staff in reviewing project-specific sediment quality data to determine whether a proposed project or a contaminated site poses potential risk to Fish and Wildlife Service trust resources. Service trust resources include migratory birds, endangered and threatened species, National Wildlife Refuges, and other natural resources, including the habitats used by these species in San Diego Bay. This document will also be helpful in determining if the beneficial uses of the Bay as designated in the Water Quality Control Plan for the San Diego Region are: 1) protective of trust resources, 2) currently being met, and/or 3) potentially impaired by sediment contamination in San Diego Bay.

The analysis presented herein is a process that employs a combination of factors specific to sediments in San Diego Bay and conservative assumptions to produce sediment benchmarks suitable for screening level decisions about potential ecological risk posed by sediment-borne contaminants. This process may also be used to help potentially responsible parties, dischargers, and regulators identify sampling needs and/or develop and select appropriate clean up levels for contaminated sediments in San Diego Bay. This process recognizes data limitations, and therefore will be helpful in the design of future studies of sediment contamination in San Diego Bay.

This Technical Memorandum is intended for use as guidance only. Contents of this memorandum do not necessarily represent the official position of USFWS or the US Government. The use of firm, trade, or brand names or commercial products in this memorandum is for identification purposes only and does not constitute endorsement by the U.S. Fish and Wildlife Service.

This document has been improved by the critical review by staff from CFWO-EC (Judy Gibson and Scott Sobiech), SFWO-EC (Beckye Stanton), CDF&G (Michael Martin), and NOAA (Denise Klimas and Donald A. MacDonald).

Ecological Risk-Based Screening Levels for Contaminants in Sediments of San Diego Bay

Technical Memorandum CFWO-EC-TM-04-01

Prepared By:

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U.S. Fish and Wildlife Service
Carlsbad Fish and Wildlife Office
Environmental Contaminants Division

Carlsbad, California
December 8, 2004

Recommended citation:

Zeeman, C.Q.T. 2004. Ecological Risk-Based Screening Levels for Contaminants in Sediments of San Diego Bay, Technical Memorandum CFWO-EC-TM-04-01. U.S. Fish and Wildlife Service, Carlsbad Fish and Wildlife Office, Carlsbad, CA.

INTRODUCTION

San Diego Bay is a natural, nearly enclosed embayment that covers an area of approximately 43 square kilometers (km^2, or 4300 hectares), with water depths ranging from near 18 meters (m) at the mouth to less than 1m at the south end. In addition to being the focus of recreational, commercial, industrial, and defense-related human activities, the Bay provides important habitat for a myriad of aquatic and terrestrial wildlife species. The Bay serves as an integral migratory stopover and wintering area for shorebirds, seabirds, and waterfowl in the Pacific flyway. It also supports significant breeding colonies of elegant tern (*Sterna elegans*), royal tern (*Sterna maxima*), Forster's tern (*Sterna forsteri*), gull-billed tern (*Sterna nilotica*), Caspian tern (*Sterna caspia*), black skimmer (*Rhynchops niger*), and double-crested cormorant (*Phalacrocorax auritus*). Federally listed endangered species that are dependent upon the Bay include Western snowy plover (*Charadrius alexandrinus nivosus*), California brown pelican (*Pelicanus occidentalis californicus*), light-footed clapper rail (*Rallus longirostris levipes*), California least tern (*Sterna antillarum browni*), and the threatened green sea turtle (*Chelonia mydas*). To help preserve the biological diversity and abundance of fish and wildlife species and their habitats in San Diego Bay, the U.S. Fish and Wildlife Service (Service) established the Sweetwater Marsh and South San Diego Bay National Wildlife Refuges (NWRs), which encompass most of what remains of San Diego Bay's historic salt marsh and intertidal mudflat habitats. The California Regional Water Quality Control Board (RWQCB), San Diego Region also recognizes the biological significance of San Diego Bay by including fish and wildlife and their habitats among the designated beneficial uses of the waters of the Bay. The designated uses specifically include (1) Preservation of Biological Habitats of Special Significance, (2) Estuarine Habitat, (3) Wildlife Habitat, (4) Rare, Threatened, or Endangered Species, (5) Marine Habitat, and (6) Migration of Aquatic Organisms. The designated beneficial uses are factored into RWQCB decisions concerning a variety of contaminant-management matters including issuance of discharge permits for point and non-point sources and cleanup actions at contaminated sites.

According to U.S. Department of the Navy, Southwest Division (USDoN, SWDIV 2000) and Fairey *et al.* (1996), San Diego Bay has a long history of human activity, dating back to the late 1700s when it was established as a harbor. It is now a major harbor for U.S. military and civilian commerce that includes food processing facilities, aircraft manufacturing plants, shipyards, and the Pacific coast's largest naval base, naval air station, and submarine base. Currently, the Bay supports residential, commercial, and industrial activities for a population of more than 1.25 million people in the City of San Diego. Prior to the early 1950s, waste water of all kinds was discharged directly into the Bay. While waste water discharges have been greatly reduced since the early 1950s, persistent pollutants from historic releases may still be present in Bay sediments. In addition, the Bay is still the recipient of contaminated material from atmospheric deposition, urban runoff, spills, and permitted discharges.

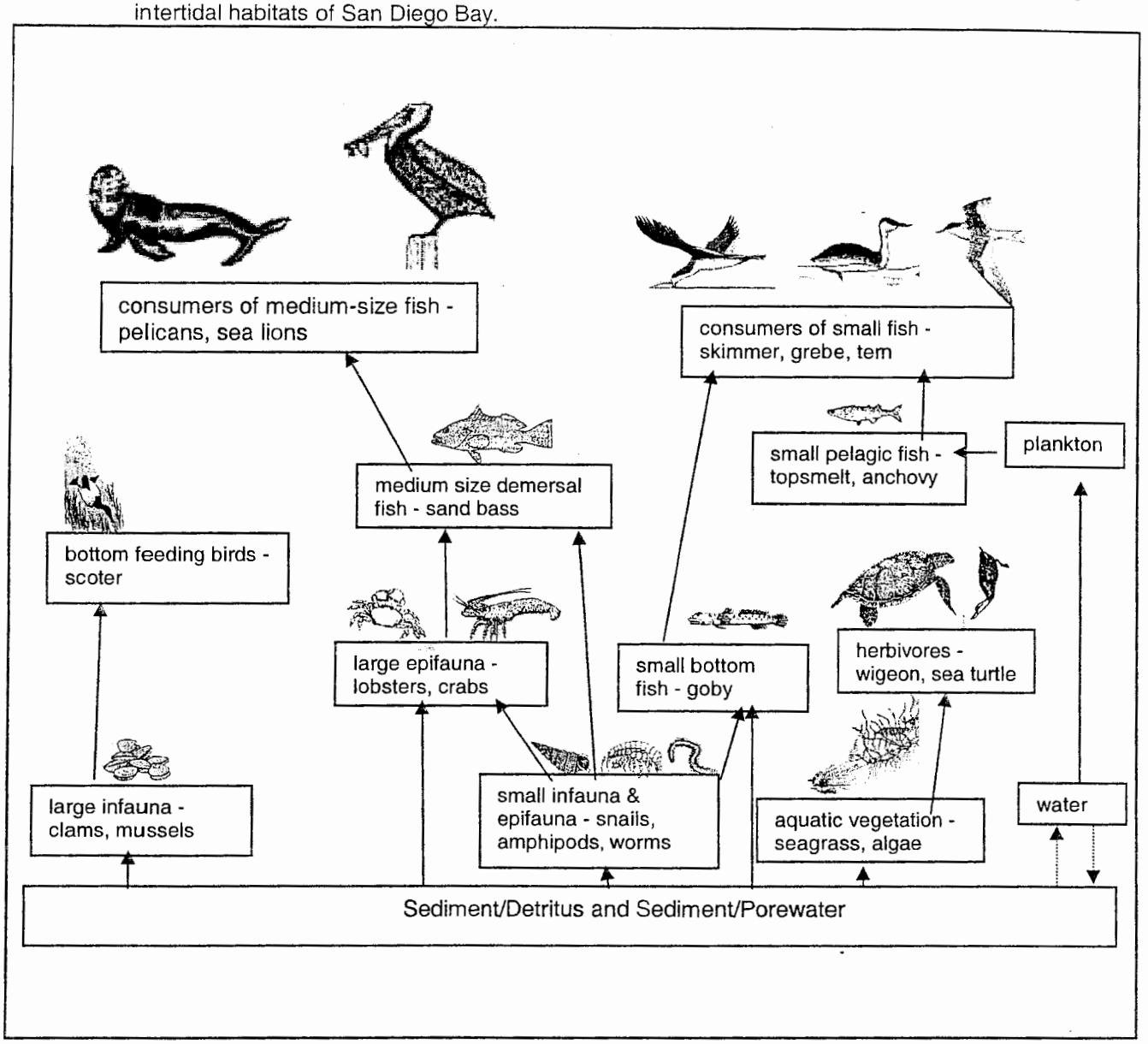
Due to the history of human activity in San Diego Bay, numerous studies have been undertaken to assess the extent and potential impacts of chemical contamination that may be associated with those activities. Early studies have demonstrated that, in general, chemical contaminants tend to be far more concentrated in sediments than in the water column (Horowitz 1991). As a result, sediments are now viewed as a contaminant reservoir that acts as a source of contaminants in the water column (dissolved and as suspended sediment) and biota. Sediments are also a substrate for processes that may render contaminants more or less bioavailable and/or toxic (e.g., methylation of mercury), and provide spatial information (and historical record) that may be used to identify contaminant sources in a system. These

observations are reflected in studies on chemical contamination in San Diego Bay. Monitoring programs established since 1984 are focused on sediment chemistry, sediment toxicity to invertebrates, benthic community structure, chemical analysis of bottom fish livers and stomachs, and chemical analysis of resident bivalves (City of San Diego 2003, Fairey *et al.* 1996, McCain *et al.* 2000, Meador *et al.* 1994). In support of such studies, Long *et al.* (1998), MacDonald (1994), and others have developed screening levels, against which measured contaminant levels can be compared for assessing contaminant-related risk to benthic invertebrates. The screening levels make it possible to identify specific contaminants and areas in the Bay that require further attention, based on risks to invertebrates that live in direct contact with sediment (USDoN, SWDIV 2000).

The health of the benthic invertebrate community is important for the Service's trust resources. However, conclusions based on risks to benthic invertebrates are not necessarily protective of other potentially exposed receptors. These include organisms that have direct exposure to sediment associated contaminants (e.g., vegetation and bottom fish), organisms that have indirect exposure via diet to sediment-borne contaminants that have entered and accumulated in food chain organisms (e.g., birds that consume fish or benthic vegetation), and organisms that have a combination of direct and indirect exposure (e.g., birds that consume benthic biota). The currently available screening values based on risks to benthic invertebrates do not address risks posed by sediment-borne contaminants to vegetation or other food web organisms, and therefore do not fully address concerns about all the ecological designated beneficial uses for San Diego Bay. Sediment screening levels based on risk to wildlife and vegetation, used in conjunction with existing screening levels for invertebrates, would help with initial efforts to ensure that sediment management decisions address concerns about all ecological receptors. Ecological receptors and the routes by which they may be exposed to sediment-borne contaminants are presented in a simplified conceptual model illustrated in Figure 1. The model represents species that use lower intertidal and subtidal habitats. Species that use upper intertidal and saltmarsh habitats, such as wading birds and shorebirds, especially clapper rails, are also of concern and may be specifically addressed in the future.

The EPA (2000) has derived wildlife risk-based screening levels for selected contaminants in soils. However, because soils and sediments are different with regard to physical and chemical characteristics, EPA specifically recognizes that the soil screening levels are not applicable to "wetland soils that are regularly flooded (i.e., sediment)." There are few if any comparable sediment screening levels for plant and wildlife receptors. This is partly because such screening values incorporate contaminant uptake, accumulation, and transfer factors that tend to be site-specific. Often, studies do not include the collection of co-located samples so that the data needed to calculate site-specific factors tend to be sparse. Studies conducted by Exponent of Bellevue, Washington for the National Steel and Shipbuilding Company (NASSCO) and Southwest Marine, Incorporated (SWM) shipyard facilities have generated some of the requisite data for sediments and biota in San Diego Bay. Data from the studies are presented in a detailed sediment investigation report by Exponent (2003). Data obtained from locations used as study reference areas by Exponent (2003) helped support this initial effort to develop wildlife risk-based screening levels for sediments in San Diego Bay.

Figure 1. Receptor groups and routes of exposure to sediment-borne contaminants in subtidal and lower intertidal habitats of San Diego Bay.



OVERVIEW

Data from the Exponent (2003) report were combined with literature-based exposure factors and benchmark toxicity values to calculate risk-based sediment screening levels for receptor groups shown in Figure 1. The analysis is presented as a process that employs a combination of factors specific to sediments in San Diego Bay and conservative assumptions to produce sediment benchmarks suitable for screening level decisions about ecological risk posed by sediment-borne contaminants. The sediment screening levels for each receptor group are developed in receptor-specific worksheets. The worksheet for each receptor group also provides information on data sources, literature-based (benchmark) toxicity values, exposure factors, and the applicable sediment-to-water or biota transfer factors that were used.

Not all of the data in the Exponent report are applicable, and the data that are applicable are limited for the following reasons:

1. While Exponent (2003) collected data for both shipyard and reference study areas, only those data from the reference area stations are used to derive screening levels. The focus is to help ensure as best as possible that resulting screening levels are not specific to an individual contaminated site, and that they represent conditions of greatest bioavailability. Both of these factors are important because of the intended use for screening levels, which is to provide conservative values for initial efforts to identify potential areas and contaminants of concern. The same concerns are factored into protocols for deriving risk-based screening levels for other media such as soils (e.g., EPA 2000). For this exercise, only reference area transfer factors were used to derive sediment screening levels. The transfer factors that were used were sediment-to-porewater partition coefficients (Kps) and biota-to-sediment accumulation factors (BSAFs), where Kp represents the concentration of a contaminant in sediment to its concentration in a corresponding porewater sample, and the BSAF represents the concentration of a contaminant in biota to its concentration in a corresponding sediment sample;

2. For the few locations represented, contaminants were not always present at detectable levels, or were not analyzed in both sediment and biota samples (e.g., organochlorine pesticides); and,

3. Sediment screening levels were not calculated for contaminants lacking readily available benchmark toxicity values in the literature.

Consequently, the screening levels developed below represent an initial effort that is expected to expand and change over time as more data on the nature, fate, and toxicity of contaminants that occur in San Diego Bay sediments become available.

Currently, data from Exponent 2003 and readily available benchmark toxicity values support the development of wildlife/plant risk-based sediment screening levels for arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, zinc, tributyltin (TBT), polynuclear aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs). It is recognized that PAHs and PCBs are classes of compounds that occur as complex mixtures in the environment. There are hundreds or thousands by some counts of individual PAH compounds and 209 individual PCB compounds (i.e., congeners). Screening levels for mixtures may be developed using a whole mixture approach or by combining benchmarks for individual constituents. Each approach has advantages and disadvantages. The Exponent (2003) report offers data that support the whole mixture approach for both PAHs and PCBs, and the individual constituent approach for PCBs. However, the individual constituent approach adds a level of complexity to the approach used here. Because of the added complexity, wildlife risk-based screening levels were not developed for individual PAHs or PCBs, and only whole mixture values (total PAHs and total PCBs) were selected for this analysis. Screening levels may be developed for individual PCB congeners in a separate exercise in the future.

Both no-effect and low-effect benchmark toxicity values were located for all receptors but the aquatic vegetation, and sediment screening levels were computed from both no-effect and low-effect values when available. The lower of the two values calculated for each receptor (e.g., the

no-effect-based screening level) is preferred for the initial evaluation of contaminant levels in sediment.

The sediment screening levels are believed to be conservative (protective), and decisions based on screening levels for the most sensitive receptors (i.e., the lowest for all receptors) will ensure that concerns about all potential ecological receptors are addressed.

The screening levels developed in this report are proposed as guidelines with uncertainties relating to site-specific data, benchmark toxicity values, and exposure factors. Consistent with standard risk assessment guidance (e.g., EPA 1997), conservative values were used when directly applicable data were lacking. The following should be considered when using the screening levels.

1. The BSAFs used to calculate screening levels for fish and wildlife receptors are based on a small database (representing six sample stations at best). The BSAFs that were used may overestimate or underestimate the bioavailability of sediment-borne contaminants for the Bay in general. More specifically:

    a) The BSAFs are based on data from reference area stations used for the Exponent (2003) study. While they reflect less contaminated conditions, compared with other locations sampled by Exponent (2003), they are few in number and as such may not be representative of reference conditions for San Diego Bay as a whole; and,

    b) Confidence in the BSAFs is variable, depending on the degree to which sediment and biota samples can be considered co-located, and the number of locations for which BSAFs could be calculated.

        The BSAFs for bivalves are based on data for co-located samples from six locations (five with clam samples and one with a mussel sample). The occurrence of a non-detect in a sediment or corresponding biota sample resulted in even fewer BSAFs for some contaminants ($N \leq 6$).

        The BSAFs for demersal fish are based on data for a species with poor site fidelity. The BSAFs are based on data for five individuals assumed to be associated with multiple locations within a single area in San Diego Bay ($N=1$).

        The BSAFs for eelgrass are based on data for co-located samples from one location ($N=1$).

    c) The BSAFs for bivalves are considered the most reliable. However, because only six stations are represented, the degree to which the BSAFs reflect conditions in other parts of the Bay is uncertain.

2. Sediment to porewater partition coefficients (Kp) used to calculate screening levels for aquatic vegetation are based on data from five reference area stations used for the Exponent (2003) study ($N=5$). While they reflect less contaminated conditions, compared with other locations sampled by Exponent (2003), they are few in number and as such may not be representative of reference conditions for San Diego Bay as a whole.

3. Literature-based benchmark toxicity values used for birds, mammals, and fish are for the most sensitive species for which experimental data could be found. Lowest values are used to allow for uncertainty about species differences in sensitivity. However, toxicity databases are variable, and benchmark toxicity values for some contaminants are based on very limited information.

4. Literature-based benchmark toxicity values used for vegetation are for the most sensitive species for which experimental data could be found. Toxicity databases for saltwater vegetation are limited. Benchmark toxicity values for some contaminants may be based on information from only two studies.

5. There are no readily available literature-based toxicity reference values for turtles, and toxicity values for sensitive avian species were used instead. Extrapolating reference doses across vertebrate classes is generally not recommended (e.g., TNRCC 2001). However, green sea turtles are present and they are a listed species. Reference toxicity values for sensitive avian species may be more or less protective for turtles than for birds.

6. Sediment screening levels are calculated for the potentially most exposed receptors, which may, or may not be listed as endangered or threatened.

7. Exposure factors used for birds, mammals, and turtles include the assumptions that the receptors are present year-round (seasonal use factor = 1) and that they obtain all of their food from within the Bay (area use factor = 1). While not true for all potential receptors, these conservative assumptions are used to ensure that the species that do meet the criteria are afforded adequate protection. Exposure estimates also include the assumption that all (100%) of a contaminant present in ingested material is absorbed into the system of the receptor. Less than 100 percent may be absorbed. However, actual percentages will vary, depending on the chemical nature of the contaminant, the receptor species, receptor condition, diet composition, and the mode of exposure used to develop each contaminant's benchmark toxicity value. Assuming 100 percent absorption ensures that uptake from the diet may be overestimated, but will not be underestimated. The assumptions about use and contaminant absorption are consistent with guidance on screening level risk assessments which are intended to minimize the risk of making a false negative determination (i.e., contamination is deemed not significant when it really is) early in the site evaluation process (EPA 1997).

8. Sediment screening levels are not adjusted for potential added risk posed by exposure to more than one contaminant at a time. To do so is beyond the scope of this exercise. There are approaches, when using the screening levels for risk management decisions, that account for exposure to multiple contaminants.

9. Sediment screening levels do not account for relative source contributions. Instead, they reflect the assumption that most if not all of the contaminant exposure is through direct or indirect contact via diet with sediment from San Diego Bay.

10. Pelicans and sea lions are considered top avian and mammalian carnivores for San Diego Bay food webs (USDoN, SWDIV 2000). As such, they may consume fish that occupy a higher trophic level than that represented by spotted sand bass, which is the

species upon which accumulation factors for this exercise are based. If such is the case, the sediment screening levels derived for pelicans and sea lions may reflect an underestimation of risk to those receptors.

The screening levels are presented in the following table (Table 1). The screening levels can be used to help decide if contaminant levels measured in sediments are low enough to be of no further concern, or elevated enough to warrant additional consideration. The screening levels have conservative elements to minimize the chance of making a false negative determination (i.e., conclude that there is no risk when there is risk). Details on the process and data used to derive sediment screening levels and worksheets for each receptor are presented in subsequent sections.

Table 1. Sediment screening levels (mg/kg dry weight) for ecological receptors potentially exposed to contaminants from sediment in San Diego Bay. Values reflect inputs and assumptions specific to San Diego Bay, as presented in the text.

Receptor group	benthic invertebrates	benthic vegetation	fish	bottom-feeding birds	consumers of small fish			consumers of medium-size fish		herbivores	
(represented by)				(scoter)	(grebe)	(tern)	(skimmer)	(pelican)	(sea lion)	(wigeon)	(turtle)
Basis[1]	TEL	LCV	NOEC	TRV-L	TRV-L	TRV-L	TRV-L	TRV-L	TRV-L	TRV-L	TRV-L
Arsenic	7.2	16	14	21	185	59	116	183	36	206	3,633
Cadmium	0.68	-	0.43	0.72	1.45	0.45	0.88	1.4	3.5	0.49	8.6
Chromium	52	7,037	-	-	-	-	-	-	-	-	-
Copper	19	23	649	101	289	120	235	368	1,454	73	1,291
Lead	30	175	121	1.3	3.0	1.65	3.2	5.1	1,230	1.03	18.2
Mercury	0.13	59	<0.12[2]	0.21	0.17	0.05	0.10	0.16	0.46	-	-
Nickel	16	3,107	-	44	97	34	67	105	34	59	1,034
Selenium	-	-	-	2.5	-	-	-	-	-	-	-
Silver	0.73	260	-	-	-	-	-	-	-	-	-
Zinc	124	286	404	234	492	157	306	480	914	290	5,118
TBT	0.06[6]	0.002	0.13[2,3]	1.07[3]	0.6[3]	0.19[3]	0.37[3]	0.57[3]	0.67[3]	-	-
PAHs	1.68	-	1.0[5]	-	-	-	-	-	-	-	-
PCB (homolog)[4]	0.022	0.24	0.09[3]	0.31[3]	0.025[3]	0.007[3]	0.014[3]	0.022[3]	0.31[3]	3.62	63.8
PCB (Aroclor)[4]	-	-	0.15[3]	0.32[3]	0.042[3]	0.013[3]	0.024[3]	0.038[3]	0.52[3]	3.88	68.4
PCB (congener)[4]	-	-	0.08[3]	0.31[3]	0.021[3]	0.006[3]	0.012[3]	0.019[3]	0.26[3]	3.46	61.0

1. Basis = Benchmark toxicity value (see text for details). TEL = Threshold Effect Level (mg/kg sediment); LCV lowest chronic value for contaminants in water (mg/L); NOEC = No Observed Effect Concentration in fish tissue (mg/kg fish tissue, dry weight); and, TRV-L = Toxic Reference Value-Low (mg/kg-day).
2. No NOEC available. Screening level based on LOEC = Lowest Observed Effect Concentration (mg/kg fish tissue, dry weight).
3. Screening levels calculated using TOC normalized accumulation factors. The screening values are for sediment with 1% TOC (fTOC = 0.01).
4. PCB concentrations were quantified three different ways (as homologs, Aroclors, and congeners), producing different BSAFs. Results obtained by all three approaches shown for reference.
5. From Johnson *et al.*, 2002. Screening level based on LOEC concentration in bulk sediment (mg/kg dry weight).
6. From Meador *et al.*, 2002. Based on 6000 ng/g_{oc}. The screening value is for sediment with f-toc = 0.01. To adjust for site-specific TOC use 0.060 mg/kg x (measured f-toc/0.01).

PROCESS

Step 1. Identify receptors (conceptual site model, Figure 1).

Receptors were selected to represent all aquatic and aquatic-dependent components of the system that are potentially exposed to sediment-borne contaminants in San Diego Bay. This analysis focuses largely on receptors using resources in subtidal or low intertidal areas. Species that feed in intertidal marshes, such as clapper rails, herons, and egrets are not directly addressed in this exercise and may require further attention in the future.

Some receptors were selected partly to address concerns specific to federally listed species. For example, the sea turtle and the California least tern may have limited contact, either direct or indirect, with sediment-borne contaminants. This is because sea turtles eat very little relative to their body weight, while terns may prefer prey species that are part of a pelagic food chain. In either case, there are conditions under which exposure for these receptors to sediment-borne contaminants, particularly the tern, may still be significant. The receptors were selected using general knowledge of estuarine ecosystems, supplemented with information specific to San Diego Bay (USDoN, SWDIV 2000).

The following receptor types may experience significant exposure to sediment-borne contaminants, depending on the contaminant (nature and concentration) and life history characteristics of the receptor.

(1) Benthic invertebrates that live in direct contact with the sediment;

(2) Benthic vegetation that lives in direct contact with the sediment;

(3) Fish that consume benthic biota at the sediment-water interface (i.e., bottom fish and demersal fish);

(4) Avian species that feed on benthic biota at the sediment-water interface, and therefore may experience significant exposure both directly through incidental ingestion of sediment and indirectly through diet to sediment-borne contaminants;

(5) Herbivores exposed through diet to sediment-borne contaminants accumulated in the tissues of benthic aquatic vegetation and through incidental ingestion of sediment; and,

(6) Avian and mammalian species that have little direct contact with sediment, but are exposed through diet to substances that have a potential for uptake and bioaccumulation in food chain organisms (includes birds and mammals that consume bottom-feeding fish).

"Benthic invertebrates" is a category of receptors that includes both large and small infauna and epifauna that live in direct contact with sediment (Figure 1).

"Benthic aquatic vegetation" is a category of receptors that includes benthic algae from single celled species to multicellular seaweeds, such as sea lettuce and rooted angiosperms, such as eelgrass.

Fish that feed on benthic invertebrates include bottom dwelling species such as gobies and blennies, and demersal species that feed at the bottom but move throughout the water column, such as spotted sand bass. The distinction between "bottom" and "demersal" is not always clear. For example, juvenile flatfish, such as the California halibut may be considered a bottom fish by some authors (Fairey *et al.* 1996) and a demersal fish by others (USDoN, SWDIV 2000). Members of both groups are of concern as a source of food and contaminant exposure for upper trophic level receptors. Recreationally fished species such as the halibut and sand bass have economic significance as well.

Avian species that consume benthic biota are represented for this analysis by the surf scoter (*Melanitta perspicillata*), a diving duck whose diet is mostly bivalves. Because of their feeding habits, food ingestion rates, and body size, scoters represent the potentially most exposed of avian species when dealing with sediment-borne contaminants that enter, but do not necessarily increase in concentration with trophic transfer in the food web (e.g., PAHs). No mammalian representatives of this group, such as sea otters, are reported to occur in San Diego Bay.

Herbivores are represented by the green sea turtle and American wigeon (*Anas americana*). The turtle is of concern because it is federally listed as endangered, and a year-round consumer of eelgrass in the Bay. However, turtles do not represent the potentially most exposed of the herbivores, because their food ingestion rate is small relative to their body size. The wigeon, a dabbling duck, was selected to represent the potentially most exposed of the herbivorous receptors.

Avian species that rely on fish as their primary source of food are represented for this analysis by the western grebe (*Aechmophorus occidentalis occidentalis*), the black skimmer (*Rhynchops niger*), and federally listed California least tern and California brown pelican. Grebes, terns, and skimmers are species that consume small fish, including bottom feeding fish (e.g., gobies and demersal fish) and pelagic species that may be bottom feeders when in shallow waters (e.g., topsmelt). Pelicans consume medium size fish. Because of their feeding preferences, pelicans may be the receptors in this group with the highest contaminant levels in their diets. However, terns and skimmers have the potential to be the most exposed, because of their high food ingestion rates relative to its body size. Grebes and skimmers are more likely than terns to consume fish that have been in contact with sediment.

Mammals that consume fish are represented by the California sea lion (*Zalophus californianus californianus*). It is one of two piscivorous mammals commonly observed in San Diego Bay. The other is the coastal bottlenose dolphin (*Tursiops truncates*), which is larger than the sea lion and is expected to ingest less fish relative to its body weight.

Receptors that feed in intertidal mudflats and salt marshes are not considered in this analysis, primarily because the original focus was intended to be on subtidal and lower intertidal habitats. The feeding strategies of wading birds (e.g., herons and egrets) and shorebirds (e.g., rails, curlews, and willets) are such that they may ingest more sediment

than other receptors, as well as consume prey that have accumulated sediment-borne contaminants in their tissues.

Step 2. Identify basic approaches for developing screening levels.

It has been determined that with current, readily available data sources, sediment screening levels can be developed for each of the selected receptors using one of four basic approaches. These approaches are:

(1) Locate existing sediment screening levels. Most, but not all of the currently available sediment screening levels are for benthic invertebrates. When available, screening levels for receptors other than benthic invertebrates are presented in worksheet tables for the appropriate receptors as bulk sediment-based values;

(2) For aquatic vegetation - Identify reference toxicity levels (mg/L) for aquatic vegetation exposed to contaminants in water, and use locally derived sediment-to-porewater partition coefficients (Kp) to back-calculate from the reference concentration in water to a corresponding screening level in bulk sediment;

(3) For fish - Identify contaminant concentrations in fish tissue that represent no observed- and lowest observed effect concentrations (NOECs and LOECs) for fish, and use locally derived biota-to-sediment accumulation factors (BSAFs) for demersal fish to back-calculate from the fish tissue NOEC or LOEC to a corresponding concentration in bulk sediment. As derived, screening levels are for fish that consume bottom-dwelling organisms; and,

(4) For wildlife - Combine benchmark toxicity values (i.e., daily contaminant dose rates, mg/kg-day) with literature-based exposure factors to establish reference concentrations for contaminants in the receptor's diet (mg/kg in the diet). Then, use locally-derived BSAFs to back-calculate from the reference concentration in the diet to a corresponding screening level in sediment.

Step 3. Develop equations for calculating screening levels.

Screening levels for vegetation, fish, and wildlife were derived through calculations that required the use of specific equations and data inputs, including locally-derived BSAFs and Kps. The equations used to compute sediment screening levels are presented below using simplified formats to make them easier to read. The simplified equations are copied from Attachment A, where they were derived using standard units of measure (e.g., mg/kg rather than ppm). Equations can be reviewed in Attachment A for units, if so desired. All data inputs, including percent lipid in biota are dry weight based.

(1) Sediment screening levels for aquatic vegetation are computed as:

Screening level ppm_{sed} = benchmark toxicity value for water x K_p, where

$Kp = ppm_{sed} / ppm_{porewater}$.

The benchmark toxicity value for water is a literature-based lowest chronic value (LCV, for surface water) from studies reviewed by the U.S. Environmental Protection Agency (EPA) for developing Ambient Water Quality Criteria. Details on the LCVs are provided in the following section (Step 4) of this document.

Values of Kp are from data specific to San Diego Bay sediments reported by Exponent (2003). See Attachment B for details on the data and computations.

(2) Sediment screening levels for bottom-feeding fish are computed as:

For organics, including tributyltin (TBT) -

Screening level ppm_{sed} = benchmark ppm_{tissue} x (f-toc/f-lipid) x (1/BSAF), and

For inorganics -

Screening level ppm_{sed} = benchmark ppm_{tissue} x 1/BSAF, where

Benchmark tissue levels = literature-based values from a database compiled by Jarvinen and Ankley (1999) or reviews in Beyer *et al.* (1996). Details on the benchmark tissue levels are provided in the following section (Step 4) of this document.

BSAF = concentration of a specific contaminant measured in biota divided by the concentration of the same contaminant measured in a co-located sediment sample.

BSAF for organics = lipid normalized ppm_{tissue}/toc-normalized $ppm_{sediment}$
f-toc/f-lipid = fraction total organic carbon in sediment / fraction lipid in fish tissue (dry weight)

BSAF for inorganics = $ppm_{tissue}/ppm_{sediment}$

All BSAFs and f-toc/f-lipid values are calculated from data on San Diego Bay sediments and fish collected by Exponent (2003). See Attachment B for details on which data were used and how they were used.

(3) Sediment screening levels for wildlife species are computed as:

For organics, including TBT -

ppm_{sed} = TRV / [(sediment ingestion rate) + (BSAF)(f-lipid/f-toc)(food ingestion rate)], and

For inorganics (and organics for herbivorous receptors) -

ppm_{sed} = TRV / [(sediment ingestion rate) + (BSAF)(food ingestion rate)], where

TRV = "Toxicity Reference Value," a literature-based benchmark toxicity value recommended by EPA, Region 9 Biological Technical Assistance Group (BTAG), except for mercury. The low-end toxicity reference values for

mercury are from a review by the Service (USFWS 2003). Details on the TRVs are provided in Step 4.

Ingestion rate = literature-based, species-specific factor computed as:

Ingestion rate (kg_{food} / kg_{BW} - day) =
estimated daily ingestion (kg_{food} ingested / day) / body weight (kg), where daily ingestion is a dry weight-based value.

For more detail on ingestion rate, see the discussion in Step 5.

BSAF = as defined in the previous section on sediment screening levels for bottom-feeding fish.

All BSAFs and ratios of f-toc/f-lipid are calculated from data on San Diego Bay sediments and biota. Three sets of BSAFs were calculated. Bivalve-based BSAFs are used to calculate sediment screening levels for the scoter. Fish-based BSAFs are used to calculate sediment screening levels for the grebe, tern, skimmer, pelican, and sea lion. Eelgrass-based BSAFs are used to calculate sediment screening levels for the wigeon and the sea turtle. See Attachment B for details on which data were used and how they were used to calculate the BSAFs.

The sediment screening levels for herbivores are calculated using the equation for inorganics only, because data needed to normalize BSAFs for organic carbon are lacking. Specifically, the percent lipid values reported for eelgrass samples are below the limits of detection.

Step 4. Identify literature-based benchmark toxicity values.

Ideally, benchmark toxicity values are derived from extensive reviews of the primary literature on each contaminant of concern. Reference values selected for this exercise are secondary in nature, because they are from readily available lists produced as a result of literature reviews by other authors or agencies.

The benchmark toxicity values used to calculate sediment screening levels are the Lowest Chronic Values (LCVs) for aquatic vegetation, tissue-based no effect and low effect concentrations (NOECs and LOECs) for fish, and Toxicity Reference Values (TRV-Lows and TRV-Highs) for wildlife.

Lowest chronic values

The LCVs are from literature reviews used by the U.S. Environmental Protection Agency (EPA, see Table 2 below). The LCV is the lowest of the low observed effect concentrations (LOECs) considered by the EPA when developing an Ambient Water Quality Criterion (AWQC) for a particular contaminant. In this case, they are the lowest of the LOECs for tests conducted with estuarine/marine vegetation. Most toxicity data for aquatic vegetation are from tests using surface water and with short exposure durations. Because algae (the most common test subjects) have a short generation time, the EPA

guidelines recommend that tests lasting more than 4 days be treated as chronic. The LCVs are considered in the development of the AWQCs. But, because a statistical approach is used to derive AWQCs, the LCV for a particular contaminant may be lower or higher than the AWQC for that substance. The LCVs that were used to derive sediment screening levels for marine/estuarine vegetation are presented in the worksheet for that receptor group. Table 2 below provides more detail on the basis of the LCV for each contaminant.

Table 2. Lowest chronic values for estuarine/marine vegetation.

Compound	Genus	Chronic LOEC (mg/L)	Function affected	Source
Arsenic	*Skeletonema & Thalassiosira*	0.020	growth & photosynthesis	EPA 1985a
Cadmium	*Champia*	0.023	growth & sexual reproduction	EPA 2001
Chromium (CrVI, no data on CrIII w/saltwater species)	*Macrocysitis*	1.0	photosynthesis	EPA 1985b
Copper	*Scrippsiella, Champia*	0.005	growth	EPA 1985c
Lead	*Champia*	0.020	growth & sexual reproduction	EPA 1985d
Mercury, inorganic or total	*Ditylum*	0.010	growth	EPA 1985e
Nickel	*Phaeodactylum*	1.0	growth	EPA 1980a & 1986
Selenium	*Peridinopsis*	0.00001 - 0.00005	growth	EPA 1987
Silver	*Skeletonema*	0.130	growth	EPA 1980c
Zinc	*Schroederella*	0.050	growth	EPA 1980d
Organotins (TBT)	*Enteromorpha*	0.000001	zoospore settlement	IPCS 1990
PCBs, total	*Thalassiosira, Dunaliella*	0.0001	growth	EPA 1980b

Fish tissue NOECs and LOECs

Tissue-based effect levels for fish (NOECs and LOECs) are from the database developed by Jarvinen & Ankley (1999) and/or literature reviews on individual contaminants (Beyer *et al.* 1996, Meador *et al.* 2002). Only studies reporting contaminant levels in whole body samples were considered. Studies reporting both a LOEC and a NOEC were preferred. In addition, studies conducted with marine or anadromous species were preferred over studies conducted with freshwater species.

Tissue contaminant levels reported in the source documents are given as wet weight values. These were converted to dry weight concentrations using the following:

ppm (mg/kg) dry weight = ppm (mg/kg) wet weight / fraction solids, where

fraction solids = 0.2, consistent with the factor used by Jarvinen and Ankley (1999).

The NOECs and LOECs that were used to calculate sediment screening levels for fish are provided in the worksheet for that receptor group. Table 3 below provides more detail on the basis of the selected reference values.

Table 3. Fish tissue NOECs and LOECs considered for use in sediment screening level calculations.

	Note	Organism	Whole Body Concentration		Function	Source
			ppm wet	ppm dry		
Arsenic	Study with lowest LOEC	Rainbow trout (fingerling)	NOEC 1.0 LOEC 3.0	NOEC 5 LOEC 15	survival, growth	Ref #286 *in* Jarvinen & Ankley 1999
Cadmium	Study with lowest LOEC	Atlantic salmon (alevin)	NOEC 0.060 LOEC 0.12	NOEC 0.30 LOEC 0.60	growth	Ref #379 *in* Jarvinen & Ankley 1999
Copper	Study with lowest LOEC (of two)	Carp (larvae)	NOEC 7.4 LOEC 11.7	NOEC 37 LOEC 58.5	survival	Ref #432 *in* Jarvinen & Ankley 1999
Lead	Study with lowest LOEC (of two)	Brook trout (embryo)	NOEC 0.34 LOEC 0.40	NOEC 1.7 LOEC 2.0	hatchability	Ref #207 *in* Jarvinen & Ankley 1999
Mercury	Study with lowest LOEC	Rainbow trout (embryo/larvae)	NOEC - LOEC 0.04	NOEC - LOEC 0.20	survival	Ref #33 *in* Jarvinen & Ankley 1999
	general recommendation	Salmonid embryos	NOEC - LOEC 0.07-0.1	NOEC LOEC 0.35-0.5	survival	Beyer et al. 1996
Selenium	Study with lowest LOEC	Chinook salmon (swim up larvae)	NOEC 0.20 LOEC 0.66	NOEC 1.0 LOEC 3.3	growth, survival	Ref #162 *in* Jarvinen & Ankley 1999
Zinc	Study with lowest LOEC	Flagfish larvae-adult	NOEC 34 LOEC 40	NOEC 170 LOEC 200	growth	Ref #418 *in* Jarvinen & Ankley 1999
TBT		Rainbow trout yolk sac fry	NOEC - LOEC 0.4	NOEC - LOEC 2.0	growth	Meador *et al.* 2002
PCBs	Study with lowest LOEC for saltwater species	Sheepshead minnow embryo-larvae	NOEC 0.88 LOEC 5.1	NOEC 4.4 LOEC 25.5	survival	Ref #174 *in* Jarvinen & Ankley 1999

Toxicity Reference Values (TRVs) for wildlife

The TRVs recommended by the U.S. Environmental Protection Agency, Region 9 (EPA), Biological Technical Assistance Group (BTAG), and USFWS (2003) provide estimates of chronic daily contaminant dose rates (as $mg_{contaminant}/kg_{body\ weight}$ -day) that relate to no observed adverse effect (NOAEL) and low observed adverse effect levels (LOAEL) in avian and mammalian receptors. The BTAG TRVs were developed using a comprehensive literature search in a consensus effort involving the Navy, Navy contractors, the EPA, and state and federal natural resource trustee agencies (EPA-BTAG 2002).

Two TRVs are identified for each analyte.

> The TRV-Low (TRV-L) represents a chronic NOAEL. It is based on NOAELs identified in laboratory studies, often with adjustments for uncertainty about the duration of exposure and interspecies differences in sensitivity. The TRV-L is a daily dose rate below which no observable adverse effect is expected for the wildlife receptor of concern. The TRVs derived by USFWS (2003) for mercury also represent NOAELs in wildlife receptors.
>
> The TRV-High (TRV-H) represents a chronic (LOAEL). It is based on LOAELs identified in laboratory studies, often with adjustments for uncertainty about duration of exposure and interspecies differences in sensitivity. The TRV-H is a LOAEL that is mid-range in the distribution of LOAELs considered. As such, it represents a daily dose rate beyond which regulatory agencies would expect there to be adverse ecological (e.g., population level) effects. Precisely where the threshold for adverse effects falls in the range between the TRV-L and the TRV-H is uncertain. However, the probability of adverse effects increases as the TRV-H is approached.

The TRVs that were used to calculate sediment screening levels are provided in the worksheets for wildlife receptors. Table 4, on the following page provides more detail on the selected benchmark values.

The TRVs developed for avian species were also applied to screening level estimates for turtles. Extrapolating across animal classes, especially when one class consists of homeotherms (birds) and the other of poikilotherms (reptiles) is not usually recommended, unless in a situation where the species is listed as endangered or threatened and there are no other applicable values (TNRCC 2001). Although reference doses for reptiles are lacking, there is a need to consider reptiles because the green sea turtle is listed. The TRVs for birds were selected because they lay eggs, and therefore are assumed to be more biologically similar to reptiles than mammals. No uncertainty factors beyond those incorporated in the avian TRVs were applied because it is not clear what the magnitude of the cross-class extrapolation factor should be. While a factor of 10 is often applied to adjust for uncertainty about sensitivities of species within a single class, even larger uncertainty factors might be indicated for extrapolations across class. Larger uncertainty factors may in turn lead to unrealistic screening level calculations. The unadjusted avian TRVs were selected for use until reference doses (TRVs or others) specifically for reptiles, or suitable uncertainty factors are identified.

Table 4. Toxicity Reference Values for avian and mammalian receptors.

	Avian (mg/kg-d)				Mammalian (mg/kg-d)			
	TRV-L	TRV-H	test species	effect and/or affected system	TRV-L	TRV-H	test species	effect and/or affected system
PCBs	0.09	1.27	Chicken	reproduction	0.36	1.28	Mouse	reproduction
Butyltins	0.73	45.9	Quail	reproduction	0.25	15	Rat	reproduction
PAH (BaP)					1.31	32.8	Mouse	cancer
Arsenic	5.5	22	Mallard	reproduction	0.32	4.7	Rat	growth, cancer, kidneys, lungs
Cadmium	0.08	10.4	Mallard	kidney, reproduction, multiple systems	0.06	2.64	Mouse	reproduction
Copper	2.3	52.3	Chicken	growth, gizzard erosion	2.67	632	Mouse	immunotoxicity, growth, survival, water consumption
Lead	0.014	-	Quail	reproduction	1.0	-	Rat	kidney
	-	8.75	Chicken	reproduction	-	241	Mouse	growth, liver, kidney
Mercury	0.007 (n*) 0.021 (p*)	0.18	Mallard	reproduction, survival, neurotoxicity	0.018*	0.27	Mink	survival, appetite loss, neurotoxicity
Nickel	1.38	56.3	Mallard	growth	0.13	31.6	Rat	reproduction
Selenium	0.23	0.93	Mallard	growth, reproduction, multiple organs	0.05	1.21	Mouse	liver, reproduction
Zinc	17.2	172	Mallard	growth, reproduction, multiple organs	9.6	-	Mouse	pancreas, adrenal cortex
					-	411	Rat	development

* TRV-L is substituted with NOAELs derived from the same studies as those used by EPA Region 9 BTAG, but using different uncertainty factors to address concerns about Service trust resources. The NOAELs are recommended by USFWS (2003). Two values are recommended for avian receptors, one for piscivorous birds (p), such as terns and pelicans, and the other for non-piscivorous birds (n) such as scoter.

Step 5. Select literature-based wildlife exposure factors.

Screening levels for wildlife receptors (birds, mammals, and turtles) are computed using equations that incorporate assumptions about how much food and sediment each species ingests per day from the area of concern (exposure factors). The exposure factors are literature-based values given below.

Receptor Body Weight

Body weights (BW) used for receptors other than turtles, wigeon, and black skimmers were derived by Exponent (2002) for the screening level (Phase I) risk assessment for NASSCO and Southwest Marine shipyard sediment studies. There are very few data on on the size distribution of green sea turtles in San Diego Bay, and measurements are most often given as carapace length. The body weight assumed for the green sea turtle was calculated from the minimum straight-line carapace length of nesting females on the Galapagos Islands (NMFS & USFWS 1998). Length was converted to weight using a log-log transformed length-to-weight regression derived from data on five animals captured in San Diego Bay (Dutton & Dutton 1998). The body weight for the wigeon is the mean minus one standard deviation for females (Dunning 1984). The body weight assumed for black skimmer is the minimum for adult females (Horn and Dahdul 1999).

The selected BWs are represented by low end values for adult animals. Depending on the data, the weight assumed for a receptor may be a mean minus one standard deviation, a minimum average adult weight, or a minimum adult weight. Low end, rather than central tendency values are preferred for screening level assessments to ensure that the screening levels will be protective of adults of all sizes. Adult body weights are used partly because there are more data on body weight distributions for adults than for younger life stages. Sediment screening levels specific to younger life stages may be considered in the future, if the necessary data on body weight distributions become available.

Area Use and Seasonal Use

Ideally, the sediment screening levels will be protective of all wildlife receptor species, some of which may reside in the area year round and for which the San Diego Bay constitutes 100% of the foraging range. Consequently, for calculating screening levels, the area use factor (AUF) and the seasonal use factor (SUF), both of which are often used in wildlife risk calculations, are set at 1.0 for all receptors. The values assigned to the use and residence factors are based on professional judgment and are consistent with EPA (1997) guidance for screening level ecological risk assessments.

Ingestion Factors

To calculate wildlife risk-based sediment screening levels it is assumed that exposure is almost entirely by the ingestion route, which includes both the diet and incidental ingestion of sediment. Sediments were assumed to provide no nutritional value. Therefore, while sediments are considered part of the total bulk ingested material, they are not considered part of the diet. Both the food ingestion rate and the sediment ingestion rate need to be determined to evaluate the total exposure via ingestion. The

daily intake from ingestion of food (diet) is added to the daily intake from ingestion of sediment to obtain an estimate of total daily exposure via the ingestion route.

Diet Composition

Assumptions about diet composition for all but the wigeon and the skimmer are those selected by Exponent (2003). The diet composition for the wigeon is from Bellrose (1978). The diet composition for black skimmers is from Horn and Dahdul (1999).

Table 5. Assumed diet composition for wildlife receptors.

Receptor	Diet Composition
Surf scoter	100% bivalves (mussels & clams)
Western grebe	100% small fish
Least tern	100% small fish
Black skimmer	100% small fish
Brown pelican	100% medium size fish
California sea lion	100% medium size fish
American wigeon	100% eelgrass
Pacific green sea turtle	100% eelgrass

Food Ingestion (dry weight based)

The amount of food ingested per day was computed from regressions by Nagy (2001). These regressions are based on field metabolic rates measured in over 229 species of terrestrial vertebrates. Much of the variation in metabolic rates is explained by the taxonomic group and size, expressed as body mass (grams) within each taxonomic group. Nagy (2001) provides size-based regression equations for numerous taxonomic groups of vertebrates. In addition, constants are provided for estimating daily ingestion in both wet weight and dry weight terms.

Estimated daily food ingestion by wildlife receptors in this analysis are shown below, along with the equations from which the values were derived. For consistency, the regressions are for dry weight ingestion rates.

The food ingestion rate used for computing sediment screening levels is calculated as:

(grams food ingested / day) / (grams body of the receptor) = g_{food}/g_{bw}-d.

Note that, g_{food}/g_{bw}-d is the same as kg_{food}/kg_{bw}-d

The latter (kg_{food}/kg_{bw}-d) is used for computing sediment benchmarks. It is also demonstrates how the species compare as potentially most exposed receptors.

Table 6. Estimated dry weight food ingestion rates from regression equations by Nagy (2001).

Receptor	BW (g)	Equation	Ingestion/Day (g_{food}/d)	Ingestion Rate (g_{food}/g_{BW}-d) = (kg_{food}/kg_{BW}-d)	From regression for-
Surf scoter	859	$0.638(BW)^{.685}$	65	0.0757	All birds
Western grebe	808	$0.997(BW)^{.613}$	60	0.0743	Petrels, albatross
Least tern	36	$0.997(BW)^{.613}$	8.97	0.2492	Petrels, albatross
Black skimmer	212	$0.997(BW)^{.613}$	27	0.1274	Petrels, albatross
Brown pelican	2845	$0.279(BW)^{.845}$	231	0.0812	Pelicaniformes
Sea lion	45000	$0.102(BW)^{.864}$	1069	0.0238	All carnivores
American wigeon	638	$0.638\ (BW)^{.685}$	53	0.0831	All birds
Sea turtle	42000	$0.0111(BW)^{.920}$	199	0.0047	All reptiles

Sediment Ingestion (dry weight based)

As stated previously, sediment is assumed to have no nutritional value, and therefore does not contribute to the daily caloric requirements upon which regressions by Nagy (2001) are based. However, sediment ingestion rates can be calculated from food ingestion rates. The amount of sediment ingested per day is computed as a fraction (f) of the amount of food ingested per day. Sediment ingestion is incidental and expected to be greater for species that forage at the sediment-water interface (e.g., scoter) than for those that feed on pelagic organisms (e.g., terns). The fractions that are used (up to 5 percent of the food ingestion rates) are consistent with fractions recommended for similar receptors by EPA (1993). Species that probe sediment for food in intertidal mudflats and marshes (e.g., herons and rails) are not addressed in this analysis. Sediment ingestion by herons and rails is expected to be higher (EPA 1993) than values considered in this analysis. The estimated sediment ingestion rates for each of the receptors considered in this analysis are shown in the table below.

Table 7. Estimated sediment ingestion rates.

Receptor	BW (kg)	Food ingestion (kg/d)	Fraction (f)	Sediment ingestion (kg/day)	Sediment ingestion rate (kg_{sed}/kg_{BW} - d)
Surf scoter	0.859	0.065	0.05	0.0033	0.0038
Western grebe	0.808	0.060	0.05	0.0030	0.0037
Least tern	0.036	0.009	0.02	0.00018	0.0050
Black skimmer	0.212	0.027	0.02	0.00054	0.0025
Brown pelican	2.845	0.231	0.02	0.00462	0.0016
Sea lion	45.000	1.069	0.02	0.0214	0.00048
American wigeon	0.638	0.053	0.05	0.00265	0.00415
Sea turtle	42.000	0.199	0.05	0.0100	0.00024

Note: The daily intake from ingestion of food (diet) is added to the daily intake from ingestion of sediment to obtain an estimate of total daily exposure via the ingestion route.

Step 6. Derive sediment-to-porewater partition coefficients (Kp) and biota-to-sediment accumulation factors (BSAFs) for sediments from San Diego Bay.

Data are available for deriving Kps and BSAFs for San Diego Bay sediments. The data are from studies conducted by Exponent (2003) for the NASSCO and SWM shipyard facilities. As part of those studies, Exponent (2003) collected and measured contaminant levels in samples of surface sediment, porewater, and biota from shipyard and reference area stations.

With the available data, it was possible to calculate Kps and BSAFs for both shipyard and reference area stations in the Bay. For reasons stated earlier, the BSAFs and Kps deemed most appropriate for calculating sediment screening levels are those obtained with reference area samples only.

Sediment-to-Porewater Partition Coefficients (Kp)

As previously stated (Step 3), Kp is the ratio of a contaminant's concentration in bulk sediment to that in a corresponding porewater sample. Surface sediment and corresponding porewater samples were collected at five reference area stations. Consequently, as many as five values of Kp were identified for each contaminant of concern. This is an upper limit on the number of Kps that may be generated for each contaminant, because the Kp could not be calculated in those instances where the contaminant concentration in either the porewater or the corresponding sediment sample was below the detection limit.

Mean reference area Kp values were used to calculate sediment screening levels for vegetation. Alternate measures of central tendency (e.g., median or geometric mean) may be used in the future as more data become available. The minimum Kp should be used if a more conservative (protective) screening value is desired.

The Kp values used to calculate sediment screening levels are provided in the worksheet for aquatic vegetation. They are also given in the table below, along with a notation on the number of individual values that the mean represents. For more detail on data sources, how the data were evaluated, and how the Kps were calculated, please refer to Attachment B of this document.

Table 8. Mean reference area Kp values used to compute sediment screening levels for aquatic vegetation.

Analyte	N	Mean Kp
Arsenic	5	792
Cadmium	0	not detected
Chromium	5	7,037
Copper	5	4,659
Lead	5	8,725
Mercury	5	5,862
Nickel	5	3,107
Selenium	0	not detected
Silver	5	2,000
Zinc	5	5,711
TBT	1	1,591
PAHs	0	not detected
PCBs	5	2,411

Biota-to-Sediment Accumulation Factors (BSAFs).

With data from Exponent (2003), it was possible to compute BSAFs for bivalves (resident mussels and clams from bioaccumulation tests), a demersal fish (spotted sand bass), a pelagic fish (anchovy), lobsters, and eelgrass. The preferred BSAFs are those obtained with biota that can be linked to specific sediment locations (site fidelity), and/or are food for the selected wildlife receptors. The BSAFs for bivalves, demersal fish, and eelgrass are considered the most applicable for calculating the wildlife risk-based sediment screening levels, and therefore, are the only ones used in this exercise.

As previously stated (in Step 3), the BSAF is the ratio of a contaminant's concentration in tissue to that in a corresponding sediment sample. The BSAFs for organics are based on lipid/total organic carbon (toc)-normalized values, except those calculated for eelgrass in which lipids were not detected. Lipid/toc normalization is used because organic content of sediment tends to affect bioavailability of organic contaminants while lipid content in organisms may govern uptake and accumulation.

To calculate BSAFs, it was necessary to pair data on contaminant levels in biota samples with data on contaminant levels in presumed co-located sediment samples. This was possible for data on bivalves and sediment from six stations, and for eelgrass and sediment at one station. Data on five individual sand bass collected from one reference area are paired with data from four sediment stations within the same area. Although individual fish were collected and analyzed for contaminants, the five were treated as a single composite sample (i.e., one mean concentration per analyte).

With data paired as described, it was possible to identify six bivalve BSAFs, one eelgrass BSAF, and one fish BSAF for each contaminant of concern. Some contaminants may be

represented by even fewer BSAFs, because a BSAF could not be calculated in those instances where the contaminant concentration in either the tissue or the corresponding sediment sample was below the detection limit. At best, the bivalve BSAFs used to calculate sediment benchmarks represent the means for the six stations, whereas eelgrass and fish BSAFs represent single values.

The BSAFs used to calculate sediment benchmarks for each fish or wildlife receptor are provided in the worksheet for that receptor. They are also summarized in the table below. For more detail on data sources, how the data were evaluated, and how BSAFs were calculated, please refer to Attachment B.

Table 9. BSAFs used for calculating sediment screening levels.

Analyte	Units	Organism		
		Bivalves[1]	Spotted sand bass[2]	Eelgrass[3]
Organics (toc-/lipid-normalized)				
f-lipid/f-toc	unitless	4.18	10.687	not calculated[3]
PCB homologs	kg_{toc}/kg_{lipid}	0.90	4.608	0.249[3]
PCB Aroclors	kg_{toc}/kg_{lipid}	0.89	2.699	0.229[3]
PCB congeners	kg_{toc}/kg_{lipid}	0.92	5.424	0.263[3]
TPAH	kg_{toc}/kg_{lipid}	0.72	not detected	not detected
TBT	kg_{toc}/kg_{lipid}	2.14	1.464	not detected
Inorganics				
Arsenic	kg_{tissue}/kg_{sed}	3.41	0.351	0.271
Cadmium	kg_{tissue}/kg_{sed}	1.42	0.694	1.923
Chromium (total)	kg_{tissue}/kg_{sed}	0.08	not detected	0.040
Copper	kg_{tissue}/kg_{sed}	0.25	0.057	0.328
Lead	kg_{tissue}/kg_{sed}	0.09	0.014	0.113
Mercury (total)	kg_{tissue}/kg_{sed}	0.39	1.621	not detected
Nickel	kg_{tissue}/kg_{sed}	0.36	0.142	0.233
Selenium	kg_{tissue}/kg_{sed}	1.19	not detected	not detected
Silver	kg_{tissue}/kg_{sed}	0.77	0.049	0.774
Zinc	kg_{tissue}/kg_{sed}	0.92	0.421	0.664

1. Mean of six (5 clam stations and 1 mussel station, see Attachment B).
2. Mean obtained with five individual fish and the mean for four sediment stations (see Attachment B for details).
3. Based on individual sample and BSAFs for organics not lipid/toc - normalized.

Step 7. Develop sediment screening levels.

The sediment screening levels developed for each receptor are presented in the following worksheets that include applicable information on the approach and factors that were used to calculate the sediment screening levels.

Worksheet 1. Sediment Screening Levels for Directly Exposed Benthic Invertebrates

Receptors: The benthic invertebrate community consists of invertebrate fauna that reside in direct contact with the sediment. It includes organisms from unicellular microfauna, such as protozoans and ciliates to macrofauna, such as worms, clams, shrimps, crabs, and lobsters. Because they live in or on sediment, benthic invertebrates are constantly exposed to sediment-borne contaminants that may be present. Benthic invertebrates are an important and direct source of nutrition for bottom fish (e.g., goby), demersal fish (e.g., sand bass), wading birds (e.g., herons, egrets), diving ducks (e.g., surf scoter), and others not included in this analysis (e.g., shorebirds and humans) depending on the location. They also constitute an important route of exposure by vertebrate receptors to sediment-borne contaminants.

Approach: Use readily available, generic screening levels from National Oceanic and Atmospheric Administration (Long *et al.* 1995), the State of Florida (MacDonald 1994), and Meador *et al.* (2002). The generic screening levels were developed specifically for evaluating contaminant levels in sediments for potential toxicity to directly exposed benthic invertebrates.

Terms:

ERL = Effects range low, or the 10th percentile concentration within the range over which effects were observed using a variety of approaches in studies reviewed by Long *et al.* (1995). Concentrations below the ERL value represent a minimal-effects range, within which effects would be rarely observed. Concentrations above the ERL (but below the ERM) represent the possible effects range. The potential for adverse effects increases from possible to probable as concentrations approach the ERM.

ERM = Effects range median, or the 50th percentile concentration within the range over which effects were observed in studies reviewed by Long *et al.* (1995). Concentrations equal to or greater than the ERM represent probable effects levels, for which adverse effects would be expected to frequently occur.

TEL = Threshold Effect Levels represent the upper limit of the range of sediment contaminant concentrations dominated by no effects data in studies compiled and reviewed by MacDonald (1994) (i.e., minimal effects range). The TEL value is a combination of both effect levels (15th percentile) and no effect levels (50th percentile) in the database compiled by MacDonald (1994). Concentrations below the TEL are not considered to represent significant hazards to aquatic organisms.

PEL = Probable Effect Levels define the lower limit of the range of contaminant concentrations that are usually or always associated with adverse effects in studies compiled and reviewed by MacDonald (1994). The PEL is a combination of both effect concentrations (50th percentile), and no effect concentrations (85th percentile) in the database compiled by MacDonald (1994). Concentrations greater than the PEL are considered

to represent significant and immediate hazards to aquatic organisms. In other words, adverse effects are probable when concentrations exceed the PEL. Adverse effects are considered possible when contaminant levels are between the TEL and the PEL.

The ERLs, ERMs, TELs, and PELs have conservative and non-conservative attributes. The values are often derived from studies with sediments that have multiple contaminants present, yet it is assumed that all of the toxicity was caused by the individual substance for which the screening level is derived (conservative). On the other hand, lethality is often the endpoint that was measured and more sensitive endpoints may exist (non-conservative).

It is important to note that ERLs, ERMs, TELs, and PELs do not address the potential for bioaccumulation and/or potential for adverse effects in higher trophic level organisms.

Sediment screening levels for directly exposed benthic invertebrates (mg/kg or ppm dry weight).

	ER-L	ER-M	TEL	PEL	other
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
Arsenic	8.2	70	7.2	41.6	
Cadmium	1.2	9.6	0.68	4.21	
Chromium	81	370	52.3	160	
Copper	34	270	18.7	108	
Lead	46.7	218	30.2	112	
Mercury	0.15	0.71	0.13	0.7	
Nickel	20.9	51.6	15.9	42.8	
Silver	1	3.7	0.73	1.77	
Zinc	150	410	124	271	
TBT					0.060*
TPAH	4.022	44.792	1.684	16.770	
p,p'DDE	0.0022	0.027			
t-DDT	0.00158	0.0461			
total PCBs	0.0227	0.180	0.0216	0.189	

* From Meador *et al.*, 2002. Based on 6000 ng/g_{oc}. The screening value is for sediment with f-toc = 0.01. To adjust for site-specific TOC use 0.060 mg/kg x (measured f-toc/0.01).

Worksheet 2. Sediment Screening Levels for Benthic Aquatic Vegetation

Receptors: Aquatic vegetation that lives in direct contact with sediment includes rooted vascular plants and benthic algae (micro- and macro-algae). In San Diego Bay, aquatic vegetation such as eelgrass (*Zostera marina*) and benthic algae offer refuge and a source of nutrition for herbivores including invertebrates, fish, waterfowl, and the federally listed threatened green sea turtle.

Approach: Alternative A.

Use existing sediment screening levels from currently available literature. Such screening levels are for bulk sediment (mg/kg) and are generally lacking for aquatic vegetation. The screening level identified by IPCS (1990) for TBT is one exception.

Alternative B.

Use water-based benchmark toxicity values for aquatic vegetation from literature, in combination with local sediment-to-porewater partition coefficients (Kp) to derive a bulk-sediment value for vegetation.

Data sources for Alternative B.

Benchmark toxicity values for most of the contaminants are from EPA Ambient Water Quality Criteria (AWQC) documents. The benchmarks are the lowest chronic values (LCVs) identified for aquatic vegetation in literature reviews used to support development of AWQCs. The LCVs used for this analysis are from studies with saltwater species.

Partition coefficients specific to San Diego Bay sediments are calculated using sediment and porewater data from the Exponent (2003) report, Appendix B (surface sediment data) and Appendix D (porewater data).

Calculations for Kp, summarized (see Attachment A for details):

Data from each of five reference stations were used to calculate individual Kps for each contaminant, using;

Kp = ppm in sediment / ppm in the corresponding porewater sample.

Values of Kp were calculated only if the contaminant was detected in both the porewater and the corresponding bulk sediment sample.

Partition coefficients used for calculating sediment benchmarks are those obtained with reference area stations only. The Kp for each analyte is represented by the mean of the values obtained for all reference area samples (N for Kp / analyte is ≤ 5).

Calculations for sediment screening levels (target ppm in sediment, dry weight):

$K_p = ppm_{sed}/ppm_{porewater}$, and

Screening level ppm_{sed} = benchmark (LCV) for water x K_p.

Sediment screening levels could not be calculated for substances lacking a benchmark toxicity value and/or a Kp. The benchmarks that could be computed for aquatic vegetation are shown below.

Sediment Screening Levels for Benthic Aquatic Vegetation in San Diego Bay.

Analyte	Water benchmark (LCV)	Kp	Sediment screening level	
			Porewater based	Bulk sediment based
	(mg/L)	(L/kg)	(mg/kg)	(mg/kg)
Arsenic	0.02	792	15.8	none found
Chromium (III)	1.00	7037	7,037	none found
Copper	0.005	4659	23.3	none found
Lead	0.02	8725	175	none found
Mercury (total)	0.01	5862	58.6	none found
Nickel	1.00	3107	3,107	none found
Silver	0.13	2000	260	none found
Zinc	0.05	5711	286	none found
TBT	0.000001	1591	0.0016	0.10[1]
PCBs homologs	0.0001	2411	0.241	none found

1. NOEC for study on *Zostera marina* (IPCS 1990). The corresponding LOEC for reduced growth was observed with 1.0 mg/kg. Concentrations greater than 10 mg/kg were lethal to the salt marsh plant *Aster tripolium*, but not to *Limonium vulgare*.

Worksheet 3. Sediment Screening Levels for Bottom-Dwelling and Demersal Fish

Receptors: Bottom fish live and feed almost entirely at the sediment-water interface. Bottom fish are the potentially most exposed fish for sediment-borne contaminants, particularly those that do not biomagnify in the food chain (e.g., PAHs). In San Diego Bay, bottom fish include gobies and the bay blenny (USDoN, SWDIV 2000). In addition to being a source of nutrition, bottom fish constitute a route of exposure by piscivorous wildlife to sediment-borne contaminants.

Demersal fish move up and down through the water column, but feed at the sediment/water interface. As such, they are considered pelagic species that may experience significant exposure to sediment-borne contaminants (i.e., benthically coupled). For nearshore portions of San Diego Bay, these may include fantail sole, California halibut, striped mullet, rays, kelpfish, surfperch, croaker, and sand bass (USDoN, SWDIV 2000). Flatfish such as the halibut and sole are considered bottom fish by some authors.

Bottom fish and demersal fish are treated as a single group in this exercise, partly because data needed to derive screening levels specific to bottom fish are lacking. Bottom fish may be evaluated separately when the data that are needed become available.

Approach: Alternative A.

Use existing sediment screening levels from literature. Such screening levels are for bulk sediment (mg/kg) and are generally lacking for fish. The screening level identified by Johnson *et al.* (2002) for total (TPAH) is one exception.

Alternative B.

Combine tissue-based benchmark toxicity values for fish from the literature with fish-to-sediment BSAFs.

This approach was used for the eight contaminants for which BSAFs could be calculated, and tissue based reference toxicity levels could be identified, as shown in the worksheet table.

For details on how equations were derived, see Attachment A. For details on the BSAFs, see Attachment B.

Data sources for Alternative B.

Tissue-based benchmark toxicity levels for fish are from the database developed by Jarvinen and Ankley (1999) and literature reviews (in Beyer *et al.* 1996 or Meador *et a*l 2002). Both "no observed effect concentrations" (NOECs) and "lowest observed effect concentrations" (LOECs) were considered (Table 3). Unless otherwise indicated the NOEC was used to calculate sediment screening levels. The values that were used are provided in the worksheet table.

Data for BSAFs are from Exponent (2003). BSAFs and corresponding toc/lipid ratios (for organic contaminants) were computed from data on contaminant levels in sediment and whole body samples of spotted sand bass (a demersal fish). Bottom fish are the preferred species for computing fish-to-sediment BSAFs because of their association with sediment. However, data on bottom fish are lacking. The sediment data that were used are from Exponent (2003), Tables B1-1 through B1-8. The corresponding data on contaminant levels in whole body samples of fish (spotted sand bass) are from Exponent (2003), Tables E-1, E-2, E-5, and E6. Only the reference area data were used for screening level calculations.

Available data support the calculation of one reference area BSAF per contaminant of concern. Five individual fish were collected in the reference area represented by Exponent sediment sample stations 2240, 2241, 2243, and 2240. Mean contaminant levels in fish and mean contaminant levels in sediment were used to calculate BSAFs. The same data sets and approach were used to calculate the f-lipid/f-toc. For additional information on which data were used and how BSAFs were calculated, see Attachment B of this document. The BSAFs that were used to calculate sediment screening levels are provided in the worksheet table.

Calculations for Alternative B.

All values used in screening level calculations are dry weight-based and in units of parts per million (ppm, or mg/kg).

BSAFs are calculated as:

ppm_{fish}, dry weight in whole bodies / $ppm_{sediment}$, where

ppm_{fish} = mean for 5 individuals collected in the reference area and $ppm_{sediment}$ = mean for sediments from 4 reference area sample stations.

Lipid and toc-normalized values were used to calculate BSAFs for organic contaminants, including TBT. The same data sets provided corresponding values of f-toc/f-lipid for each sample.

Sediment screening levels were computed using the following:

<u>For organics, including TBT -</u>

Screening level ppm_{sed} = NOEC or LOEC ppm_{tissue} x (f-toc/f-lipid) x 1/BSAF, where

f-toc/f-lipid = 1/(f-lipid/f-toc) or 0.0936.

Values of f-toc/f-lipid and compound-specific BSAFs are provided in Table 9.

For inorganics -

Screening level ppm_{sed} = NOEC or LOEC ppm_{tissue} x 1/BSAF, where

$BSAF = ppm_{tissue}/ppm_{sediment}$.

Sediment screening levels are provided in the following table. The screening level for TPAHs is based on a review of bulk sediment concentrations associated with adverse effects in fish. All other screening levels were calculated from tissue-based benchmark toxicity values (NOECs and LOECs) and BSAFs.

The screening levels are based on BSAFs for demersal fish (spotted sand bass). They are assumed to be roughly applicable for bottom-dwelling fish. Accumulation factors based specifically on contaminant levels in bottom fish tissue are preferable, but unavailable.

Sediment screening levels could not be calculated for substances lacking a benchmark toxicity value and/or a BSAF. The screening levels that could be calculated are given below.

Sediment Screening Levels for Demersal and Bottom-Dwelling Fish in San Diego Bay.

	Tissue benchmark[1] (mg/kg dry weight)		BSAF (sand bass - whole body)	Sediment screening level (mg/kg dry weight)	
	NOEC	LOEC		NOEC-based	LOEC-based
Inorganics					
Arsenic	5	15	0.351	14	43
Cadmium	0.3	0.6	0.694	0.43	0.86
Copper	37	59	0.057	649	1,026
Lead	1.7	2.0	0.014	121	143
Mercury	-	0.20	1.621	-	0.12
Zinc	170	200	0.421	404	475
Organics (using toc-/lipid-normalized BSAF)[1]					
TBT		2.0	1.464		0.13
TPAHs	no data		not detected		1.0[2]
PCBs homologs[3]	4.4	25.5	4.608	0.09	0.52
PCBs Aroclors[3]	4.4	25.5	2.699	0.15	0.88
PCBs congeners[3]	4.4	25.5	5.424	0.08	0.44

1. f-toc/f-lipid = 1/(f-lipid/f-toc), or 0.0963. Screening levels assume sediment f-TOC = 0.01.
2. From Johnson *et al.* 2002. Guideline is for the summed concentrations of 16 - 18 individual PAHs, depending on the data source. Recommended benchmark based on bulk sediment chemistry.
3. Benchmark toxicity value for PCBs from studies with Aroclors. However, BSAFs were calculated from concentrations of PCBs quantified three different ways (i.e., as Aroclors, homologs, and congeners).

Worksheet 4. Sediment Screening Levels for a Bottom Feeding Bird Surf Scoter (*Melanitta perspicillata*)

Receptor: The surf scoter is present in San Diego Bay and represents waterfowl species that consume benthic invertebrates, primarily bivalves. As such, scoters consume organisms that live in direct contact with the sediment. Incidental ingestion of sediment during feeding is expected to occur as well. Among avian species, the scoter represents a potentially most exposed receptor for those sediment-borne contaminants that enter the food web but do not increase in concentration with trophic transfer (e.g., some metals and PAHs).

Approach: Combine literature based exposure factors and benchmark toxicity values with locally-derived BSAFs for bivalves.

Data sources:

The benchmark toxicity values used for wildlife species are the TRVs recommended by BTAG (2002) and USFWS (2003). The TRVs are estimates of chronic daily contaminant exposure rates that relate to no observed adverse effect levels (NOAELs) and mid-range low observed adverse effect levels (LOAELs). TRVs have been developed for both avian and mammalian receptors (Table 4). The avian TRVs used to calculate screening levels are provided in the table below.

Exposure factors used for surf scoter include values for body weight from Exponent (2002), diet composition as described by Exponent (2003), use factors (AUF and SUF) and sediment ingestion fractions based on professional judgment consistent with EPA guidance (EPA 1993), and food ingestion rates calculated from regressions provided by Nagy (2001). The exposure factors used to calculate sediment screening levels are provided below.

Bivalve based BSAFs and f-lipid/f-toc values were calculated from data in the shipyard report (Exponent 2003) using results of bioaccumulation tests with the clam (*Macoma nasuta*) and results of chemical analyses performed on resident benthic mussels (*Musculista senthousii*). Data on contaminant levels in bivalve tissues are from Exponent (2003), Tables E-1, E-2, E-5, and E-6. Data on contaminant levels in corresponding sediment samples are from Exponent (2003), Tables B1-1 through B1-8. For reasons given in the overview, only data from reference the area stations (N = 6) were used to compute sediment screening levels.

Calculations for BSAFs (see Attachment A for details on equations and terms):

The BSAF for each contaminant = ppm_{tissue} / $ppm_{sediment}$.

The BSAFs for organics are used in conjunction with corresponding values of f-lipid/f-toc.

The contaminant concentrations are in parts per million (ppm) dry weight.

Contaminant concentrations used to calculate BSAFs for organic compounds and TBT are normalized for lipid (dry weight f-lipid, in tissue samples) or total organic carbon (dry weight f-toc, in sediment samples).

Available data support the calculation of six reference area BSAFs for each contaminant of concern. Values were obtained with clams exposed to sediments from five stations and with mussels exposed to sediment from a sixth station. Given the few number of samples, BSAFs obtained with mussel samples were combined with BSAFs from clam samples and the mean used to calculate the sediment screening levels for each analyte.

Calculations for Sediment Screening Levels:

The equations used to calculate sediment screening levels are derived in Attachment A. They are:

For organics, including TBT -

screening level ppm_{sed} = TRV / [(sediment ingestion rate) + (BSAF)(f-lipid/f-toc)(food ingestion rate)]

For inorganics -

screening level ppm_{sed} = TRV / [(sediment ingestion rate) + (BSAF)(food ingestion rate)]

The exposure factors that were used for surf scoter are presented below.

Receptor	Surf scoter
Diet	100% bivalves (mussels & clams)
Body weight (kg_{BW})	0.859
Food ingestion (kg/day)[1]	0.065
Food ingestion rate (kg/kg_{BW}-day)[1,2]	**0.0757**
Sediment ingestion (kg/day)[1]	0.0033
Sediment Ingestion rate (kg/kg_{BW}-day)[1,2]	**0.0038**
Area use factor (AUF)	1
Seasonal use factor (SUF)	1

1. Dry weight based
2. Ingestion rate = ingestion per day / BW

Using the exposure factors for scoter, the general equations for calculating sediment screening levels become:

For organics, including TBT -

Screening level ppm_{sed} = TRV / [(0.0038 kg_{sed} / kg_{BW}-day) + (BSAF)(f_{lipid}/f_{toc})(0.0757 kg_{food} / kg_{BW}-day)]

For inorganics -

$$\text{Screening level } ppm_{sed} = TRV / [(0.0038\ kg_{sed} / kg_{BW}\text{-day}) + (BSAF)(0.0757\ kg_{food} / kg_{BW}\text{-day})].$$

Adjustments for AUF and/or SUF

Adjusted sediment screening level = estimated screening level x 1/AUF x 1/SUF. Because AUF and SUF = 1.0, estimated screening levels require no adjustment.

Screening levels could not be calculated for substances lacking a benchmark toxicity value and/or a bivalve BSAF. The sediment screening levels that could be calculated for surf scoter are presented below.

Sediment Screening Levels for Surf Scoter in San Diego Bay.

	TRV (mg/kg-day)		BSAF[1] (bivalve)	Sediment screening level (ppm dry weight)	
	Low	High		TRV-L based	TRV-H based
Inorganics					
Arsenic	5.5	22	3.41	21	84
Cadmium	0.08	10	1.42	0.72	93
Copper	2.3	52	0.25	101	2,298
Lead	0.014	8.75	0.09	1.3	821
Mercury	0.007[2]	0.18	0.39	0.21[2]	5.40
Nickel	1.38	56.3	0.36	44	1,811
Selenium	0.23	0.93	1.19[4]	2.5	9.9
Zinc	17	172	0.92	234	2,341
Organics (using toc-/lipid-normalized BSAF)[3]					
TBT	0.73	46	2.14	1.07	67
PCBs homologs[5]	0.09	1.27	0.90	0.31	4.40
PCBs Aroclors[5]	0.09	1.27	0.89	0.32	4.45
PCBs congeners[5]	0.09	1.27	0.92	0.31	4.31

1. Mean of six for reference area stations.
2. TRV-L and the corresponding screening level are based on NOAEL from USFWS (2003).
3. f-lipid/f-toc = 4.18. Screening levels assume sediment TOC = 0.01.
4. Based on single value (Se detected in one sediment sample).
5. Benchmark toxicity value for PCBs based on studies with Aroclors. However, the BSAFs were calculated from concentrations of PCBs quantified three different ways (i.e., as Aroclors, homologs, and congeners).

Worksheet 5. Sediment Screening Levels for Birds that Consume Small Fish
Western Grebe (*Aechmophorus occidentalis occidentalis*)

Receptor: The western grebe is present in San Diego Bay and is a year-round resident in San Diego County (USDoN, SWDIV 2000) that nests at inland lakes and winters in estuarine areas. The grebe diet is primarily fish, but includes crustaceans, mollusks, insects, and plant material. Grebes consume organisms that may have high concentrations of bioaccumulative contaminants in their tissues (fish). In addition, they may consume organisms that live in direct contact with the sediment, and therefore may be exposed to sediment-borne contaminants through diet and incidental ingestion of sediment. Because they may feed at the sediment-water interface, incidental ingestion of sediment by grebes is assumed to be potentially comparable to that of surf scoters.

Approach: Combine literature-based exposure factors and benchmark toxicity values with locally-derived fish-to-sediment accumulation factors (BSAFs).

Data sources:

The benchmark toxicity values that were used are the TRVs recommended by BTAG (2002) and USFWS (2003). The TRVs are estimates of chronic daily contaminant exposure rates that relate to no observed adverse effect levels (NOAELs) and mid-range low observed adverse effect levels (LOAELs). TRVs have been developed for both avian and mammalian receptors (Table 4). The avian TRVs used to calculate screening levels are provided in the table below.

Exposure factors used for the grebe include values for body weight from Exponent (2002), diet composition as described by Exponent (2003), use factors (AUF and SUF) and sediment ingestion fractions based on professional judgment consistent with EPA guidance (EPA 1993), and food ingestion rates calculated from regressions provided by Nagy (2001). The exposure factors used to calculate sediment screening levels are provided below.

Fish-to-sediment BSAFs were calculated from data in the shipyard report (Exponent 2003) using results obtained with whole body samples of spotted sand bass, a demersal fish. The sand bass that were collected had a mean fork length of 27 cm, which is larger than what might be consumed by grebes. However, it was the only demersal species that was caught. The BSAFs obtained with sand bass are assumed to represent BSAFs for demersal fish in general, including fish small enough to be consumed by grebes. Data on contaminant levels in whole body sand bass samples are from Exponent (2003), Tables E-1, E-2, E-5, and E-6. Data on contaminant levels in sediment samples are from Exponent (2003), Tables B1-1 through B1-8. For reasons given earlier (overview) only data from reference area stations (N = 1) were used to compute sediment screening levels.

Calculations for BSAFs:

The BSAF for each contaminant = ppm_{tissue} / $ppm_{sediment}$.

The BSAFs for organics are used in conjunction with corresponding values of f-lipid/f-toc.

The contaminant concentrations are in parts per million (ppm) dry weight. Contaminant concentrations used to calculate BSAFs for organic compounds and TBT are normalized for lipid (dry weight f-lipid, in tissue samples) or total organic carbon (dry weight f-toc, in sediment samples).

Available data support the calculation of one reference area BSAF per contaminant of concern. Five individual fish were collected in the reference area represented by Exponent sediment sample stations 2240, 2241, 2243, and 2240. Mean contaminant levels in fish and mean contaminant levels in sediment were used to calculate BSAFs. The same data sets and approach were used to calculate the f-lipid/f-toc. For additional information on which data were used and how BSAFs were calculated, see Attachment B of this document.

Calculations for Sediment Screening Levels:

The equations used to calculate sediment screening levels for wildlife species are derived in Attachment A. They are:

For organics, including TBT -

Screening level ppm_{sed} = TRV / [(sediment ingestion rate) + (BSAF)(f-lipid/f-toc)(food ingestion rate)]

For inorganics -

Screening level ppm_{sed} = TRV / [(sediment ingestion rate) + (BSAF)(food ingestion rate)]

The exposure factors used to calculate sediment screening levels for the western grebe are summarized below.

Receptor	Western grebe
Diet	100% small fish
Body weight (kg_{BW})	0.808
Food ingestion (kg/day)[1]	0.060
Food ingestion rate (kg/kg_{BW}-day)[1,2]	**0.0743**
Sediment ingestion (kg/day)[1]	0.0030
Sediment ingestion rate (kg/kg_{BW}-day)[1,2]	**0.0037**
Area use factor (AUF)	1
Seasonal use factor (SUF)	1

1. Dry weight
2. Ingestion rate = ingestion per day / BW

Using the factors for the grebe, the generic equations for calculating sediment screening levels become:

For organics, including TBT -

$$\text{Screening level } ppm_{sed} = TRV / [(0.0037\ kg_{sed} / kg_{BW}\text{-day}) + (BSAF)(f_{lipid}/f_{toc})(0.0743\ kg_{food} / kg_{BW}\text{-day})]$$

For inorganics -

$$\text{Screening level } ppm_{sed} = TRV / [(0.0037\ kg_{sed} / kg_{BW}\text{-day}) + (BSAF)(0.0743\ kg_{food} / kg_{BW}\text{-day})]$$

Adjustments for AUF and/or SUF

Adjusted sediment screening level = estimated screening level x 1/AUF x 1/SUF. Because AUF and SUF = 1.0, estimated screening levels require no adjustment.

Screening levels could not be calculated for substances lacking a benchmark toxicity value and/or a BSAF. The sediment screening levels computed for western grebe are shown below.

Sediment Screening Levels for Western Grebe in San Diego Bay.

	TRV (mg/kg-day)		BSAF[1] (sand bass - whole body)	Sediment screening level (ppm dry weight)	
	Low	High		TRV-L based	TRV-H based
Inorganics					
Arsenic	5.5	22	0.351	185	739
Cadmium	0.08	10	0.694	1.45	188
Copper	2.3	52	0.057	289	6,582
Lead	0.014	8.75	0.014	2.95	1,841
Mercury	0.021[2]	0.18	1.621	0.17[2]	1.45
Nickel	1.38	56.3	0.142	97	3,949
Zinc	17	172	0.421	492	4,918
Organics (using toc-/lipid-normalized BSAF)[3]					
TBT	0.73	45.9	1.464	0.6	39
PCBs homologs[4]	0.09	1.27	4.608	0.025	0.35
PCBs Aroclors[4]	0.09	1.27	2.699	0.042	0.59
PCBs congeners[4]	0.09	1.27	5.424	0.021	0.29

1. Mean ppm in fish / mean ppm for sediment, producing N=1 reference area BSAF for each analyte.
2. TRV-L and corresponding screening level are based on NOAEL from USFWS (2003).
3. f-lipid/f-toc = 10.687, screening levels assume sediment toc = 0.01.
4. Benchmark toxicity value for PCBs based on studies with Aroclors. However, the BSAFs were calculated from concentrations of PCBs quantified three different ways (i.e., as Aroclors, homologs, and congeners).

Worksheet 6. Sediment Screening Levels for Birds That Consume Small Fish California Least Tern (*Sterna antillarum browni*)

Receptor: The California least tern is present in San Diego Bay and represents piscivorous birds that nest in the area. The California least tern is also a federally and state listed endangered species. Least terns in San Diego Bay consume small fish found near the water surface, such as anchovy and topsmelt. While anchovy and topsmelt are considered pelagic species, topsmelt are also a demersal species when present in shallow water, such as in South San Diego Bay near the tern nesting colonies. The tern's exposure to sediment-borne contaminants is expected to be through their diet, with incidental ingestion of sediment limited to that which is in the gut of the prey. Because of their food preference and high food ingestion rate relative to body weight, terns may represent the most exposed of the piscivorous birds to sediment-borne contaminants that enter and accumulate in food web organisms.

Approach: Combine literature based exposure factors and benchmark toxicity values with locally derived fish-to-sediment accumulation factors (BSAFs).

Data sources:

The benchmark toxicity values that were used are the TRVs recommended by BTAG (2002) and USFWS (2003). The TRVs are estimates of chronic daily contaminant exposure rates that relate to no observed adverse effect levels (NOAELs) and mid-range low observed adverse effect levels (LOAELs). TRVs have been developed for both avian and mammalian receptors (Table 4). The avian TRVs used to calculate screening levels are given in the table below.

Exposure factors used for the tern include values for body weight from Exponent (2002), diet composition as described by Exponent (2003), use factors (AUF and SUF) and sediment ingestion fractions based on professional judgment consistent with EPA guidance (EPA 1993), and food ingestion rates calculated from regressions provided by Nagy (2001). The exposure factors used to calculate sediment screening levels are provided below.

Fish-to-sediment BSAFs were calculated from data in the shipyard report (Exponent 2003) using results obtained with whole body samples of spotted sand bass, a demersal fish. The sand bass that were collected had a mean fork length of 27 cm, which is larger than what would be consumed by least terns. However, it was the only demersal species that was caught. The BSAFs obtained with sand bass are assumed to represent BSAFs for demersal fish in general, including fish small enough to be consumed by least terns. Data on contaminant levels in whole body sand bass samples are from Exponent (2003), Tables E-1, E-2, E-5, and E-6. Data on contaminant levels in sediment samples are from Exponent (2003), Tables B1-1 through B1-8. For reasons given earlier (overview) only data from reference area stations (N = 1) were used to compute sediment screening levels.

Calculations for BSAFs:

The BSAF for each contaminant = ppm_{tissue} / $ppm_{sediment}$.

The BSAFs for organics are used in conjunction with corresponding values of f-lipid/f-toc.

The contaminant concentrations are in parts per million (ppm) dry weight. Contaminant concentrations used to calculate BSAFs for organic compounds and TBT are normalized for lipid (dry weight f-lipid, in tissue samples) or total organic carbon (dry weight f-toc, in sediment samples).

Available data support the calculation of one reference area BSAF per contaminant of concern. Five individual fish were collected in the reference area represented by Exponent sediment sample stations 2240, 2241, 2243, and 2240. Mean contaminant levels in fish and mean contaminant levels in sediment were used to calculate BSAFs. The same data sets were used to calculate the f-lipid/f-toc. See Attachment B for additional information on the data and BSAFs.

Calculations for Sediment Screening Levels:

The equations used to calculate screening levels for wildlife species are derived in Attachment A. They are:

For organics, including TBT -

Screening level ppm_{sed} = TRV / [(sediment ingestion rate) + (BSAF)(f-lipid/f-toc)(food ingestion rate)]

For inorganics -

Screening level ppm_{sed} = TRV / [(sediment ingestion rate) + (BSAF)(food ingestion rate)]

Exposure factors used to calculate screening levels for the tern are summarized in the following table.

Receptor	California least tern
Diet	100% small fish
Body weight (kg_{BW})	0.036
Food ingestion (kg/day)[1]	0.00897
Food ingestion rate (kg/kg_{BW}-day)[1,2]	**0.2492**
Sediment ingestion (kg/day)[1]	0.00018
Sediment ingestion rate (kg/kg_{BW}-day)[1,2]	**0.0050**
Area use factor (AUF)	1
Seasonal use factor (SUF)	1

1. Dry weight
2. Ingestion rate = ingestion per day / BW

Using the factors for the tern, the generic equations for calculating sediment

screening levels become:

For organics, including TBT -

$$\text{Screening level } ppm_{sed} = TRV / [(0.0050\ kg_{sed}/\ kg_{BW}\text{-day}) + (BSAF)(f_{lipid}/f_{toc})(0.2492\ kg_{food}\ /\ kg_{BW}\text{-day})]$$

For inorganics -

$$\text{Screening level } ppm_{sed} = TRV / [(0.0050\ kg_{sed}/\ kg_{BW}\text{-day}) + (BSAF)(\ 0.2492\ kg_{food}/\ kg_{BW}\text{-day})]$$

Adjustments for AUF and/or SUF

Adjusted sediment screening level = estimated screening level x 1/AUF x 1/SUF. Because AUF and SUF = 1.0, estimated screening levels require no adjustment.

Screening levels could not be calculated for substances lacking a benchmark toxicity value and/or a BSAF. The sediment screening levels that could be computed for the California least tern are shown below.

Sediment Screening Levels for California Least Tern in San Diego Bay.

	TRV (mg/kg-day)		BSAF[1] (sand bass - whole body)	Sediment screening level (ppm dry weight)	
	Low	High		TRV-L based	TRV-H based
Inorganics					
Arsenic	5.5	22	0.351	59	238
Cadmium	0.08	10	0.694	0.45	58
Copper	2.3	52	0.057	120	2,724
Lead	0.014	8.75	0.014	1.65	1,031
Mercury	0.021[2]	0.18	1.621	0.05[2]	0.44
Nickel	1.38	56.3	0.142	34	1,394
Zinc	17	172	0.421	157	1,565
Organics (using toc/lipid-normalized BSAF)[3]					
TBT	0.73	46	1.464	0.19	11.8
PCBs homologs[4]	0.09	1.27	4.608	0.007	0.10
PCBs Aroclors[4]	0.09	1.27	2.699	0.013	0.18
PCBs congeners[4]	0.09	1.27	5.424	0.006	0.09

1. Mean ppm in fish / mean ppm for sediment, producing N=1 reference area BSAF for each analyte.
2. TRV-L and corresponding screening level are based on NOAEL from USFWS (2003).
3. f-lipid/f-toc = 10.687, screening levels assume sediment toc = 0.01.
4. Benchmark toxicity value for PCBs based on studies with Aroclors. However, the BSAFs were calculated from concentrations of PCBs quantified three different ways (i.e., as Aroclors, homologs, and congeners).

Worksheet 6. Sediment Screening Levels for Birds That Consume Small Fish
Black Skimmer (*Rhynchops niger*)

Receptor: The black skimmer is present in San Diego Bay and represents piscivorous birds that nest in the area. Skimmers in San Diego Bay consume small fish from shallow water including bottom fish such as gobies. While skimmers consume bottom fish, their feeding strategy (skimming over the water surface rather than diving, wading, or dabbling) is such that incidental ingestion of sediment is assumed to be limited to that which is in the gut of the prey. Because of their food preference and high food ingestion rate relative to body weight, skimmers are among the potentially most exposed birds for sediment-borne contaminants that accumulate in the tissues of bottom-dwelling forage fish. In the event that skimmers and least terns eat the same species of fish, the estimated contaminant exposure by skimmers would be approximately one-half that for the least tern.

Approach: Combine literature based exposure factors and benchmark toxicity values with locally derived fish-to-sediment accumulation factors (BSAFs).

Data sources:

The benchmark toxicity values that were used are the TRVs recommended by BTAG (2002) and USFWS (2003). The TRVs are estimates of chronic daily contaminant exposure rates that relate to no observed adverse effect levels (NOAELs) and mid-range low observed adverse effect levels (LOAELs). TRVs have been developed for both avian and mammalian receptors (Table 4). The avian TRVs used to calculate screening levels are provided in the worksheet table below.

Exposure factors used for the skimmer include values for body weight and diet composition from Horn and Dahdul (1999), use factors (AUF and SUF) and sediment ingestion fractions based on professional judgment consistent with EPA guidance (EPA 1993), and food ingestion rates calculated from regressions provided by Nagy (2001). The exposure factors used to calculate sediment screening levels are provided below.

Fish-to-sediment BSAFs were calculated from data in the shipyard report (Exponent 2003) using results obtained with whole body samples of spotted sand bass, a demersal fish. The sand bass that were collected had a mean fork length of 27 cm, which is larger than what would be consumed by skimmers. However, it was the only demersal species that was caught. The BSAFs obtained with sand bass are assumed to represent BSAFs for demersal fish in general, including fish small enough to be consumed by skimmers. Data on contaminant levels in whole body sand bass samples are from Exponent (2003), Tables E-1, E-2, E-5, and E-6. Data on contaminant levels in sediment samples are from Exponent (2003), Tables B1-1 through B1-8. For reasons given earlier (overview) only data from reference area stations (N = 1) were used to compute sediment screening levels.

Calculations for BSAFs:

The BSAF for each contaminant = ppm_{tissue} / $ppm_{sediment}$.

The BSAFs for organics are used in conjunction with corresponding values of f-lipid/f-toc.

The contaminant concentrations are in parts per million (ppm) dry weight. Contaminant concentrations used to calculate BSAFs for organic compounds and TBT are normalized for lipid (dry weight f-lipid, in tissue samples) or total organic carbon (dry weight f-toc, in sediment samples).

Available data support the calculation of one reference area BSAF per contaminant of concern. Five individual fish were collected in the reference area represented by Exponent sediment sample stations 2240, 2241, 2243, and 2240. Mean contaminant levels in fish and mean contaminant levels in sediment were used to calculate BSAFs. The same data sets and approach were used to calculate the f-lipid/f-toc. For additional information on which data were used and how BSAFs were calculated, see Attachment B of this document.

Calculations for Sediment Screening Levels:

The equations used to calculate screening levels for wildlife species are derived in Attachment A. They are:

For organics, including TBT -

Screening level ppm_{sed} = TRV / [(sediment ingestion rate) + (BSAF)(f-lipid/f-toc)(food ingestion rate)]

For inorganics -

Screening level ppm_{sed} = TRV / [(sediment ingestion rate) + (BSAF)(food ingestion rate)]

The exposure factors that were used to calculate screening levels for the skimmer are presented below.

Receptor	Black skimmer
Diet	100% small fish
Body weight (kg_{BW})	0.212
Food ingestion (kg/day)[1]	0.027
Food ingestion rate (kg/kg_{BW}-day)[1,2]	**0.1274**
Sediment ingestion (kg/day)[1]	0.00054
Sediment Ingestion rate (kg/kg_{BW}-day)[1,2]	**0.0025**
Area use factor (AUF)	1
Seasonal use factor (SUF)	1

1. Dry weight
2. Ingestion rate = ingestion per day / BW

Using the factors for the skimmer, the generic equations for calculating sediment screening levels become:

For organics, including TBT -

$$\text{Screening level } ppm_{sed} = TRV / [(0.0025\ kg_{sed} / kg_{BW}\text{-day}) + (BSAF)(f_{lipid}/f_{toc})(0.1274\ kg_{food} / kg_{BW}\text{-day})]$$

For inorganics -

$$\text{Screening level } ppm_{sed} = TRV / [(0.0025\ kg_{sed} / kg_{BW}\text{-day}) + (BSAF)(0.1274\ kg_{food} / kg_{BW}\text{-day})]$$

Adjustments for AUF and/or SUF

Adjusted sediment screening level = estimated screening level x 1/AUF x 1/SUF. Because AUF and SUF = 1.0, estimated screening levels require no adjustment.

Screening levels could not be calculated for substances lacking a benchmark toxicity value and/or a BSAF. The sediment screening levels that could be computed for the skimmer are shown below.

Sediment Screening Levels for Black Skimmer in San Diego Bay.

	TRV (mg/kg-day)		BSAF[1] (sand bass - whole body)	Sediment screening level (ppm dry weight)	
	Low	High		TRV-L based	TRV-H based
Inorganics					
Arsenic	5.5	22	0.351	116	466
Cadmium	0.08	10	0.694	0.88	114
Copper	2.3	52	0.057	235	5,333
Lead	0.014	8.75	0.014	3.2	2,021
Mercury	0.021[2]	0.18	1.621	0.10[2]	0.86
Nickel	1.38	56.3	0.142	67	2,729
Zinc	17	172	0.421	306	3,062
Organics (using toc-/lipid-normalized BSAF)[3]					
TBT	0.73	46	1.464	0.37	23.0
PCBs homologs[4]	0.09	1.27	4.608	0.014	0.20
PCBs Aroclors[4]	0.09	1.27	2.699	0.024	0.35
PCBs congeners[4]	0.09	1.27	5.424	0.012	0.17

1. Mean ppm in fish / mean ppm for sediment, producing N=1 reference area BSAF for each analyte.
2. TRV-L and corresponding screening level based on NOAEL from USFWS (2003).
3. f-lipid/f-toc = 10.687, screening levels assume sediment toc = 0.01.
4. Benchmark toxicity value for PCBs based on studies with Aroclors. However, the BSAFs were calculated from concentrations of PCBs quantified three different ways (i.e., as Aroclors, homologs, and congeners).

Worksheet 7. Sediment Screening Levels for Birds That Consume Medium Size Fish California Brown Pelican (*Pelicanus occidentalis californicus*)

Receptor: The California brown pelican is present in San Diego Bay and represents piscivorous species that consume medium size fish. It is also a federally and state listed endangered species. Pelicans consume fish captured from the water column. Consequently, their exposure to sediment-borne contaminants is expected to be primarily through consumption of fish that have accumulated the contaminants in their tissues. Incidental ingestion of sediment is assumed to be limited to that which is in the gut of their prey. Pelicans are considered a top avian carnivore in the San Diego Bay food web (USDoN, SWDIV 2000), particularly if the medium size fish consumed by pelicans have a diet that consists of small fish. Because of their trophic status, pelicans may be considered representative of avian species with the potential for having the highest concentrations of bioaccumulative contaminants in their diet.

Approach: Combine literature based exposure factors and benchmark toxicity values with locally derived fish-to-sediment BSAFs.

Data sources:

The benchmark toxicity values that were used are the TRVs recommended by BTAG (2002) and USFWS (2003). The TRVs are estimates of chronic daily contaminant exposure rates that relate to no observed adverse effect levels (NOAELs) and mid-range low observed adverse effect levels (LOAELs). TRVs have been developed for both avian and mammalian receptors (Table 4). The avian TRVs used to calculate screening levels are provided in the worksheet table below.

Exposure factors used for the pelican include values for body weight from Exponent (2002), diet composition as described by Exponent (2003), use factors (AUF and SUF) and sediment ingestion fractions based on professional judgment consistent with EPA guidance (EPA 1993), and food ingestion rates calculated from regressions provided by Nagy (2001). The exposure factors used to calculate sediment screening levels are provided below.

Fish-to-sediment BSAFs were calculated from data in the shipyard report (Exponent 2003) using results obtained with whole body samples of spotted sand bass, a demersal fish. The sand bass that were collected had a mean fork length of 27 cm, consistent with a medium size fish that might be consumed by pelicans. The BSAFs obtained with sand bass are assumed to represent BSAFs for all demersal fish. Data on contaminant levels in whole body sand bass samples are from Exponent (2003), Tables E-1, E-2, E-5, and E-6. Data on contaminant levels in sediment samples are from Exponent (2003), Tables B1-1 through B1-8. For reasons given earlier (overview) only data from reference area stations (N = 1) were used to compute sediment screening levels.

Calculations for BSAFs:

The BSAF for each contaminant = ppm_{tissue} / $ppm_{sediment}$.

The BSAFs for organics are used in conjunction with corresponding values of f-lipid/f-toc.

The contaminant concentrations are in parts per million (ppm) dry weight. Contaminant concentrations used to calculate BSAFs for organic compounds and TBT are normalized for lipid (dry weight f-lipid, in tissue samples) or total organic carbon (dry weight f-toc, in sediment samples).

Available data support the calculation of one reference area BSAF per contaminant of concern. Five individual fish were collected in the reference area represented by Exponent sediment sample stations 2240, 2241, 2243, and 2240. Mean contaminant levels in fish and mean contaminant levels in sediment were used to calculate BSAFs. The same was done to calculate f-lipid/f-toc. See Attachment B for details on which data were used and how BSAFs were calculated.

Calculations for Sediment Screening Levels:

The equations used to calculate sediment screening levels for wildlife species are derived in Attachment A. They are:

For organics, including TBT -

Screening level ppm_{sed} = TRV / [(sediment ingestion rate) + (BSAF)(f-lipid/f-toc)(food ingestion rate)]

For inorganics -

Screening level ppm_{sed} = TRV / [(sediment ingestion rate) + (BSAF)(food ingestion rate)]

The exposure factors used to calculate screening levels for the pelican are presented below.

Receptor	California brown pelican
Diet	100% medium size fish
Body weight (kg_{BW})	2.845
Food ingestion (kg/day)[1]	0.231
Food ingestion rate (kg/kg_{BW}-day)[1,2]	**0.0812**
Sediment ingestion (kg/day)[1]	0.00462
Sediment ingestion rate (kg/kg_{BW}-day)[1,2]	**0.0016**
Area use factor (AUF)	1
Seasonal use factor (SUF)	1

1. Dry weight
2. Ingestion rate = ingestion per day / BW

Using exposure factors for the pelican, the generic equations for calculating sediment screening levels become:

For organics, including TBT -

$$\text{Screening level } ppm_{sed} = TRV / [(0.0016\ kg_{sed} / kg_{BW}\text{-day}) + (BSAF)(f_{lipid}/f_{toc})(0.0812\ kg_{food} / kg_{BW}\text{-day})]$$

For inorganics -

$$\text{Screening level } ppm_{sed} = TRV / [(0.0016\ kg_{sed} / kg_{BW}\text{-day}) + (BSAF)(0.0812\ kg_{food} / kg_{BW}\text{-day})]$$

Adjustments for AUF and/or SUF

Adjusted sediment screening level = estimated screening level x 1/AUF x 1/SUF. Because AUF and SUF = 1.0, estimated screening levels require no adjustment.

Screening levels could not be calculated for substances lacking a benchmark toxicity value and/or a BSAF. The sediment screening levels that could be computed for the brown pelican are shown below.

Sediment Screening Levels for California Brown Pelican in San Diego Bay.

	TRV (mg/kg-day)		BSAF[1] (sand bass)	Sediment screening level (ppm dry weight)	
	Low	High		TRV-L based	TRV-H based
Inorganics					
Arsenic	5.5	22	0.351	183	730
Cadmium	0.08	10	0.694	1.38	179
Copper	2.3	52	0.057	368	8,365
Lead	0.014	8.75	0.014	5.07	3,170
Mercury	0.021[2]	0.18	1.621	0.16[2]	1.35
Nickel	1.38	56.3	0.142	105	4,280
Zinc	17	172	0.421	480	4,804
Organics (using toc-/lipid-normalized BSAF)[3]					
TBT	0.73	46	1.464	0.574	36
PCBs homologs[4]	0.09	1.27	4.608	0.022	0.32
PCBs Aroclor[4]	0.09	1.27	2.699	0.038	0.54
PCBs congeners[4]	0.09	1.27	5.424	0.019	0.27

1. Mean ppm in fish / mean ppm for sediment, producing N=1 reference area BSAF for each analyte.
2. TRV-L and corresponding screening level are based on NOAEL from USFWS (2003).
3. f-lipid/f-toc = 10.687, screening levels assume sediment toc = 0.01.
4. Benchmark toxicity values for PCBs based on studies with Aroclors. However, the BSAFs were calculated from concentrations of PCBs quantified three different ways (i.e., as Aroclors, homologs, and congeners).

Worksheet 8. Sediment Screening Levels for Mammals That Consume Medium Size Fish California Sea Lion (*Zalophus californianus californianus*)

Receptor: The California sea lion is commonly encountered in San Diego Bay and represents mammals that consume medium size fish. Because of their feeding habits, California sea lions are expected to be exposed to sediment-borne contaminants primarily through their diet. Incidental ingestion of sediment is assumed to be limited to that which is in the gut of their prey. Sea lions are considered a top mammalian carnivore in the San Diego Bay food web (USDoN, SWDIV 2000), particularly if the medium size fish consumed by sea lions have a diet that consists of small fish. Because of their trophic status, sea lions may be considered representative of mammalian species with the potential for having the highest concentrations of bioaccumulative contaminants in their diet.

Approach: Combine literature based exposure factors and benchmark toxicity values with locally derived fish-to-sediment BSAFs.

Data sources:

The benchmark toxicity values that were used are the TRVs recommended by BTAG (2002) and USFWS (2003). The TRVs are estimates of chronic daily contaminant exposure rates that relate to no observed adverse effect levels (NOAELs) and mid-range low observed adverse effect levels (LOAELs). TRVs have been developed for both avian and mammalian receptors (Table 4). The mammalian TRVs used to calculate screening levels are provided in the worksheet table below.

Exposure factors used for the sea lion include values for body weight from Exponent (2002), diet composition as described by Exponent (2003), use factors (AUF and SUF) and sediment ingestion fractions based on professional judgment consistent with EPA guidance (EPA 1993), and food ingestion rates calculated from regressions provided by Nagy (2001). The exposure factors used to calculate sediment screening levels are provided below.

Fish-to-sediment BSAFs were calculated from data in the shipyard report (Exponent 2003) using results obtained with whole body samples of spotted sand bass, a demersal fish. The sand bass that were collected had a mean fork length of 27 cm, consistent with a medium size fish that might be consumed by sea lions. The BSAFs obtained with sand bass are assumed to represent BSAFs for demersal fish in general. Data on contaminant levels in whole body sand bass samples are from Exponent (2003), Tables E-1, E-2, E-5, and E-6. Data on contaminant levels in sediment samples are from Exponent (2003), Tables B1-1 through B1-8. For reasons given earlier (overview) only data from reference area stations (N = 1) were used to compute sediment screening levels.

Calculations for BSAFs:

The BSAF for each contaminant = ppm_{tissue} / $ppm_{sediment}$.

The BSAFs for organics are used in conjunction with corresponding values of f-lipid/f-toc.

The contaminant concentrations are in parts per million (ppm) dry weight. Contaminant concentrations used to calculate BSAFs for organics (including TBT) are normalized for lipid (dry weight f-lipid, in tissue samples) or total organic carbon (dry weight f-toc, in sediment samples).

Available data support the calculation of one reference area BSAF per contaminant of concern. Five individual fish were collected in the reference area represented by Exponent sediment sample stations 2240, 2241, 2243, and 2240. Mean contaminant levels in fish and mean contaminant levels in sediment were used to calculate BSAFs. The same data sets and approach were used to calculate the f-lipid/f-toc. For additional information on which data were used and how BSAFs were calculated, see Attachment B of this document.

Calculations for Sediment Benchmarks:

The equations used to calculate sediment benchmarks for wildlife species are derived in Attachment A. They are:

For organics, including TBT -

Screening level ppm_{sed} = TRV / [(sediment ingestion rate) + (BSAF)(f-lipid/f-toc)(food ingestion rate)]

For inorganics -

Screening level ppm_{sed} = TRV / [(sediment ingestion rate) + (BSAF)(food ingestion rate)]

The exposure factors used to calculate sediment screening levels for the sea lion are presented below.

Receptor	California sea lion
Diet	100% medium size fish
Body weight (kg_{BW})	45
Food ingestion (kg/day)[1]	1.069
Food ingestion rate (kg/kg_{BW}-day)[1,2]	**0.0238**
Sediment ingestion (kg/day)[1]	0.0214
Sediment ingestion rate (kg/kg_{BW}-day)[1,2]	**0.00048**
Area use factor (AUF)	1
Seasonal use factor (SUF)	1

1. Dry weight
2. Ingestion rate = ingestion per day / BW

Using exposure factors for the sea lion, the equation for calculating sediment benchmarks becomes:

For organics, including TBT -

$$\text{Screening level } ppm_{sed} = TRV / [(0.00048\ kg_{sed} / kg_{BW}\text{-day}) + (BSAF)(f_{lipid}/f_{toc})(0.0238\ kg_{food} / kg_{BW}\text{-day})]$$

For inorganics -

$$\text{Screening level } ppm_{sed} = TRV / [(0.00048\ kg_{sed} / kg_{BW}\text{-day}) + (BSAF)(0.0238\ kg_{food} / kg_{BW}\text{-day})]$$

Adjustments for AUF and/or SUF

Adjusted sediment screening level = estimated screening level x 1/AUF x 1/SUF. Because AUF and SUF = 1.0, estimated screening levels require no adjustment.

Screening levels could not be calculated for substances lacking a benchmark toxicity value and/or a BSAF. The screening levels that could be calculated for the sea lion are presented below.

Sediment Benchmarks for California Sea Lion in San Diego Bay.

	TRV (mg/kg-day)		BSAF[1] (sand bass)	Sediment screening level (ppm dry weight)	
	Low	High		TRV-L based	TRV-H based
Inorganics					
Arsenic	0.32	4.7	0.351	36	532
Cadmium	0.06	2.64	0.694	3.5	155
Copper	2.67	632	0.057	1,454	344,114
Lead	1.0	241	0.014	1,230	296,360
Mercury	0.018[2]	0.27	1.621	0.46[2]	6.91
Nickel	0.13	31.6	0.142	34	8,187
Zinc	9.6	411	0.421	914	39,144
Organics (using toc/lipid-normalized BSAF)[3]					
TBT	0.25	15	1.464	0.67	40
PCBs homologs[4]	0.36	1.28	4.608	0.31	1.09
PCBs Aroclors[4]	0.36	1.28	2.699	0.52	1.86
PCBs congeners[4]	0.36	1.28	5.424	0.26	0.93

1. Mean ppm in fish / mean ppm for sediment, producing N=1 reference area BSAF for each analyte.
2. TRV-L and the corresponding screening level are based on NOAEL from USFWS (2003).
3. f-lipid/f-toc = 10.687, screening levels assume sediment toc = 0.01.
4. Benchmark toxicity value for PCBs based on studies with Aroclors. However, the BSAFs were calculated from concentrations of PCBs quantified three different ways (i.e., as Aroclors, homologs, and congeners).

Worksheet 9. Sediment Benchmarks for Avian Herbivore American wigeon (*Anas americana*)

Receptor: The American wigeon is present in San Diego Bay and represents avian species that consume aquatic vegetation. Wigeons are dabbling ducks that are potentially exposed to sediment-borne contaminants accumulated in the tissues of the vegetation that they eat. Incidental ingestion of sediment during feeding is expected to occur as well. Because of its food ingestion rate, the wigeon represents the potentially most exposed of the herbivores considered in this analysis to sediment-borne contaminants that accumulate in eelgrass tissue.

Approach: Combine literature based exposure factors and benchmark toxicity values with locally derived eelgrass-to-sediment accumulation factors (BSAFs).

Data sources:

The benchmark toxicity values that were used are the TRVs recommended by BTAG (2002) and USFWS (2003). The TRVs are estimates of chronic daily contaminant exposure rates that relate to no observed adverse effect levels (NOAELs) and mid-range low observed adverse effect levels (LOAELs). TRVs have been developed for both avian and mammalian receptors (Table 4). The avian TRVs used to calculate screening levels are provided in the worksheet table below.

Exposure factors used for the wigeon include values for body weight from Dunning (1984), diet composition from Bellrose (1978), use factors (AUF and SUF) and sediment ingestion fractions based on professional judgment consistent with EPA guidance (EPA 1993), and food ingestion rates calculated from regressions provided by Nagy (2001). The exposure factors used to calculate sediment screening levels are provided below.

Eelgrass-to-sediment BSAFs are calculated from data in the shipyard report (Exponent 2003). Data on contaminant levels in eelgrass samples are from Exponent (2003), Tables E-1, E-2, E-5, and E-6. Data on contaminant levels in sediment samples are from Exponent (2003), Tables B1-1 through B1-8. For reasons discussed earlier (overview), only data from the reference area station (N = 1) were used.

Calculations for BSAFs:

The BSAF for each contaminant = ppm_{tissue} / $ppm_{sediment}$.

The contaminant concentrations are in parts per million (ppm) dry weight. The tissue and sediment concentrations used to calculate BSAFs for organic compounds and TBT are <u>not</u> normalized for lipid (in tissue samples) or total organic carbon (toc, in sediment samples), because lipid levels in eelgrass samples were below the limits of detection.

The available data support the calculation of one eelgrass BSAF for each contaminant of concern. For more detail on which data were used and how the BSAFs were calculated, see Attachment B.

Calculations for Sediment Screening Levels:

The equations used to calculate sediment screening levels for wildlife species are derived in Attachment A. Because data for BSAFs are not toc/lipid normalized, only one equation is needed to compute sediment screening levels for both organic and inorganic analytes, as follows:

Screening level ppm_{sed} = [TRV / (sediment ingestion rate) + (BSAF)(food ingestion rate)].

Exposure factors used to calculate sediment benchmarks for the wigeon are summarized below.

Receptor	American wigeon
Diet	100% eelgrass
Body weight (kg_{BW})	0.638
Food ingestion (kg/day)[1]	0.053
Food ingestion rate (kg/kg_{BW}-day)[1,2]	**0.0831**
Sediment ingestion (kg/day)[1]	0.00265
Sediment Ingestion rate (kg/kg_{BW}-day)[1,2]	**0.00415**
Area use factor (AUF)	1
Seasonal use factor (SUF)	1

1. Dry weight
2. Ingestion rate = ingestion per day / BW

Using exposure factors for the wigeon, the equation for calculating sediment screening levels becomes:

Screening level ppm_{sed} = TRV / [(0.00415 kg_{sed} / kg_{BW}-day) + (BSAF)(0.0831 kg_{food} / kg_{BW}-day)].

Adjustments for AUF and/or SUF

Adjusted sediment screening level = estimated screening level x 1/AUF x 1/SUF. Because AUF and SUF = 1.0, estimated screening levels require no adjustment.

Screening levels could not be calculated for substances lacking a benchmark toxicity value and/or a BSAF. The screening levels that could be computed for the wigeon are presented below.

Sediment Screening Levels for American Wigeon in San Diego Bay.

	TRV (mg/kg-day)		BSAF[1] (eelgrass)	Sediment screening level (ppm dry weight)	
	Low	High		TRV-L based	TRV-H based
Inorganics					
Arsenic	5.5	22	0.271	206	825
Cadmium	0.08	10	1.923	0.49	63
Copper	2.3	52	0.328	73	1,661
Lead	0.014	8.75	0.113	1.03	646
Nickel	1.38	56.3	0.233	59	2,395
Zinc	17	172	0.664	290	2,900
Organics (BSAFs not normalized for toc or lipid)					
PCBs homologs[2]	0.09	1.27	0.249	3.62	51
PCBs Aroclors[2]	0.09	1.27	0.229	3.88	55
PCBs congeners[2]	0.09	1.27	0.263	3.46	49

1. Based on single reference area sample.
2. Benchmark toxicity value for PCBs based on studies with Aroclors. However, the BSAFs were calculated from concentrations of PCBs quantified three different ways (i.e., as Aroclors, homologs, and congeners).

Worksheet 10. Sediment Screening Levels for Herbivorous Reptiles
Green Sea Turtle (*Chelonias midas*)

Receptor: The green sea turtle is present in San Diego Bay and represents herbivorous reptiles. The green sea turtle is a federally listed threatened species. Both juvenile and adult turtles are observed in the bay year-round, but nesting appears to occur elsewhere. The green sea turtle is an herbivorous species that consumes aquatic vegetation such as rooted angiosperms (e.g., eelgrass) and benthic algae (e.g., sea lettuce). Green sea turtles are potentially exposed to sediment-borne contaminants accumulated in the tissues of the vegetation that they eat, as well as through incidental ingestion of sediment that is present on or near their food items.

Approach: Combine literature based exposure factors and benchmark toxicity values with locally derived eelgrass-to-sediment BSAFs.

Data sources:

The benchmark toxicity values that were used are the TRVs recommended by BTAG (2002) and USFWS (2003). The TRVs are estimates of chronic daily contaminant exposure rates that relate to no observed adverse effect levels (NOAELs) and mid-range low observed adverse effect levels (LOAELs). TRVs have been developed for both avian and mammalian receptors (Table 4). Unfortunately, there are no readily available TRVs for turtles. Absent a better alternative, the BTAG (2002) TRVs for avian species were used to calculate sediment screening levels for turtles. The avian TRVs were selected because turtles lay eggs, and therefore are assumed to be more similar in biology to birds than to mammals. The TRVs used to calculate screening levels are provided in the worksheet table below.

Exposure factors used for the green sea turtle include a value for body weight computed from a minimum adult length (66.7 cm; NMFS & USFWS 1999) using a log-log transformed length-weight regression derived from data collected by Dutton & Dutton (1998). The regression is based on data for five individuals (juveniles and adults) captured in San Diego Bay ($r^2 = 0.98$). The diet composition is as described by Exponent (2003), use factors (AUF and SUF) and sediment ingestion fractions based on professional judgment consistent with EPA guidance (EPA 1993), and food ingestion rates calculated from regressions provided by Nagy (2001). The exposure factors used to calculate sediment screening levels are provided below.

Eelgrass-to-sediment BSAFs are calculated from data in the shipyard report (Exponent 2003). Data on contaminant levels in eelgrass samples are from Exponent (2003), Tables E-1, E-2, E-5, and E-6. Data on contaminant levels in sediment samples are from Exponent (2003), Tables B1-1 through B1-8. For reasons discussed earlier (overview), only data from the reference area station (N = 1) were used.

Calculations for BSAFs:

The BSAF for each contaminant = ppm_{tissue} / $ppm_{sediment}$.

The contaminant concentrations are in parts per million (ppm) dry weight. The tissue and sediment concentrations used to calculate BSAFs for organic compounds and TBT are not normalized for lipid (in tissue samples) or total organic carbon (toc, in sediment samples), because lipid levels in eelgrass samples were below the limits of detection.

The available data support the calculation of one eelgrass BSAF for each contaminant of concern. For more detail on which data were used and how the BSAFs were calculated, see Attachment B.

Calculations for Sediment Screening Levels:

The equations used to calculate sediment screening levels for wildlife species are derived in Attachment A. Because data for BSAFs are not toc/lipid normalized, only one equation is needed to compute sediment screening levels for both organic and inorganic analytes, as follows:

Screening level ppm_{sed} = TRV / [(sediment ingestion rate) + (BSAF)(food ingestion rate)].

The exposure factors used to calculate sediment screening levels for the sea turtle are summarized below.

Receptor	Green sea turtle
Diet	100% eelgrass
Body weight (kg_{BW})	42
Food ingestion (kg/day)[1]	0.199
Food ingestion rate (kg/kg_{BW}-day)[1,2]	**0.0047**
Sediment ingestion (kg/day)[1]	0.0100
Sediment Ingestion rate (kg/kg_{BW}-day)[1,2]	**0.00024**
Area use factor (AUF)	1
Seasonal use factor (SUF)	1

1. Dry weight
2. Ingestion rate = ingestion per day / BW

Using exposure factors for the turtle, the equation for calculating sediment screening levels becomes:

Screening level ppm_{sed} = TRV / [(0.00024 kg_{sed} / kg_{BW}-day) + (BSAF)(0.0047 kg_{food} / kg_{BW}-day)].

Adjustments for AUF and/or SUF

Adjusted sediment screening level = estimated screening level x 1/AUF x 1/SUF.

Because AUF and SUF = 1.0, estimated screening levels require no adjustment.

Screening levels could not be calculated for substances lacking a benchmark toxicity value and/or a BSAF. The screening levels that could be computed are presented below.

Sediment Screening Levels for Green Sea Turtle in San Diego Bay.

	TRV (mg/kg-d)		BSAF[1] (eelgrass)	Sediment screening level (ppm dry weight)	
	Low	High		TRV-L based	TRV-H based
Inorganics					
Arsenic	5.5	22	0.271	3,633	14,534
Cadmium	0.08	10	1.923	8.6	1,121
Copper	2.3	52.3	0.328	1,291	29,356
Lead	0.014	8.75	0.113	18.2	11,347
Nickel	1.38	56.3	0.233	1,034	42,169
Zinc	17	172	0.664	5,118	51,178
Organics (BSAFs not normalized for toc or lipid)					
PCBs homologs[2]	0.09	1.27	0.249	63.8	901
PCBs Aroclors[2]	0.09	1.27	0.229	68.4	965
PCBs congeners[2]	0.09	1.27	0.263	61.0	860

1. Based on single reference area sample.
2. Benchmark toxicity value for PCBs based on studies with Aroclors. However, the BSAFs were calculated from concentrations of PCBs quantified three different ways (i.e., as Aroclors, homologs, and congeners).

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ATTACHMENT A.

DERIVATION OF EQUATIONS FOR COMPUTING SEDIMENT SCREENING LEVELS

AQUATIC VEGETATION

Sediment screening levels for aquatic vegetation are estimated using lowest chronic values in water (LCVs as mg/L) from EPA Ambient Water Quality Criteria (AWQC) documents, in combination with compound-specific sediment-to-porewater partition coefficients (Kp as $L_{porewater}/kg_{sediment}$). The water-based values are used as benchmark concentrations for contaminant levels in porewater, or in surface water at the sediment-water interface. Data from studies by Exponent (2003) were used to calculate values of Kp specific to sediments in San Diego Bay, as follows.

To simplify, data on contaminant levels in sediment and corresponding porewater samples were first standardized for units, as parts per million (ppm, or mg/kg_{sed} and mg/L_{water}). Then,

Kp for a contaminant ($L_{porewater}/kg_{sed}$) = (mg/kg_{sed}) / ($mg/L_{porewater}$), or more simply,

$$Kp\ (L_{porewater}/kg_{sed}) = ppm_{sed} / ppm_{porewater}.$$

By setting the concentration in water to the LCV, the screening level in bulk sediment is calculated as:

Screening level $ppm_{sediment}$ (mg/kg) = LCV (mg/L) x Kp ($L_{porewater}/kg_{sed}$), or more simply,

Screening level ppm_{sed} = benchmark $ppm_{porewater}$ x Kp.

The relationship for organics can be more complex if the Kp is calculated from concentrations normalized for total organic carbon (toc) content in sediment and porewater samples. However, doing so with the available data had no effect on the outcome. For simplicity, the Kps for organics were calculated using non-normalized data, and only one equation was required for all of the analytes.

Data and calculation spreadsheets used to obtain values of Kp are provided in Attachment B.

FISH

The process for calculating sediment screening levels for fish that live and/or feed at the sediment-water interface applies to both bottom-dwelling and demersal fish. However, the currently available data support calculations specific to demersal fish. The resultant sediment screening levels are most applicable for demersal fish. It is assumed that the screening levels for demersal fish will suffice for bottom fish as well, at least until data specific to bottom fish become available.

Sediment screening levels for demersal fish are derived from literature-based benchmark tissue concentrations for effects in fish, combined with locally-derived fish-to-sediment bioaccumulation

factors (BSAFs). The benchmark concentrations used for each contaminant are for whole bodies, and concentrations are in parts per million (ppm, or mg/kg) dry weight. Data from studies by Exponent (2003) were used to calculate fish-to-sediment BSAFs specific to sediments in San Diego Bay, as follows.

Calculating BSAFs:

To simplify, data on contaminant levels in sediment and corresponding fish tissue samples are standardized for units, as parts per million (ppm, or mg/kg_{sed} and mg/kg_{tissue}) dry weight. Then,

For inorganic analytes, BSAF (kg_{sed}/kg_{tissue}) = (mg/kg_{tissue}) / (mg/kg_{sed}), or more simply,

$$BSAF_{inorganics} = ppm_{tissue}/ppm_{sed}.$$

For organic analytes, BSAFs are computed using lipid-normalized concentrations in tissue and total organic carbon (TOC)-normalized concentrations in sediment.

The lipid-normalized concentration of a contaminant = mg/kg_{tissue} x 1/f-lipid, where f-lipid (fraction lipid, dry weight) = kg_{lipid}/kg_{tissue}.

The TOC-normalized concentration of a contaminant = mg/kg_{sed} x 1/f-toc, where f-toc (fraction toc, dry weight) = kg_{toc}/kg_{sed}.

The BSAF for organics (kg_{toc}/kg_{lipid}) =
[(mg/kg_{tissue})(kg_{tissue}/kg_{lipid})] / [(mg/kg_{sed})(kg_{sed}/kg_{toc})], or more simply,

$$BSAF_{organics} = (ppm_{tissue}/ppm_{sed}) \times (\text{f-toc/f-lipid}).$$

Data and calculation spreadsheets for deriving BSAFs are provided in Attachment B.

Calculating sediment screening levels:

The sediment screening level for an individual contaminant is calculated by setting the concentration in tissue (mg/kg_{tissue}) to the benchmark concentration and solving the BSAF equation for $mg/kg_{sediment}$.

For organics and TBT, $mg/kg_{sed} = mg/kg_{tissue} \times kg_{tissue}/kg_{lipid} \times kg_{TOC}/kg_{sed} \times kg_{lipid}/kg_{TOC}$, or more simply,

Screening level ppm_{sed} = benchmark ppm_{tissue} x 1/f-lipid x f-toc x 1/BSAF.

For inorganics, $mg/kg_{sed} = mg/kg_{tissue} \times kg_{tissue}/kg_{sed}$, or more simply,

Screening level ppm_{sed} = benchmark ppm_{tissue} x 1/BSAF.

WILDLIFE

Sediment screening levels for wildlife are computed from literature-based benchmark toxicity values in combination with literature-based wildlife exposure factors and locally-derived BSAFs for contaminants in biota that comprise the diets of wildlife receptors.

The benchmark toxicity value is a daily reference dose expressed as (mg/kg_{BW}-day). The reference values used for this exercise are toxicity reference values (TRVs) recommended by the EPA, Region 9 BTAG (2002), and USFWS (2003).

The wildlife exposure factors are species-specific values that include food and sediment ingestion rates (as $kg_{ingested}/kg_{BW}$-day), the area use factor (AUF, unitless), and a seasonal use factor (SUF, unitless). Ingestion rates equal estimated daily ingestion ($kg_{ingested}$/day) divided by the receptor's body weight (BW, as kg).

The BSAFs, calculated from data collected by Exponent (2003) provide quantitative measures of the relationship between contaminant levels measured in sediment and those measured in directly exposed bivalves (clams and mussels), demersal fish, and eelgrass that constitute the diet of wildlife receptors.

A basic assumption in the equations used to calculate wildlife risk-based sediment screening levels is that exposure is almost entirely by the ingestion route (diet and sediment). In equation form, the premise is that

Total daily contaminant intake =
daily intake from ingestion of food + daily intake from ingestion of sediment.

For reasons given earlier (see Overview), another basic assumption in this exercise is that receptors are present year-round and conduct all of their foraging in the area of concern (i.e., San Diego Bay). The assumption is expressed by assigning the AUF and the SUF each a value of 1.0.

The AUF is used to adjust estimated total daily intake to account for food obtained from outside the area of concern. The value assigned to the AUF is often determined by computing the ratio of the species foraging range (acres or hectares) to the size of the study area. Depending on the species and the study area, the AUF may be any value ranging from 0 to 1.0. A value of 1.0 indicates that the species conducts all of its foraging, and therefore obtains all of its food from within the area of concern. Similarly, the SUF is used to adjust estimates of total daily intake for time (typically seasons) spent outside the area of concern. The SUF is computed as the fraction of the year that the species may be present in the study area. A value of 1.0 indicates that the species is present year-round. The AUF and SUF are unitless constants that are used to adjust exposure estimates, and

Total daily contaminant intake = Total daily intake from ingestion (food + sediment) x AUF x SUF.

Alternatively, the AUF and SUF can be introduced at the end of the process where they are used to adjust screening levels, once calculated, as was done for this exercise. Note that the screening levels derived for this analysis remain essentially unadjusted by the AUF or SUF because both factors were assigned a value of 1.0.

For each receptor species:

Food ingestion rate (kg_{food}/kg_{BW}-d) =

(kg food ingested/day) x (1/kg body weight of the receptor).

Sediment ingestion rate (kg_{sed}/kg_{BW}-d) =

(kg sediment ingested/day) x (1/kg body weight of the receptor).

Daily exposure to contaminant through food and sediment ingestion is =

(mg contaminant ingested with sediment/kg_{BW}-day) + (mg contaminant ingested with food/kg_{BW}-day), or

daily contaminant intake (mg/kg_{BW}-d) =

$[(mg/kg_{sed})(kg_{sed}ingested/kg_{BW}\text{-day})] + [(mg/kg_{food})(kg_{food}ingested/kg_{BW}\text{-day})]$.

The equation can be used to calculate sediment screening levels, if the concentration in food term (mg/kg_{food}) is first converted to an equivalent sediment value (mg/kg_{sed}). This is accomplished with the use of BSAFs, as characterized in the previous section on screening levels for fish. To convert the concentration in food term:

For inorganics, $mg/kg_{sed} = (mg/kg_{food})$ x 1 / (BSAF).
For organics, $mg/kg_{sed} = (mg/kg_{food})$ x (1/BSAF) x (f-toc/f-lipid), where:

BSAFs for inorganics $(kg_{sed}/kg_{tissue}) = (mg/kg_{tissue}) / (mg/kg_{sed})$, or

ppm_{tissue}/ppm_{sed}; and,

BSAFs for organics $(kg_{toc}/kg_{lipid}) = [(mg/kg_{tissue})(kg_{tissue}/kg_{lipid})] / [(mg/kg_{sed})(kg_{sed}/kg_{toc})]$, or

(ppm_{tissue}/ppm_{sed}) x (f-toc/f-lipid).

By substituting the concentration in food term with the corresponding sediment-based value, equations for average daily contaminant exposure via ingestion become:

<u>For inorganics</u>

Daily exposure rate (mg/kg_{BW}-day) =
$[(mg/kg_{sed})(kg_{sed}ingested/kg_{BW}\text{-d})] + [(mg/kg_{sed})\ (kg_{sed}/kg_{tissue})(kg_{food}ingested/kg_{BW}\text{-day})]$,
or more simply,

Daily exposure = $(ppm_{sed})(kg_{sed}ingested/kg_{BW}\text{-day}) + (ppm_{sed})(BSAF)(kg_{food}ingested/kg_{BW}\text{-day})$.

<u>For organics and TBT</u>

Daily exposure rate (mg/kg_{BW}-day) =
$[(mg/kg_{sed})(kg_{sed}ingested/kg_{BW}\text{-day})] + [(mg/kg_{sed})(kg_{TOC}/kg_{lipid})(f_{lipid}/f_{toc})(kg_{food}ingested/kg_{BW}\text{-day})]$,
or more simply,

$(ppm_{sed})(kg_{sed}ingested/kg_{BW}\text{-}day) + (ppm_{sed})(BSAF)(f_{lipid}/f_{toc})(kg_{food}ingested/kg_{BW}\text{-}day)$.

The screening level in sediment for an individual contaminant is computed by setting the daily intake equal to the compound-specific TRV and solving the equation for the concentration in sediment (mg/kg_{sed}, or ppm_{sed}).

Sediment screening levels for inorganics are calculated as

mg/kg_{sed} = TRV / (kg_{sed} ingested/kg_{BW}-day) + (BSAF)(kg_{food} ingested/kg_{BW}-day), where
TRV = mg/kg_{BW}-day and
BSAF = kg_{sed}/kg_{tissue}, or more simply,

Screening level ppm_{sed} = TRV/[(sediment ingestion rate) + (BSAF)(food ingestion rate)].

Sediment screening levels for organics, including TBT are calculated as

mg/kg_{sed} = TRV / (kg_{sed}ingested/kg_{BW}-day) + (BSAF)(f-lipid/f-toc)(kg_{food}ingested/kg_{BW}-day), where
TRV = mg/kg_{BW}-day and
BSAF = kg_{toc}/kg_{lipid}, or more simply,

Screening level ppm_{sed} = TRV/[(sediment ingestion rate) + (BSAF)(f-lipid/f-toc)(food ingestion rate)].

Adjustment for AUF and/or SUF

As indicated earlier,

Adjusted total daily contaminant intake =
Total daily intake from ingestion (food + sediment) x AUF x SUF, and

Adjusted sediment screening levels for wildlife =
(TRV) x (1/total daily intake) x (1/AUF) x (1/SUF), or

Sediment screening level x AUF x SUF.

ATTACHMENT B
DATA AND CALCULATION SPREADSHEETS

Data used to calculate partition coefficients (Kp) and accumulation factors (BSAFs) are from tables in the Exponent (2003) report. The applicable original data, following standardization, are provided as supplemental information (SI) at the end of this document (Tables SI.1 - SI.8). To simplify subsequent calculations, all data are presented in standard units of parts per million (ppm, or mg/kg or mg/L), and as dry weight for sediment and tissue samples. It was necessary to convert some of the data from tables in the Exponent report to the desired standard units. Details on which raw data were converted, and the conversion factors that were used accompany data Tables SI.1 - SI.8 in the SI section at the end of this document. The details on conversion factors are offered to help the reader relate values in Tables SI.1 - S1.8 to the original data as presented in tables from the Exponent (2003) report.

Data provided in the supplemental information tables were further reduced to obtain estimates of Kp and BSAF. The data manipulations that were carried out are discussed below, along with tables showing results of data reductions, data inputs, and results of Kp and BSAF calculations.

SEDIMENT / POREWATER PARTITION COEFFICIENTS (Kp)

Surface sediment and corresponding porewater samples were collected at several stations in San Diego Bay as part of studies by Exponent (2003). The data that were generated can be used to compute sediment-to-porewater partition coefficients (Kp) for analytes detected in both sediment and corresponding porewater samples.

Equation:

The Kp for an individual contaminant is computed as:

$(mg_{contaminant}/kg_{sediment})$ / $(mg_{contaminant}/L_{porewater})$, or more simply as

$Kp = ppm_{sediment} / ppm_{porewater}$.

This equation was used to derive Kp for both organic and inorganic contaminants.

Data:

Contaminant levels measured in porewater samples and corresponding surface sediment samples are from Exponent (2003). Both sediment and porewater samples were collected at a number of stations in the NASSCO and SWM shipyard areas, as well as in reference areas. These stations are shown below.

	Reference area	NASSCO shipyard area	SWM shipyard area
Sediment & porewater samples collected	2231, 2243, 2433, 2440, 2441	NA01, NA06, NA13, NA16, NA17	SW01, SW02, SW04, SW08, SW12, SW24

Contaminant levels reported by Exponent (2003) for individual surface sediment samples and corresponding porewater samples (i.e., original standardized data) are provided as

supplemental information (Tables SI.1- SI.3) of this document. Only those stations from which both sediment and porewater samples were collected are represented. Porewater samples were analyzed for inorganics, PAHs, and PCB homologs. Only those analytes that were detected in both porewater and sediment samples are included in the tables. To simplify calculations, all concentrations are presented as parts per million (ppm), which required that original data for some analytes be converted for units. Details on the data conversions are provided with tables of original data in the supplemental information section.

While there was only one porewater sample per station, there were two or more sediment samples per station. Mean concentrations were used to represent contaminant levels in the sediment for each station. Therefore, the Kp for each analyte at a given station is:

$$Kp = \text{mean } ppm_{sediment} / ppm_{porewater}.$$

Sediment and pore water contaminant levels entered into Kp calculations are presented in Tables B1 and B2, below. Sediment concentrations in Table B1 were divided by corresponding porewater concentrations in Table B2 to obtain estimates of Kp shown in Table B3.

Table B1. **Sediment** contaminant levels used to compute values of Kp for NASSCO (NA), SWM (SW), and reference study areas as parts per million (ppm or mg/kg) dry weight.

station	TBT ppm	PCB hom ppm	As ppm	Cd ppm	Cr ppm	Cu ppm	Pb ppm	Hg ppm	Ni ppm	Se ppm	Ag ppm	Zn ppm
2231	0.013	0.109	8.25	0.09	41.0	91.0	43.0	0.41	10.0	-	0.27	150.0
2243	0.0026	0.042	4.35	0.12	24.5	53.0	21.5	0.25	5.7	-	0.61	106.5
2433	0.0046	0.033	4.50	0.27	24.5	43.5	18.0	0.22	7.1	-	0.40	96.0
2440	0.035	0.155	4.40	0.31	26.5	56.0	68.0	0.28	7.1	-	0.46	115.0
2441	0.0034	0.0185	5.25	0.29	23.5	41.0	13.5	0.16	9.0	1.00	0.27	87.5
NA01	0.176	0.530	10.47	0.25	69.3	240.0	25.7	1.05	15.3	1.05	1.33	286.7
NA06	0.225	0.935	10.50	0.27	61.5	395.0	20.0	2.35	14.5	1.10	1.02	335.0
NA13	0.068	0.265	10.75	0.24	59.0	185.0	75.0	0.65	15.5	1.00	0.94	295.0
NA16	0.170	0.617	10.33	0.37	69.0	250.0	88.7	1.09	15.0	1.00	1.33	313.3
NA17	1.350	0.620	14.50	0.41	74.0	510.0	115.0	0.85	17.5	1.10	1.30	620.0
SW01	0.450	2.400	13.5	0.71	78.5	560.0	145.0	1.45	98.0	-	1.07	520.0
SW02	0.200	8.167	14.0	2.97	108.3	570.0	176.7	4.13	94.7	1.70	3.53	573.3
SW04	3.250	5.200	73.0	1.95	87.5	1500.0	430.0	1.75	18.0	1.50	1.60	3450.0
SW08	1.850	2.700	24.0	0.73	82.5	920.0	225.0	2.25	21.0	-	1.45	830.0
SW12	0.036	-	7.4	0.14	39.0	119.5	52.0	0.53	10.8	-	0.76	160.0
SW24	0.165	1.500	10.0	0.33	52.5	300.0	88.0	1.90	16.0	-	1.15	300.0
SW25	0.231	0.510	11.5	0.36	64.5	230.0	85.5	0.78	16.5	-	1.20	345.0
SW28	0.150	3.000	14.0	0.32	65.5	265.0	100.0	0.88	15.0	1.20	1.10	330.0

Table B2. Porewater contaminant levels measured in samples from the NASSCO (NA), SWM (SW), and reference study areas as parts per million (ppm or mg/L).

Station	TBT	PCB hom	As	Cd	Cr	Cu	Pb	Hg	Ni	Se	Ag	Zn
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
2231	-	0.000018	0.0033	-	0.0038	0.0230	0.0025	0.000047	0.0016	-	0.000200	0.022
2243	-	0.000022	0.0098	-	0.0036	0.0084	0.0029	0.000045	0.0026	-	0.000200	0.023
2433	-	0.000038	0.0170	-	0.0042	0.0110	0.0036	0.000042	0.0039	-	0.000200	0.017
2440	0.000022	0.000075	0.0140	-	0.0043	0.0120	0.0074	0.000059	0.0034	-	0.000200	0.020
2441	-	0.000016	0.0120	-	0.0042	0.0093	0.0028	0.000030	0.0028	-	0.000200	-
NA01	-	0.000680	0.0190	-	0.0032	0.0140	0.0052	0.000051	0.0023	0.0052	0.000100	0.023
NA06	0.000100	0.000200	0.0091	-	0.0066	0.0330	0.0120	0.000190	0.0022	-	0.000400	0.044
NA13	0.000022	0.000056	0.0120	-	0.0045	0.0140	0.0065	0.000067	0.0025	-	0.000200	0.030
NA16	0.000054	0.000094	0.0170	-	0.0063	0.0220	0.0090	0.000082	0.0027	-	0.000250	0.032
NA17	0.000077	0.000084	0.0200	-	0.0061	0.0230	0.0070	0.000074	0.0029	-	0.000450	0.032
SW01	0.000037	0.000500	0.0061	-	0.0037	0.0170	0.0066	0.000078	0.0030	-	0.000100	0.022
SW02	0.000059	0.016000	0.0110	0.004	0.1160	0.3900	0.1200	0.001900	0.0370	-	0.002700	0.610
SW04	0.000550	0.000600	0.0150	-	0.0081	0.0550	0.0200	0.000150	0.0033	0.0061	0.000400	0.060
SW08	0.000490	0.000520	0.0099	-	0.0048	0.0330	0.0120	0.000130	0.0020	-	0.000100	0.034
SW12	0.000022	not done	0.0190	-	0.0051	0.0170	0.0071	0.000068	0.0028	-	0.000300	0.032
SW24	0.000074	0.000670	0.0100	-	0.0058	0.0250	0.0098	0.000130	0.0026	-	0.000100	0.037
SW25	0.000063	0.000180	0.0170	-	0.0079	0.0280	0.0130	0.000140	0.0029	-	0.000200	0.042
SW28	-	0.000290	0.0090	-	0.0048	0.0190	0.0075	0.000060	0.0024	-	0.000200	0.031

Table B3. Estimated **Kp** for each detected contaminant at each station in NASSCO (NA), SWM (SW), and reference (shaded) study areas.

	TBT Kp	PCB hom Kp	As Kp	Cd Kp	Cr Kp	Cu Kp	Pb Kp	Hg Kp	Ni Kp	Se Kp	Ag Kp	Zn Kp
2231	-	6056	2500	-	10789	3957	17200	8723	6250	-	1350	6818
2243	-	1909	444	-	6806	6310	7414	5556	2192	-	3025	4630
2433	-	868	265	-	5833	3955	5000	5119	1821	-	2000	5647
2440	1591	2067	314	-	6163	4667	9189	4746	2074	-	2300	5750
2441	-	1156	438	-	5595	4409	4821	5167	3196	-	1325	-
NA01	-	779	551	-	21667	17143	4936	20588	6667	202	13333	12464
NA06	2250	4675	1154	-	9318	11970	1667	12368	6591	-	2538	7614
NA13	3091	4732	896	-	13111	13214	11538	9627	6200	-	4700	9833
NA16	3148	6560	608	-	10952	11364	9852	13293	5556	-	5333	9792
NA17	17532	7381	725	-	12131	22174	16429	11419	6034	-	2889	19375
SW01	12162	4800	2213	-	21216	32941	21970	18590	32667	-	10650	23636
SW02	3384	510	1273	742	934	1462	1472	2175	2559	-	1309	940
SW04	5909	8667	4867	-	10802	27273	21500	11667	5455	246	4000	57500
SW08	3776	5192	2424	-	17188	27879	18750	17308	10500	-	14500	24412
SW12	1636	-	389	-	7647	7029	7324	7721	3857	-	2517	5000
SW24	2230	2239	1000	-	9052	12000	8980	14615	6154	-	11500	8108
SW25	3659	2833	676	-	8165	8214	6577	5536	5690	-	6000	8214
SW28		10345	1556	-	13646	13947	13333	14583	6250	-	5500	10645

Mean Kp for each study area. Shaded values used to calculate sediment screening levels.

	TBT	PCB hom	As	Cd	Cr	Cu	Pb	Hg	Ni	Se	Ag	Zn
Mean Ref	1591	2411	792	-	7037	4659	8725	5862	3107	-	2000	5711
Mean NA	6505	4826	787	-	13436	15173	8884	13459	6210	202	5759	11815
Mean SW	4679	4941	1800	-	11081	16343	12488	11524	9141	246	6997	17307

For reasons given earlier, only reference area data were considered for sediment screening levels (shaded in Table B3). Given that there are five reference area stations, it was possible to obtain as many as five estimates of reference area Kp for each analyte of concern. Fewer than five estimates of reference area Kp were obtained for some analytes, because Kp cannot be calculated in those instances where the concentration of the analyte is below the limits of detection for either the sediment or the corresponding porewater sample. In most cases, if an analyte was detected in sediment and porewater from one station, it was detected in samples from all five.

The mean reference area Kp was used to calculate sediment screening levels for all but TBT, which is based on a single value. If a more conservative approach is desired, the minimum Kp value should be used.

ATTACHMENT B

BIOTA / SEDIMENT ACCUMULATION FACTORS (BSAFs)

Samples collected for the study by Exponent (2003) made it possible to calculate BSAFs for bivalves (resident mussels and clams from bioaccumulation tests), a demersal fish (spotted sand bass), a pelagic fish (anchovy), lobsters, and eelgrass. BSAFs were calculated for organisms with links to the sediment and that are food for the selected wildlife receptors. The BSAFs for bivalves, demersal fish, and eelgrass are the most applicable for calculating wildlife risk-based sediment screening level and are the only ones used for this exercise.

Studies by Exponent (2003) involved collection of samples from within the NASSCO and Southwest Marine (SWM) shipyard areas as well as at reference locations. BSAFs were calculated from data for all three areas for general information purposes. However, for reasons stated earlier (see Overview, Item 1) only those from the study reference areas were used to calculate sediment screening levels.

Equations (from Attachment A):

BSAFs for inorganics (kg_{sed}/kg_{tissue}) = (mg/kg_{tissue}) / (mg/kg_{sed}), or

ppm_{tissue}/ppm_{sed}.

BSAFs for organics (kg_{toc}/kg_{lipid}) = [(mg/kg_{tissue})(kg_{tissue}/kg_{lipid})] / [(mg/kg_{sed})(kg_{sed}/kg_{toc})], or

(ppm_{tissue}/ppm_{sed}) x (f-toc/f-lipid), where

f-toc = the fraction (dry weight) of total organic carbon in the sediment sample, and
f-lipid = the fraction (dry weight) of lipid in the tissue sample.

Data sources:

Data on contaminant levels in biota are from Exponent (2003), Tables E-1 (inorganics, including butyltins, especially TBT), E-2 (PAHs), E-5, and E-6 (PCBs). Data on contaminant levels in corresponding surface sediment samples are from Exponent (2003), Appendix B. The data on bivalves are for soft tissues only. The data on fish are for whole body samples. The data on eelgrass are for blades.

Original data on contaminant levels in surface sediment samples from stations with corresponding biota samples are provided as supplemental information (Tables SI.4 & SI.5). Original data on contaminant levels in individual samples of bivalves, fish, and eelgrass are also provided as supplemental information (Tables SI.6 - SI.8). Only those stations from which both sediment and biota samples were collected are represented. Only those analytes that were detected in both biota and sediment samples are included in the tables. To simplify calculations, all concentrations are presented as parts per million (ppm) dry weight which required that original data for some analytes be converted for units. Details on the data conversions are provided with with original data in the supplemental information section.

Pairing biota data with sediment data and calculations:

To compute BSAFs, it was necessary to pair data on tissue contaminant levels with data on contaminant levels in corresponding sediment samples. The individual sediment stations that have associated bivalve, fish, and eelgrass samples are listed, along with the sediment contaminant levels, in Tables SI-3 and SI-4.

A. Bivalve BSAFs:

Bivalve samples were clearly matched by sample identifiers with sediment samples from specific stations, as shown below.

Surface sediment stations with corresponding bivalve samples from NASSCO (NA), SWM (SW), and reference study areas.

	Reference	NASSCO shipyard area	SWM shipyard area
Mussels	2240	NA12, NA24	SW18, SW27
Clams	2231, 2243, 2433, 2440, 2441	NA06, NA11, NA12, NA20	SW04, SW08, SW13, SW21, SW28

Two individual sediment samples were collected at some of the stations (e.g, station NA01 in Tables SI.3 and SI.4). In those cases, the mean was used to represent sediment contaminant levels for BSAF estimates. Sediment contaminant levels that were entered into BSAF calculations for bivalves are shown in Table B4 (next page). Note that values for organic contaminants are toc-normalized.

The clam data are from bioaccumulation tests that used five replicates for each sediment station. Data for the individual replicates, each a composite of approximately 35 animals, are provided as supplemental information in Tables Tables SI.5 and SI.6. The means of the five replicates were used to represent contaminant levels in clams exposed to sediment from a particular station. Mussels were collected at only a few stations, and there is only one composite mussel sample of approximately 500 individuals per station.

For bivalves, one BSAF per station was generated for each analyte using:

mean ppm in tissue / mean ppm in sediment (clams),

or

single ppm in tissue / mean ppm in sediment (mussels).

Bivalve tissue contaminant levels entered in to BSAF calculations are provided in Table B5, below. Note that values for organic contaminants are lipid-normalized. Values in Table B5 were divided by corresponding values in Table B4 to obtain BSAFs for each station (Tables B6 and B7).

Depending on the study area, it was possible to generate up to 6 or 7 bivalve BSAFs for each analyte.

Table B4. Sediment contaminant levels (mean/station) used to calculate bivalve BSAFs. Concentrations of inorganics are as parts per million (ppm or mg/kg) dry weight. Concentrations of organic analytes are toc-normalized (ppm dry / f-toc).

station* (* = mean)	f - TOC	As ppm	Cd ppm	Cr ppm	Cu ppm	Pb ppm	Hg ppm	Ni ppm	Se ppm	Ag ppm	Zn ppm	TBT/toc ppm/oc	TPAH/toc ppm/toc	PCB cong/toc ppm/toc	PCB aro/toc ppm/toc	PCB hom/toc ppm/toc
NA06*	0.021	10.5	0.265	61.5	395	130.0	2.35	14.5	1.10	1.015	335	10.450	203.46	27.71	73.59	43.02
NA11	0.017	9.3	0.280	59.0	180	73.0	0.85	15.0	-	1.100	230	2.249	177.51	11.24	15.98	15.98
NA12	0.015	9.5		54.0	150	59.0	0.62	-	1.10	0.790	210	5.405	148.65	10.14	14.86	14.86
NA19	0.018	14.0	0.370	65.0	270	100.0	0.78	17.0	1.00	1.100	450	30.978	173.91	53.80	32.61	76.09
NA20	0.014	6.6	0.440	26.0	96	53.0	0.24	8.4	1.00	0.530	190	19.718	225.35	8.45	14.08	11.97
NA24	0.021	9.6	0.200	60.0	200	88.0	0.90	11.0		0.900	280	2.783	108.49	13.68	25.00	19.34
SW04*	0.023	73.0	1.950	87.5	1500	430.0	1.75	18.0	1.50	1.600	3450	149.512	943.40	251.57	188.68	258.80
SW08*	0.038	24.0	0.730	82.5	920	225.0	2.25	21.0	-	1.450	830	52.231	865.67	62.69	119.40	76.61
SW13	0.023	15.0	0.420	72.0	800	93.0	0.86	24.0	-	1.400	580	33.906	600.86	21.03	22.32	30.47
SW18	0.022	11.0	0.330	74.0	220	86.0	0.75	20.0	-	1.300	280	5.936	401.83	20.09	17.35	30.14
SW21	0.021	11.0	0.510	70.0	260	120.0	1.40	14.0	-	1.300	330	8.095	476.19	114.29	161.90	171.43
SW27	0.021	10.0	0.270	63.0	210	80.0	0.68	18.0	-	1.100	250	12.019	673.08	9.62	18.75	15.38
SW28*	0.025	14.0	0.315	65.5	265	100.0	0.88	15.0	1.20	1.100	330	5.865	869.57	83.00	146.25	101.60
2231*	0.013	8.3	0.085	41.0	91	43.0	0.41	10.0	-	0.270	150	1.017	51.74	5.87	20.62	8.54
2240	0.011	8.8	0.220	59.0	98	40.0	0.46	12.0	-	1.000	260	0.257	33.03	5.60	11.93	7.89
2243*	0.006	4.4	0.120	24.5	53	21.5	0.25	5.7	-	0.605	107	0.461	37.25	5.37	6.70	7.26
2433*	0.007	4.5	0.270	24.5	44	18.0	0.22	7.1	-	0.400	96	0.674	42.74	2.30	5.33	3.23
2440*	0.012	4.400	0.310	27	56	68	0.280	7.050	-	0.460	115	2.779	163.47	5.57	13.55	7.75
2441*	0.012	5.3	0.285	23.5	41	13.5	0.16	9.0	1.00	0.265	88	0.289	33.0	0.75	1.28	1.03

Table B5. Tissue contaminant levels (mean/station) used to calculate bivalve BSAFs. Concentrations of inorganic analytes are as parts per million (ppm or mg/kg) dry weight. Concentrations of organics are lipid-normalized (ppm dry / f-lipid dry).

station (* = mean)	f-lipid	As	Cd	Cr	Cu	Pb	Hg	Ni	Se	Ag	Zn	TBT	TPAH	PCB con	PCB-aro	PCB hom
		ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm/lipid	ppm/lipid	ppm/lipid	ppm/lipid	ppm/lipid
NA06*	0.034	19.5	0.282	2.13	15.4	4.10	0.120	2.57	2.01	0.272	131	6.635	54.61	9.170	15.988	13.200
NA11*	0.034	20.2	0.263	1.85	12.9	2.66	0.105	2.29	1.90	0.329	113	2.949	43.85	5.381	9.833	7.618
NA12*	0.035	19.0	0.211	1.72	13.1	2.33	0.107	2.31	2.12	0.224	114	3.046	48.98	3.585	6.456	4.977
NA19	0.061	15.2	0.376	6.09	81.2	6.60	0.122	9.64	3.05	0.609	102	7.833	20.83	7.000	8.333	9.167
NA20*	0.032	18.0	0.192	1.98	11.1	2.83	0.120	2.71	1.49	0.141	113	4.784	86.22	4.015	6.745	5.753
NA24	0.075	15.0	0.310	2.7	48.5	4.55	0.100	5.50	3.50	0.430	80	5.000	30.67	7.333	9.333	10.000
SW04*	0.042	24.2	0.262	3.23	33.0	9.10	0.133	3.00	1.62	0.234	195	54.780	271.96	23.665	35.052	34.708
SW08*	0.033	19.6	0.216	2.58	23.5	6.15	0.132	2.36	1.53	0.255	111	32.286	305.15	21.982	34.953	32.714
SW13*	0.033	19.4	0.220	2.16	25.0	2.55	0.101	2.58	1.88	0.292	131	25.715	208.05	14.423	14.919	21.496
SW18	0.088	17.6	0.446	2.57	52.0	4.32	0.115	3.99	4.05	0.554	108	6.308	54.62	7.692	10.769	10.769
SW21*	0.034	20.7	0.273	2.67	16.5	4.34	0.106	2.45	1.93	0.347	131	3.364	209.61	30.896	53.935	52.452
SW27	0.091	15.5	0.326	2.67	44.4	4.33	0.096	3.69	3.74	0.439	96	5.529	54.71	7.059	8.824	10.000
SW28*	0.034	19.9	0.240	1.55	13.5	2.78	0.113	2.49	1.75	0.227	125	2.489	209.45	23.649	43.797	33.325
2231*	0.035	19.0	0.215	1.40	8.9	1.68	0.143	2.04	1.55	0.149	109	0.673	20.09	2.487	4.412	3.339
2240	0.084	9.6	0.292	4.33	24.7	2.98	0.073	3.43	3.65	0.472	73	1.733	9.33	4.267	8.667	5.667
2243*	0.029	20.3	0.198	2.05	11.7	2.01	0.113	2.44	1.61	0.257	110	0.704	23.81	2.979	5.933	3.865
2433*	0.028	19.1	0.249	2.41	10.5	1.92	0.079	2.90	1.52	0.293	102	0.899	27.24	2.960	5.750	4.093
2440*	0.035	18.2	0.198	2.15	10.5	4.26	0.127	2.75	1.98	0.248	110	2.657	138.48	4.926	8.637	7.094
2441*	0.032	21.1	0.422	3.17	20.3	2.44	0.084	3.92	1.19	0.511	128	0.464	50.65	1.215	2.273	1.594

Table B6. Bivalve BSAFs for inorganic analytes ($kg_{sediment}/kg_{tissue}$).

Station	As BSAF	Cd BSAF	Cr BSAF	Cu BSAF	Pb BSAF	Hg BSAF	Ni BSAF	Se BSAF	Ag BSAF	Zn BSAF
NA06 (clams)	1.85	1.07	0.035	0.039	0.032	0.051	0.177	1.83	0.268	0.392
NA11 (clams)	2.18	0.94	0.031	0.072	0.036	0.124	0.153	-	0.299	0.490
NA12 (clams)	2.00	-	0.032	0.088	0.040	0.173	-	1.92	0.283	0.542
NA19 (mussels)	1.09	1.02	0.094	0.301	0.066	0.156	0.567	3.05	0.554	0.226
NA20 (clams)	2.73	0.44	0.076	0.116	0.053	0.498	0.323	1.49	0.266	0.593
NA24 (mussels)	1.56	1.55	0.045	0.243	0.052	0.111	0.500	-	0.478	0.286
SW04 (clams)	0.33	0.13	0.037	0.022	0.021	0.076	0.167	1.08	0.146	0.057
SW08 (clams)	0.81	0.30	0.031	0.026	0.027	0.059	0.112	-	0.176	0.134
SW13 (clams)	1.29	0.52	0.030	0.031	0.027	0.118	0.107	-	0.209	0.225
SW18 (mussels)	1.60	1.35	0.035	0.236	0.050	0.153	0.199	-	0.426	0.386
SW21 (clams)	1.88	0.54	0.038	0.064	0.036	0.076	0.175	-	0.267	0.397
SW27 (clams)	1.55	1.21	0.042	0.211	0.054	0.142	0.205	-	0.399	0.385
SW28 (mussels)	1.42	0.76	0.024	0.051	0.028	0.129	0.166	1.46	0.206	0.379
2231 (clams)	2.30	2.53	0.034	0.098	0.039	0.349	0.204	-	0.551	0.727
2240 (mussels)	1.09	1.33	0.073	0.252	0.074	0.159	0.286	-	0.472	0.281
2243 (clams)	4.67	1.65	0.084	0.220	0.093	0.452	0.428	-	0.425	1.029
2433 (clams)	4.25	0.92	0.098	0.242	0.106	0.367	0.408	-	0.732	1.066
2440 (clams)	4.14	0.64	0.081	0.187	0.063	0.452	0.389	-	0.540	0.960
2441 (clams)	4.02	1.48	0.135	0.495	0.181	0.541	0.438	1.19	1.927	1.464

Mean BSAF/study area*	As	Cd	Cr	Cu	Pb	Hg	Ni	Se	Ag	Zn
NA mean	1.90	1.0	0.05	0.14	0.05	0.19	0.344	2.06	0.36	0.42
SWM mean	1.27	0.69	0.03	0.09	0.03	0.11	0.16	1.27	0.26	0.28
Ref mean	3.41	1.42	0.08	0.25	0.09	0.39	0.36	1.19	0.77	0.92

* Because there are so few mussel data, means are for clams and mussels combined.

Table B7. Bivalve BSAFs for organic analytes (kg_{toc}/kg_{lipid}).

Station	lipid/toc BSAF	TBT BSAF	TPAH BSAF	PCB con BSAF	PCB-aro BSAF	PCB hom BSAF
NA06 (clams)	1.58	0.635	0.268	0.331	0.217	0.307
NA11 (clams)	2.00	1.312	0.247	0.479	0.615	0.477
NA12 (clams)	2.34	0.564	0.329	0.354	0.434	0.335
NA19 (mussels)	3.31	0.253	0.120	0.130	0.256	0.120
NA20 (clams)	2.23	0.243	0.383	0.475	0.479	0.481
NA24 (mussel)	3.54	1.797	0.283	0.536	0.373	0.517
SW04 (clams)	1.83	0.366	0.288	0.094	0.186	0.134
SW08 (clams)	0.86	0.618	0.353	0.351	0.293	0.427
SW13 (clams)	1.43	0.758	0.346	0.686	0.669	0.705
SW18 (mussels)	4.01	1.063	0.136	0.383	0.621	0.357
SW21 (clams)	1.61	0.416	0.440	0.270	0.333	0.306
SW27 (mussel)	4.37	0.460	0.081	0.734	0.471	0.650
SW28 (clams)	1.34	0.424	0.241	0.285	0.299	0.328
2231 (clams)	2.84	0.662	0.388	0.423	0.214	0.391
2240 (mussels)	7.73	6.748	0.283	0.762	0.727	0.718
2243 (clams)	4.82	1.527	0.639	0.555	0.886	0.532
2433 (clams)	4.06	1.334	0.637	1.286	1.079	1.266
2440 (clams)	2.99	0.956	0.847	0.884	0.637	0.915
2441 (clams)	2.66	1.606	1.535	1.620	1.771	1.552
Mean BSAF/study area*	lipid/toc	TBT	TPAH	PCB con	PCB-aro	PCB hom
NA mean	2.50	0.80	0.27	0.38	0.40	0.37
SWM mean	2.21	0.59	0.27	0.40	0.41	0.42
Ref mean	4.18	2.14	0.72	0.92	0.89	0.90

* Because there are so few mussel samples, means are for clams and mussels are combined.

B. Demersal Fish BSAFs:

Demersal fish BSAFs were calculated from data on spotted sand bass collected by Exponent (2003). The fish that were collected had an average fork length of 27 cm (from Marty 2003). For the purpose of calculating sediment screening levels, the BSAFs based on sand bass data are assumed to represent BSAFs for demersal fish of any size.

Because of their mobility, the fish that were collected are assumed to be associated with multiple sediment stations. The sediment stations with which samples of demersal fish could be associated were determined from Exponent (2003), Figures 2-2, 2-3, 2-4, and 2-5 and are listed in the following table. Sediment stations with which sand bass samples were associated for this exercise are also indicated in Tables SI.3 and SI.4.

Surface sediment stations from the Exponent (2003) related to sand bass samples.

	Reference	NASSCO shipyard area	SWM shipyard area
	(4 stations)	(31 stations)	(35 stations)
Sand bass	2240, 2241,2243, 2244	NA01 - NA31	SW01-SW34, SW36

The sediment contaminant levels used to calculate BSAFs are the means for the stations within the designated area. Values entered in to BSAF calculations for sand bass are shown in Table B8.

Five individual fish were captured in the reference area and ten were captured in each of the shipyard areas. Contaminant levels measured in the individual fish are provided in supporting information Tables SI.7 and SI.8. Mean concentrations were used to represent contaminant levels in fish from each of the study areas. Fish tissue contaminant levels entered in to BSAF calculations are provided in Table B9.

Ultimately, one BSAF per study area was generated for each analyte using the relationship:

mean ppm in tissue / mean ppm in sediment.

Values in Table B9 were divided by corresponding values in Table B8 to produce the sand bass BSAFs shown in Table B10.

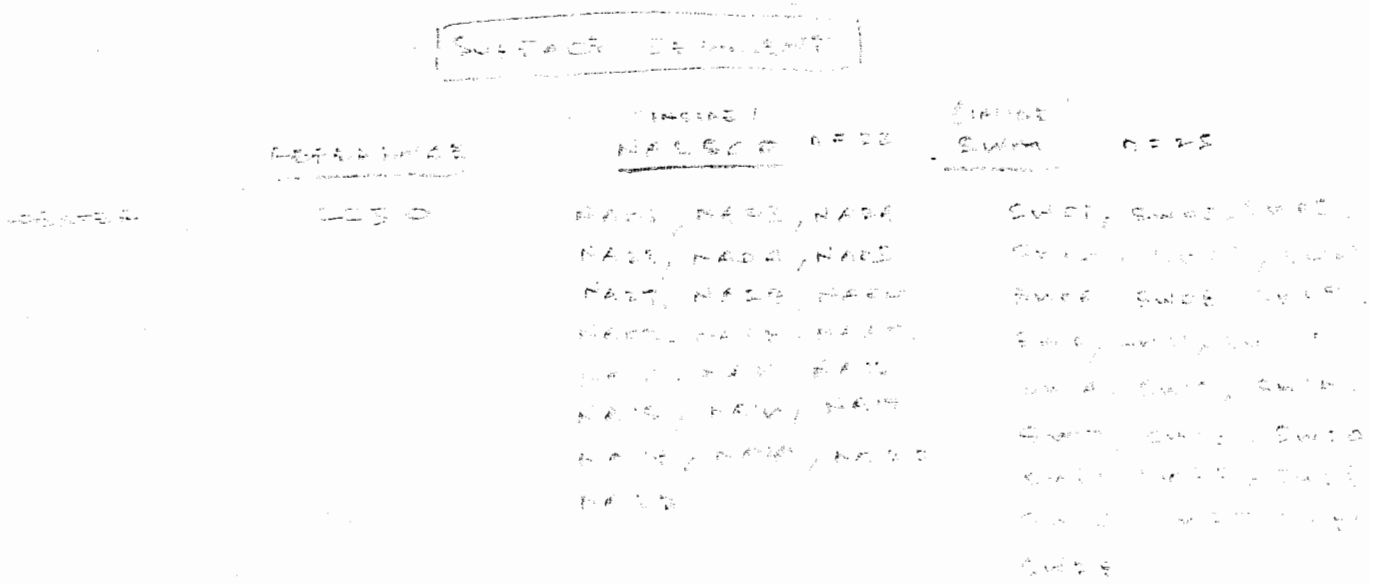

Table B8. Mean sediment contaminant levels used to calculate sand bass BSAFs. Concentrations of inorganics are as parts per million (ppm or mg/kg) dry weight. Concentrations of organics are toc-normalized (ppm dry / f-toc).

	Concentrations in sediment														
	f-toc	TBT ppm/toc	PCBhom ppm/toc	PCB aro ppm/toc	PCBcon ppm/toc	TPAH ppm/toc	As ppm	Cd ppm	Cr ppm	Cu ppm	Pb ppm	Hg ppm	Ni ppm	Se ppm	Ag ppm	Zn ppm
Reference	0.006	0.516	7.142	8.661	5.198	38.83	4.7	0.13	28	59	22	0.263	6.2	nd	0.610	12
NASSCO (NA)	0.019	10.817	22.434	26.123	15.348	207.10	10.6	0.28	61	229	84	0.908	15.3	1.063	1.064	294
SWM (SW)	0.024	18.888	68.044	73.875	44.019	590.13	14.8	0.66	64	369	117	1.254	25.8	1.383	1.275	499

Reference = mean of 2240, 2241, 2243, 2244; NA = mean of all NA stations; SWM = mean of all SW stations.

Table B9. Mean tissue contaminant levels used to calculate sand bass BSAFs. Concentrations of inorganics are as parts per million (ppm or mg/kg) dry weight. Concentrations of organics are lipid-normalized (ppm dry / f-lipid dry).

	Concentration in fish tissue (whole bodies)															
	f-lipid	TBT ppm/lipid	PCBhom ppm/lipid	PCB aro ppm/lipid	PCBcon ppm/lipid	TPAH ppm/lipid	As ppm	Cd ppm	Cr ppm	Cu ppm	Pb ppm	Hg ppm	Ni ppm	Se ppm	Ag ppm	Zn ppm
Reference mean	0.064	0.756	32.913	23.374	28.194	nd	1.662	0.090		3.39	0.31	0.427	0.882	nd	0.030	54
NA mean	0.055	3.333	60.324	56.009	51.865	nd	2.326	0.076	2.66	4.32	0.79	0.600	1.060	1.68	0.065	57
SWM mean	0.075	2.409	35.762	50.826	30.385	nd	2.403	0.080	1.59	7.67	0.83	0.535	1.039	1.99	0.062	54

Table B10. BSAFs for sand bass whole bodies as $kg_{sediment}/kg_{tissue}$ for inorganic analytes and as kg_{toc}/kg_{lipid} for organic analytes.

Sand bass		TBT	PCBhom	PCB aro	PCBcon	TPAH	As	Cd	Cr	Cu	Pb	Hg	Ni	Se	Ag	Zn
	f-lipid/toc	BSAF	BSAF	BSAF	BSAF	BSAF	BSAF	BSAF	BSAF	BSAF	BSAF	BSAF	BSAF	BSAF	BSAF	BSAF
Reference	10.69	1.464	4.608	2.699	5.424	#DIV/0!	0.35	0.694	-	0.057	0.014	1.621	0.142	-	0.049	0.421
NA	2.902	0.308	2.689	2.144	3.379	#DIV/0!	0.22	0.273	0.044	0.019	0.009	0.660	0.069	1.576	0.061	0.194
SWM	3.154	0.128	0.526	0.688	0.690	#DIV/0!	0.16	0.122	0.025	0.021	0.007	0.427	0.040	1.44	0.048	0.109

C. Eelgrass BSAFs:

Only one eelgrass sample was collected from each of the Exponent study areas, as indicated in Tables SI.7 and SI.8. Sample identifiers indicate that the single reference area eelgrass sample is very near if not co-located with reference sediment station 2240. The same is not the case for eelgrass samples from the shipyard areas. For those areas, it is assumed that contaminant levels measured in the nearest sediment station samples are representative of contaminant levels in sediments within the eelgrass beds. The locations of the eelgrass sample stations (Bed 1 at NASSCO shipyard and Bed 1 at SWM) were determined from Exponent (2003), Figures 2-8 and 2-9. Corresponding sediment stations were selected from Exponent (2003), Figure 2-4. Sediment stations used to estimate eelgrass BSAFs are shown below.

Surface sediment stations from the Exponent (2003) associated with eelgrass.

	Reference	NASSCO shipyard area	SWM shipyard area
Eelgrass	2240 (co-located)	NA20 (nearest)	SW20 - SW24 (nearest)

The eelgrass sample from the SWM shipyard study area is near five sediment stations. Mean concentrations were used to represent sediment contaminant levels for the SWM study area. Contaminant levels measured in sediments from all of the stations used for eelgrass BSAFs are provided in Tables SI.5 and SI.6. The sediment contaminant levels that were entered into BSAF calculations are shown in Table B11.

Contaminant levels measured in eelgrass samples are provided in Tables SI.7and SI.8. Because there was only one eelgrass sample per study area, the same values were entered into BSAF calculations (Table B12).

Overall, one BSAF per study area was generated for each analyte using:

ppm in a single tissue sample / ppm in a single sediment sample, or

ppm in a single tissue sample / mean ppm in sediment.

Values in Table B12 were divided by corresponding values in Table B11 to produce the eelgrass BSAFs in Table B13.

Table B11. Sediment contaminant levels used to calculate eelgrass BSAFs. Concentrations are in parts per million (ppm or mg/kg) dry weight.

	Concentrations in sediment															
	f-toc	TBT	PCBhom	PCBaro	PCBcon	TPAH	As	Cd	Cr	Cu	Pb	Hg	Ni	Se	Ag	Zn
	(not used)	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Reference	0.011	0.0028	0.086	0.130	0.061	0.360	8.80	0.22	59.0	98	40	0.460	12.0		1.00	260
NASSCO (NA)	0.014	0.280	0.170	0.200	0.120	3.200	6.60	0.44	26.0	96	53	0.240	8.4	1.000	0.53	190
SWM (SW)	0.021	0.172	2.017	2.200	1.370	22.600	12.17	0.38	67.0	282	104	1.382	18.3		1.22	327

Reference = Station 2240, NA = Station NA20, SWM = mean of SW20-SW24

Table B12. Tissue contaminant levels used to calculate eelgrass BSAFs. Concentrations for all analytes are as parts per million (ppm or mg/kg) dry weight, and no values were normalized for lipid because lipid content in eelgrass samples was below the limits of detection.

	Concentrations in eelgrass															
Location	f - lipid	TBT	PCBhom	PCBaro	PCBcon	tPAH	As	Cd	Cr	Cu	Pb	Hg	Ni	Se	Ag	Zn
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Reference	<0.006	nd	0.021	0.030	0.016	nd	2.381	0.423	2.38	32.14	4.52	nd	2.798	nd	0.774	172.6
NASSCO	<0.006	nd	0.103	0.048	0.071	0.903	3.871	0.774	9.68	193.55	19.35	0.129	3.871	nd	1.613	348.4
SWM	<0.006	0.02	0.071	0.123	0.052	2.645	5.484	0.774	18.06	206.45	24.52	0.258	6.452	nd	1.484	354.8

Table B13. BSAFs for eelgrass ($kg_{sediment}/kg_{tissue}$).

		TBT	PCBhom	PCB aro	PCBcon	TPAH	As	Cd	Cr	Cu	Pb	Hg	Ni	Se	Ag	Zn
	f-lipid/toc	BSAF	BSAF	BSAF	BSAF	BSAF	BSAF	BSAF	BSAF	BSAF	BSAF	BSAF	BSAF	BSAF	BSAF	BSAF
Refence	not done	nd	0.249	0.229	0.263	nd	0.27	1.92	0.040	0.328	0.113	nd	0.233	nd	0.774	0.664
NA	not done	nd	0.607	0.242	0.591	0.282	0.59	1.76	0.372	2.016	0.365	0.538	0.461	nd	3.043	1.834
SWM	not done	0.1165	0.035	0.056	0.038	0.117	0.45	2.03	0.270	0.733	0.235	0.187	0.352	nd	1.220	1.086

Summary of Reference Area BSAFs:

BSAFs were calculated for all of the stations for which data were available, including shipyard study areas. Only reference area BSAFs are summarized below because they were the ones used to calculate sediment screening levels.

A. For bivalves

With the available data, it was possible to identify six reference area BSAFs for each analyte (5 with clams and 1 with mussels). The range of reference area BSAFs obtained with individual reference area stations can be seen in Tables B6 and B7. The mean reference area BSAF (mussels and clams combined) for each analyte was used to calculate sediment screening levels. The maximum for the six stations might be used if a more conservative sediment value is desired.

B. For fish and eelgrass

For both fish and eelgrass, it was possible to identify one reference area BSAF for each analyte. These are presented in the following table, along with the bivalve BSAFs that were used to calculate sediment screening levels.

Reference area BSAFs used to calculate sediment screening levels.

Analyte	Units	Organism		
		Bivalves[1]	Spotted sand bass[2]	Eelgrass[3]
Organics				
f-lipid/f-toc	unitless	4.18	10.687	not calculated[3]
PCB homolog	kg_{toc}/kg_{lipid}	0.90	4.608	0.249[3]
PCB Aroclors	kg_{toc}/kg_{lipid}	0.89	2.699	0.229[3]
PCB congener	kg_{toc}/kg_{lipid}	0.92	5.424	0.263[3]
TPAH	kg_{toc}/kg_{lipid}	0.72	not detected	not detected
TBT	kg_{toc}/kg_{lipid}	2.14	1.464	not detected
Inorganics				
Arsenic	kg_{tissue}/kg_{sed}	3.41	0.351	0.271
Cadmium	kg_{tissue}/kg_{sed}	1.42	0.694	1.923
Chromium	kg_{tissue}/kg_{sed}	0.08	not detected	0.040
Copper	kg_{tissue}/kg_{sed}	0.25	0.057	0.328
Lead	kg_{tissue}/kg_{sed}	0.09	0.014	0.113
Mercury	kg_{tissue}/kg_{sed}	0.39	1.621	not detected
Nickel	kg_{tissue}/kg_{sed}	0.36	0.142	0.233
Selenium	kg_{tissue}/kg_{sed}	1.19	not detected	not detected
Silver	kg_{tissue}/kg_{sed}	0.77	0.049	0.774
Zinc	kg_{tissue}/kg_{sed}	0.92	0.421	0.664

1. Mean of six (5 clam stations and 1 mussel station).
2. Mean obtained with five individual fish and the mean for four sediment stations.
3. Based on individual sample, and BSAFs for organics not lipid/toc - normalized.

Supplemental Information (SI)

Data for Kp Calculations

Original data factored into Kp estimates are presented in Tables SI.1 and SI.2. Data were taken directly from tables in the Exponent (2003) report. Concentrations for some analytes were first converted for units so that all of the concentrations used to calculate Kp are in parts per million (ppm, or $mg/kg_{sediment}$ and $mg/L_{porewater}$). Details on unit conversions are provided so that values presented in the following tables can be related back to values from tables in the Exponent (2003) report.

Only those stations from which both sediment and porewater samples were collected are represented.

Porewater and sediment samples were analyzed for inorganics, PAHs, and PCB homologs. Only those analytes that were detected in both porewater and sediment samples are included in the tables (i.e., TBT, PCB homologs, and metals).

A. Data on inorganics

Sources from the report by Exponent (2003) -

Porewater data are from Exponent, Table D-1. Sediment data for corresponding stations are from Exponent, Table B1-3.

Data Conversions -

Concentrations of some inorganics are reported as parts per billion (ppb or $\mu g/L$ in water or $\mu g/kg$ in sediment). These were converted to ppm using ppb/1,000.

B. Data on organics

Sources from the report by Exponent (2003) -

Concentrations of polychlorinated biphenyls (PCBs), measured as homologs in porewater are from Exponent, Table D-3. Concentrations of PCBs in corresponding sediment samples are from Table B1-8.

Concentrations of total PCBs were taken directly from the specified tables in the Exponent report. The reported concentrations equal the sum of the concentrations of the homologs, with ½ quantitation limits used for non-detects.

Data Conversions -

Concentrations of PCBs in porewater were reported as parts per trillion (ppt, or ng/L), and were converted to ppm using ppt/1,000,000.

Concentrations of PAHs and PCBs in sediment were reported as ppb (ug/kg) and converted to ppm (mg/kg) using ppb/1,000.

Supplemental Information (SI)

Data for BSAF Calculations

Original sediment data factored into BSAF estimates are presented in Tables SI.3 and SI.4. Original bivalve tissue data factored in to BSAF calculations are presented in tables SI.5 and SI.6. Original sand bass and eelgrass data factored in to BSAF calculations are presented in tables SI.7 and SI.8.

All of the data are from tables in the Exponent (2003) report. To simplify calculations, all concentrations are presented as parts per million (ppm or mg/kg), which required that original data for some analytes be converted for units. In addition, tissue contaminant levels are presented in the Exponent (2003) tables as wet weight concentrations. Tissue contaminant and lipid levels were converted to dry weight concentrations for tables in this document. Details on data conversions are provided so that values presented in the following tables an be related back to values from tables in the Exponent (2003) report.

Only those stations for which there are both sediment and biota samples are represented.

Tissue and sediment samples were analyzed for inorganics, butyltins, PAHs, polychlorinated terphenyls (PCTs), and PCBs (as aroclors, homologs, and congeners). Only those analytes that were detected in both media (required for calculating BSAFs) are included in the tables.

A. <u>Data on inorganics, TBT, and sample parameters (lipids, toc, solids)</u>

Sources -

Concentrations of inorganics, lipid, and fraction solids measured in biota samples are from Exponent, Table E-1. Sediment data for corresponding stations are from Exponent, Table B1-3.

Data conversions -

Lipid in tissue and toc in sediment were originally reported as percent. They were converted to f-lipid and f-toc using percent / 100.

The solids in tissue and sediment samples were originally reported as percent, and converted to f-solids using percent /100.

Concentrations of butyltins (specifically, TBT) in sediment and biota samples were originally reported as parts per billion (ppb or ug/kg) and were converted to ppm using ppb / 1000.

Contaminant and lipid levels reported by Exponent (2003) for tissue samples are wet weight values. Contaminant concentrations and f-lipid in each sample were converted to dry weight values using f-solids for the respective sample, and calculating:

ppm contaminant or f-lipid dry = ppm contaminant or f-lipid wet / f-solids.

(No wet weight-dry weight conversions were needed for sediment, because the data were already presented as dry weight values.)

B. Data on organics

Sources -

Concentrations of PAHs in biota samples are from Exponent (2003), Table E-2. Concentrations of PAHs in corresponding sediment samples are from Exponent (2003), Table B1-5.

Total PAH (TPAH) concentrations were taken directly from tables in the Exponent report. The reported TPAH for each sample equals the sum of the concentrations of 15 individual compounds, and ½ the quantitation limit was used for compounds that were not detected.

Concentrations of PCB aroclors in biota samples are from Exponent (2003), Table E-5. Concentrations of PCBs as homologs and congeners in biota samples are from Exponent (2003), Table E-6. Concentrations of PCBs in corresponding sediment samples are from Exponent (2003), Tables B1-7 (aroclors) and B1-8 (congeners and homologs).

Total PCB concentrations were taken directly from tables in the Exponent report. Concentrations of total PCBs as Aroclors = the sum of the concentrations of the aroclors detected. Total PCB concentrations as homologs and congeners factor in ½ quantitation limits for non-detects.

Data conversions -

Concentrations of organics in sediments and biota were originally reported as parts per billion (ppb, or ug/kg) and were converted to ppm using ppb/1000.

Data on tissue samples were converted from wet weight to dry weight values using f-solids as described for inorganic analytes.

Levels of organic contaminants are presented as both dry weight concentrations and as lipid or toc-normalized concentrations. Normalized values were obtained for each sample using:

ppm (dry weight) / f-lipid (dry weight) for tissue, and
ppm (dry weight) / f-toc (dry weight) for sediment.

Organic contaminant levels in eelgrass samples could not be normalized for lipid because lipid levels were below the limits of detection.

Table Si.1. Original sediment data for Kp estimates.

Data for stations with corresponding porewater samples in NASSCO (NA), SWM (SW), and reference study areas, as parts per million (ppm or mg/kg) dry weight.

station	TBT	PCB hom	As	Cd	Cr	Cu	Pb	Hg	Ni	Se	Ag	Zn
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
NA01	0.21	0.53	11.0	0.26	68	210	21	0.95	17	1.0	1.30	260
NA01	0.22	0.52	11.0	0.27	69	220	14	1.10	16	1.1	1.40	270
NA01	0.10	0.54	9.4	0.21	71	290	42	1.10	13	-	1.30	330
NA06	0.18	0.90	11.0	0.28	67	410	22	3.20	17	-	0.93	330
NA06	0.27	0.97	10.0	0.25	56	380	18	1.50	12	1.1	1.10	340
NA13	0.07	0.25	12.0	0.24	64	170	79	0.69	17	1.0	0.93	280
NA13	0.07	0.28	9.50	0.23	54	200	71	0.60	14	1.0	0.95	310
NA16	0.19	0.56	11.0	0.35	74	260	93	1.10	18	1.0	1.40	310
NA16	0.17	0.81	10.0	0.41	69	250	91	0.97	14	-	1.40	330
NA16	0.15	0.48	10.0	0.34	64	240	82	1.20	13	-	1.20	300
NA17	1.00	0.76	16.0	0.54	76	660	130	0.93	20	1.1	1.30	770
NA17	1.70	0.48	13.0	0.27	72	360	100	0.76	15	1.1	1.30	470
SW01	0.52	2.40	15.0	0.75	67	620	170	1.40	66	-	0.73	610
SW01	0.38	2.40	12.0	0.67	90	500	120	1.50	130	-	1.40	430
SW02	0.22	8.10	16.0	2.5	86	570	170	3.90	68	-	2.70	550
SW02	0.31	7.60	13.0	2.6	89	530	210	3.10	76	-	2.90	550
SW02	0.07	8.80	13.0	3.8	150	610	150	5.40	140	1.7	5.00	620
SW04	2.80	5.80	96.0	2.4	65	1900	480	1.20	20	1.2	1.70	4600
SW04	3.70	4.60	50.0	1.5	110	1100	380	2.30	16	1.8	1.50	2300
SW08	1.90	3.00	26.0	0.67	78	1000	250	2.50	23	-	1.40	860
SW08	1.80	2.40	22.0	0.79	87	840	200	2.00	19	-	1.50	800
SW12	0.03	0.22	7.7	0.16	43	140	56	0.55	12	-	0.76	170
SW12	0.04	0.24	7.1	0.12	35	99	48	0.50	9.6	-	0.75	150
SW24	0.17	1.40	10.0	0.39	51	260	96	1.60	14	-	1.20	260
SW24	0.16	1.60	10.0	0.26	54	340	80	2.20	18	-	1.10	340
SW25	0.37	0.51	13.0	0.47	63	230	93	0.80	18	-	1.10	370
SW25	0.09	-	10.0	0.24	66	230	78	0.75	15	-	1.30	320
SW28	0.18	3.00	15.0	0.36	63	270	100	0.98	17	1.1	1.10	310
SW28	0.12	-	13.0	0.27	68	260	100	0.77	13	1.3	1.10	350
2231	0.02	0.120	8.3	0.1	37	82	42	0.43	10.0	-	0.26	120
2231	0.01	0.098	8.2	0.07	45	100	44	0.39	10.0	-	0.28	180
2243	0.00	0.032	4.3	0.12	23	47	21	0.25	5.6	-	0.56	93
2243	0.00	0.052	4.4	0.12	26	59	22	0.25	5.8	-	0.65	120
2433	0.00	0.031	4.6	0.29	24	40	19	0.21	7.4	-	0.39	92
2433	0.01	0.035	4.4	0.25	25	47	17	0.22	6.8	-	0.41	100
2440	0.03	0.180	4.3	0.33	26	48	77	0.29	7.1	-	0.46	120
2440	0.04	0.130	4.5	0.29	27	64	59	0.27	7.0	-	0.46	110
2441	0.00	0.015	5.4	0.29	22	37	13	0.16	9.9	1.0	0.24	80
2441	0.00	0.022	5.1	0.28	25	45	14	0.15	8.0	-	0.29	95

Table SI.2. Original porewater data used for Kp estimates.
Contaminant levels measured in pore water samples for NASSCO (NA), SWM (SW), and reference study areas, as parts per million (ppm or mg/L).

Station	TBT	PCB hom	As	Cd	Cr	Cu	Pb	Hg	Ni	Se	Ag	Zn
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
2231	-	0.000018	0.0033	-	0.0038	0.0230	0.0025	0.000047	0.0016	-	0.000200	0.022
2243	-	0.000022	0.0098	-	0.0036	0.0084	0.0029	0.000045	0.0026	-	0.000200	0.023
2433	-	0.000038	0.0170	-	0.0042	0.0110	0.0036	0.000042	0.0039	-	0.000200	0.017
2440	0.000022	0.000075	0.0140	-	0.0043	0.0120	0.0074	0.000059	0.0034	-	0.000200	0.020
2441	-	0.000016	0.0120	-	0.0042	0.0093	0.0028	0.000030	0.0028	-	0.000200	-
NA01	-	0.000680	0.0190	-	0.0032	0.0140	0.0052	0.000051	0.0023	0.0052	0.000100	0.023
NA06	0.000100	0.000200	0.0091	-	0.0066	0.0330	0.0120	0.000190	0.0022	-	0.000400	0.044
NA13	0.000022	0.000056	0.0120	-	0.0045	0.0140	0.0065	0.000067	0.0025	-	0.000200	0.030
NA16	0.000054	0.000094	0.0170	-	0.0063	0.0220	0.0090	0.000082	0.0027	-	0.000250	0.032
NA17	0.000077	0.000084	0.0200	-	0.0061	0.0230	0.0070	0.000074	0.0029	-	0.000450	0.032
SW01	0.000037	0.000500	0.0061	-	0.0037	0.0170	0.0066	0.000078	0.0030	-	0.000100	0.022
SW02	0.000059	0.016000	0.0110	0.004	0.1160	0.3900	0.1200	0.001900	0.0370	-	0.002700	0.610
SW04	0.000550	0.000600	0.0150	-	0.0081	0.0550	0.0200	0.000150	0.0033	0.0061	0.000400	0.060
SW08	0.000490	0.000520	0.0099	-	0.0048	0.0330	0.0120	0.000130	0.0020	-	0.000100	0.034
SW12	0.000022	not done	0.0190	-	0.0051	0.0170	0.0071	0.000068	0.0028	-	0.000300	0.032
SW24	0.000074	0.000670	0.0100	-	0.0058	0.0250	0.0098	0.000130	0.0026	-	0.000100	0.037
SW25	0.000063	0.000180	0.0170	-	0.0079	0.0280	0.0130	0.000140	0.0029	-	0.000200	0.042
SW28	-	0.000290	0.0090	-	0.0048	0.0190	0.0075	0.000060	0.0024	-	0.000200	0.031

Table SI.3. Original surface sediment data used for BSAF estimates - Inorganic analytes as (ppm or mg/kg dry weight). Data for individual samples from stations with corresponding biota samples. The type of biota sample associated with each sediment station is indicated ("c" for clams, "m" for mussels, "e" for eelgrass, and "f" for fish).

station	biota	f - TOC	As ppm dry	Cd ppm dry	Cr ppm dry	Cu ppm dry	Pb ppm dry	Hg ppm dry	Ni ppm dry	Se ppm dry	Ag ppm dry	Zn ppm dry
NA01	f	0.021	11.0	0.26	68.0	210	88.0	0.95	17.0	1.00	1.3	260
NA01	f	0.0215	11.0	0.27	69.0	220	90.0	1.10	16.0	1.10	1.4	270
NA01	f	0.0224	9.4	0.21	71.0	290	79.0	1.10	13.0		1.3	330
NA02	f	0.02	10.0	0.21	67.0	170	76.0	0.70	18.0	1.00	1	240
NA03	f	0.0233	11.0	0.29	69.0	220	94.0	1.10	18.0	1.10	1.4	260
NA04	f	0.0204	12.0	0.27	73.0	260	93.0	1.10	19.0	1.10	1.2	310
NA05	f	0.016	9.5	0.17	57.0	170	65.0	0.61	15.0		0.89	210
NA06	c, f	0.0231	11.0	0.28	67.0	410	130.0	3.20	17.0		0.93	330
NA06	c, f	0.0206	10.0	0.25	56.0	380	130.0	1.50	12.0	1.10	1.1	340
NA07	f	0.0198	15.0	0.27	61.0	210	90.0	1.50	16.0		1.1	240
NA07	f	0.0205	12.0	0.27	60.0	240	110.0	1.40	16.0		1.2	270
NA08	f	0.0218	18.0	0.31	79.0	270	96.0	0.82	21.0		1	330
NA09	f	0.0226	13.0	0.4	75.0	260	97.0	1.20	20.0		1.1	330
NA10	f	0.0118	6.9	0.22	52.0	160	59.0	0.58	14.0		0.78	190
NA11	c, f	0.0169	9.3	0.28	59.0	180	73.0	0.85	15.0		1.1	230
NA12	c, f	0.0148	9.5		54.0	150	59.0	0.62		1.10	0.79	210
NA13	f	0.021	12.0	0.24	64.0	170	79.0	0.69	17.0	1.00	0.93	280
NA13	f	0.0187	9.5	0.23	54.0	200	71.0	0.60	14.0	1.00	0.95	310
NA14	f	0.0182	9.0	0.25	56.0	130	66.0	0.55	15.0		0.78	200
NA15	f	0.0195	12.0	0.25	62.0	250	83.0	0.98	16.0	1.00	1.3	310
NA16	f	0.0188	11.0	0.35	74.0	260	93.0	1.10	18.0	1.00	1.4	310
NA16	f	0.0204	10.0	0.41	69.0	250	91.0	0.97	14.0		1.4	330
NA16	f	0.0196	10.0	0.34	64.0	240	82.0	1.20	13.0		1.2	300
NA17	f	0.0233	16.0	0.54	76.0	660	130.0	0.93	20.0	1.10	1.3	770
NA17	f	0.0224	13.0	0.27	72.0	360	100.0	0.76	15.0	1.10	1.3	470
NA18	f	0.0204	14.0	0.36	67.0	230	97.0	0.79	17.0		1	380
NA19	m, f	0.0184	14.0	0.37	65.0	270	100.0	0.78	17.0	1.00	1.1	450
NA20	c, e, f	0.0142	6.6	0.44	26.0	96	53.0	0.24	8.4	1.00	0.53	190
NA21	f	0.0215	11.0	0.39	51.0	150	83.0	0.51	14.0		0.88	250
NA22	f	0.0165	8.5	0.46	39.0	150	95.0	0.38	12.0		0.91	230
NA23	f	0.0221	12.0	0.26	77.0	350	120.0	1.10	18.0	1.30	1.3	430
NA24	m, f	0.0212	9.6	0.2	60.0	200	88.0	0.90	11.0		0.9	280
NA25	f	0.0124	6.0	0.11	33.0	85	41.0	0.42	8.5		0.72	130
NA26	f	0.0122	6.2	0.11	32.0	80	41.0	0.48	8.0		0.66	140
NA27	f	0.0201	13.0	0.29	100.0	390	110.0	1.20	27.0		1.5	500
NA28	f	0.0187	10.0	0.31	86.0	290	84.0	0.89	23.0		1.4	390
NA29	f	0.017	6.9	0.14	39.0	110	56.0	0.55	11.0		0.86	170
NA30	f	0.0138	7.5	0.22	37.0	140	59.0	0.71	9.3		1	170
NA31	f	0.0092	5.3	0.13	29.0	71	34.0	0.35	7.5		0.57	110

Table SI.3, cont. Original surface sediment data for BSAF estimates - Inorganics.

station	biota	f - TOC	As ppm dry	Cd ppm dry	Cr ppm dry	Cu ppm dry	Pb ppm dry	Hg ppm dry	Ni ppm dry	Se ppm dry	Ag ppm dry	Zn ppm dry
SW01	f	0.0225	15.0	0.75	67.0	620	170.0	1.40	66.0		0.73	610
SW01	f	0.0231	12.0	0.67	90.0	500	120.0	1.50	130.0		1.4	430
SW02	f	0.0427	16.0	2.5	86.0	570	170.0	3.90	68.0		2.7	550
SW02	f	0.039	13.0	2.6	89.0	530	210.0	3.10	76.0		2.9	550
SW02	f	0.0642	13.0	3.8	150.0	610	150.0	5.40	140.0	1.70	5	620
SW03	f	0.0311	11.0	0.7	52.0	190	79.0	1.20	18.0		1.2	230
SW04	c, f	0.0159	96.0	2.4	65.0	1900	480.0	1.20	20.0	1.20	1.7	4600
SW04	c, f	0.0301	50.0	1.5	110.0	1100	380.0	2.30	16.0	1.80	1.5	2300
SW05	f	0.0155	11.0	0.86	53.0	230	120.0	0.96	19.0		1.2	280
SW06	f	0.0182	15.0	0.85	56.0	170	81.0	0.75	20.0		1.1	280
SW07	f	0.0173	8.1	0.19	43.0	150	57.0	0.52	13.0		0.74	170
SW08	c, f	0.0335	26.0	0.67	78.0	1000	250.0	2.50	23.0		1.4	860
SW08	c, f	0.0377	22.0	0.79	87.0	840	200.0	2.00	19.0		1.5	800
SW09	f	0.0194	27.0	1.1	56.0	660	220.0	0.96	18.0		1.3	1200
SW10	f	0.0121	13.0	0.87	45.0	160	79.0	0.58	17.0		0.82	360
SW11	f	0.0181	9.6	0.24	62.0	170	74.0	0.75	17.0		1.1	240
SW12	f	0.0158	7.7	0.16	43.0	140	56.0	0.55	12.0		0.76	170
SW12	f	0.0135	7.1	0.12	35.0	99	48.0	0.50	9.6		0.75	150
SW13	c, f	0.0233	15.0	0.42	72.0	800	93.0	0.86	24.0		1.4	580
SW14	f	0.0213	10.0	0.31	63.0	280	88.0	1.00	17.0		1.2	300
SW15	f	0.0231	11.0	0.45	67.0	230	90.0	0.90	19.0		1.3	290
SW16	f	0.0224	12.0	0.66	68.0	430	97.0	1.00	16.0		1.9	370
SW17	f	0.0253	12.0	0.37	73.0	270	93.0	0.98	20.0		1.5	310
SW18	m, f	0.0219	11.0	0.33	74.0	220	86.0	0.75	20.0		1.3	280
SW19	f	0.0115	7.1	0.15	42.0	110	51.0	2.10	12.0		0.78	150
SW20	e, f	0.0214	14.0	0.41	68.0	290	110.0	0.99	18.0		1.1	390
SW21	c, e, f	0.021	11.0	0.51	70.0	260	120.0	1.40	14.0		1.3	330
SW22	e, f	0.0246	13.0	0.35	70.0	260	110.0	1.10	21.0		1.3	310
SW23	e, f	0.0252	15.0	0.37	89.0	280	110.0	1.00	25.0		1.3	330
SW24	e, f	0.0161	10.0	0.39	51.0	260	96.0	1.60	14.0		1.2	260
SW24	f	0.0206	10.0	0.26	54.0	340	80.0	2.20	18.0		1.1	340
SW25	f	0.0203	13.0	0.47	63.0	230	93.0	0.80	18.0		1.1	370
SW25	f	0.0236	10.0	0.24	66.0	230	78.0	0.75	15.0		1.3	320
SW26	f	0.0131	9.0	0.14	45.0	120	58.0	0.43	12.0		0.46	160
SW27	m, f	0.0208	10.0	0.27	63.0	210	80.0	0.68	18.0		1.1	250
SW28	c, f	0.0253	15.0	0.36	63.0	270	100.0	0.98	17.0	1.10	1.1	310
SW28	c, f	0.026	13.0	0.27	68.0	260	100.0	0.77	13.0	1.30	1.1	350
SW29	f	0.0134	8.3	0.49	44.0	220	72.0	0.93	37.0		1.2	230
SW30	f	0.0205	8.9	0.23	72.0	240	72.0	1.10	13.0		1.2	300
SW31	f	0.0066	4.0	0.06	18.0	54	21.0	0.23	4.9		0.36	80
SW32	f	0.0156	9.4	0.06	43.0	92	57.0	0.51	11.0		0.33	160
SW33	f	0.0209	10.0	0.07	41.0	100	58.0	0.53	11.0	1.20	0.24	170
SW34	f	0.0168	8.3	0.21	53.0	320	99.0	0.75	11.0		0.95	310
SW36	f	0.0223	9.9	0.21	70.0	240	79.0	0.75	13.0		1.2	300

Table S1.3, cont. Original surface sediment data for BSAF estimates - Inorganics.

station	biota	f - TOC	As ppm dry	Cd ppm dry	Cr ppm dry	Cu ppm dry	Pb ppm dry	Hg ppm dry	Ni ppm dry	Se ppm dry	Ag ppm dry	Zn ppm dry
2231	c	0.013	8.3	0.1	37.0	82	42.0	0.43	10.0		0.26	120
2231	c	0.0125	8.2	0.07	45.0	100	44.0	0.39	10.0		0.28	180
2240	m, e, f	0.0109	8.8	0.22	59.0	98	40.0	0.46	12.0		1	260
2241	f	0.0025	3.0	0.08	15.0	34	13.0	0.18	3.4		0.42	70
2243	c, f	0.0051	4.3	0.12	23.0	47	21.0	0.25	5.6		0.56	93
2243	c, f	0.0063	4.4	0.12	26.0	59	22.0	0.25	5.8		0.65	120
2244	f	0.0055	3.8	0.12	23.0	58	18.0	0.20	4.9		0.5	110
2244	f	0.0051	4.1	0.12	23.0	59	19.0	0.24	5.6		0.53	110
2433	c	0.0067	4.6	0.29	24.0	40	19.0	0.21	7.4		0.39	92
2433	c	0.0069	4.4	0.25	25.0	47	17.0	0.22	6.8		0.41	100
2440	c	0.0162	4.3	0.33	26.0	48	77.0	0.29	7.1		0.46	120
2440	c	0.0107	4.5	0.29	27.0	64	59.0	0.27	7.0		0.46	110
2441	c	0.011	5.4	0.29	22.0	37	13.0	0.16	9.9	1.00	0.24	80
2441	c	0.0128	5.1	0.28	25.0	45	14.0	0.15	8.0		0.29	95

Table S1.4. Original surface sediment data used for BSAF estimates - Organic analytes as (ppm or mg/kg dry weight). Data for individual samples from stations with corresponding biota samples. The type of biota sample associated with each sediment station is indicated ("c" for clams, "m" for mussels, "e" for eelgrass, and "f" for fish).

								toc-normalized				
station	biota	f - TOC	TBT	TPAH	PCB cong	PCB aro	PCB hom	TBT	TPAH	PCB cong	PCB aro	PCB hom
			ppm dry	ppm dry	ppm dry	ppm dry	ppm dry	ppm/toc	ppm/toc	ppm/toc	ppm/toc	ppm/toc
NA01	f	0.021	0.21	8.90	0.38	0.63	0.53	10.0	424	18	30	25
NA01	f	0.022	0.22	7.30	0.37	0.58	0.52	10.2	340	17	27	24
NA01	f	0.022	0.099				0.54	4.4				24
NA02	f	0.020	0.082	3.00	0.21	0.29	0.30	4.1	150	10	15	15
NA03	f	0.023	0.18	6.60	0.37	0.58	0.52	7.7	283	16	25	22
NA04	f	0.020	0.3	3.70	0.25	0.43	0.35	14.7	181	12	21	17
NA05	f	0.016	0.11	3.00	0.18	0.24	0.25	6.9	188	11	15	16
NA06	c, f	0.023	0.18	4.70	0.64	1.70	0.90	7.8	203	28	74	39
NA06	c, f	0.021	0.27				0.97	13.1				47
NA07	f	0.020	0.13	5.00	0.46	0.49	0.66	6.6	253	23	25	33
NA07	f	0.021	0.091	28.00	0.53	1.20	0.76	4.4	1366	26	59	37
NA08	f	0.022	0.11	3.80	0.31	0.38	0.43	5.0	174	14	17	20
NA09	f	0.023	0.12	3.00	0.29	0.41	0.41	5.3	133	13	18	18
NA10	f	0.012	0.091	1.90	0.16	0.30	0.23	7.7	161	14	25	19
NA11	c, f	0.017	0.038	3.00	0.19	0.27	0.27	2.2	178	11	16	16
NA12	c, f	0.015	0.08	2.20	0.15	0.22	0.22	5.4	149	10	15	15
NA13	f	0.021	0.069	1.60	0.17	0.24	0.25	3.3	76	8	11	12
NA13	f	0.019	0.067				0.28	3.6				15
NA14	f	0.018	0.045	1.20	0.13	0.21	0.18	2.5	66	7	12	10
NA15	f	0.020	0.67	3.60	0.34	0.48	0.48	34.4	185	17	25	25
NA16	f	0.019	0.19	4.20	0.59	0.66	0.81	10.1	223	31	35	43
NA16	f	0.020	0.17				0.56	8.3				27
NA16	f	0.020	0.15				0.48	7.7				24
NA17	f	0.023	1	4.30	0.55	0.95	0.76	42.9	185	24	41	33
NA17	f	0.022	1.7				0.48	75.9				21
NA18	f	0.020	0.21	2.60	0.35	0.87	0.49	10.3	127	17	43	24
NA19	m, f	0.018	0.57	3.20	0.99	0.60	1.40	31.0	174	54	33	76
NA20	c, e, f	0.014	0.28	3.20	0.12	0.20	0.17	19.7	225	8	14	12
NA21	f	0.022	0.41	2.20	0.18	0.27	0.26	19.1	102	8	13	12
NA22	f	0.017	0.12	4.00	0.18	0.35	0.25	7.3	242	11	21	15
NA23	f	0.022	0.12	3.70		1.10		5.4	167		50	
NA24	m, f	0.021	0.059	2.30	0.29	0.53	0.41	2.8	108	14	25	19
NA25	f	0.012	0.025	1.10	0.08	0.18	0.12	2.0	89	7	15	10
NA26	f	0.012	0.037	0.91	0.18	0.19	0.25	3.0	75	15	16	20
NA27	f	0.020	0.1	3.00	0.21	0.61	0.29	5.0	149	10	30	14
NA28	f	0.019	0.09	3.70	0.18	0.63	0.26	4.8	198	10	34	14
NA29	f	0.017	0.058	2.00	0.19	0.33	0.26	3.4	118	11	19	15
NA30	f	0.014	0.022	1.10	0.10	0.38	0.15	1.6	80	7	28	11
NA31	f	0.009	0.02	0.58	0.07	0.17	0.10	2.2	63	7	18	10

Table SI.4, cont. Original surface sediment data used for BSAF estimates - Organic analytes.

station	biota	f - TOC	TBT	TPAH	PCB cong	PCB aro	PCB hom	toc-normalized TBT	TPAH	PCB cong	PCB aro	PCB hom
			ppm dry	ppm dry	ppm dry	ppm dry	ppm dry	ppm/toc	ppm/toc	ppm/toc	ppm/toc	ppm/toc
SW01	f	0.023	0.52	12.00	1.60	7.10	2.40	23.1	533	71	316	107
SW01	f	0.023	0.38				2.40	16.5				104
SW02	f	0.043	0.22	17.00	5.60	6.80	8.10	5.2	398	131	159	190
SW02	f	0.039	0.31	14.00	5.30	5.80	7.60	7.9	359	136	149	195
SW02	f	0.064	0.069				8.80	1.1				137
SW03	f	0.031	0.053	7.50	0.41	0.78	0.58	1.7	241	13	25	19
SW04	c, f	0.016	2.8	15.00	4.00	3.00	5.80	176.1	943	252	189	365
SW04	c, f	0.030	3.7				4.60	122.9				153
SW05	f	0.016	0.17	17.00	1.20	1.90	1.80	11.0	1097	77	123	116
SW06	f	0.018	0.1	14.00	0.38	1.10	0.58	5.5	769	21	60	32
SW07	f	0.017	0.044	4.10	0.17	0.23	0.23	2.5	237	10	13	13
SW08	c, f	0.034	1.9	29.00	2.10	4.00	3.00	56.7	866	63	119	90
SW08	c, f	0.038	1.8				2.40	47.7				64
SW09	f	0.019	0.91	20.00	0.71	1.50	1.10	46.9	1031	37	77	57
SW10	f	0.012	0.25	25.00	0.61	1.50	0.93	20.7	2066	50	124	77
SW11	f	0.018	0.14	8.50	0.20	0.63	0.28	7.7	470	11	35	15
SW12	f	0.016	0.031	3.30	0.16	0.33	0.22	2.0	209	10	21	14
SW12	f	0.014	0.041				0.24	3.0				18
SW13	c, f	0.023	0.79	14.00	0.49	0.52	0.71	33.9	601	21	22	30
SW14	f	0.021	0.45	9.10	0.40	0.62	0.57	21.1	427	19	29	27
SW15	f	0.023	0.17	8.40	0.38	0.40	0.54	7.4	364	16	17	23
SW16	f	0.022	1.1	6.10	0.43	0.59	0.61	49.1	272	19	26	27
SW17	f	0.025	0.44	11.00	0.54	0.81	0.88	17.4	435	21	32	35
SW18	m, f	0.022	0.13	8.80	0.44	0.38	0.66	5.9	402	20	17	30
SW19	f	0.012	0.037	1.20	0.09	0.21	0.14	3.2	104	8	18	12
SW20	e, f	0.021	0.13	12.00	1.60	3.10	2.60	6.1	561	75	145	121
SW21	c, e, f	0.021	0.17	10.00	2.40	3.40	3.60	8.1	476	114	162	171
SW22	e, f	0.025	0.19	13.00	0.90	1.50	1.40	7.7	528	37	61	57
SW23	e, f	0.025	0.21	12.00	1.00	1.30	1.50	8.3	476	40	52	60
SW24	e, f	0.016	0.17	66.00	0.95	1.70	1.40	10.6	4099	59	106	87
SW24	f	0.021	0.16				1.60	7.8	. . .			78
SW25	f	0.020	0.37	12.00	0.35	0.71	0.51	18.2	591	17	35	25
SW25	f	0.024	0.091				0.49	3.9				21
SW26	f	0.013	0.049	1.70	0.29	0.26	0.42	3.7	130	22	20	32
SW27	m, f	0.021	0.25	14.00	0.20	0.39	0.32	12.0	673	10	19	15
SW28	c, f	0.025	0.18	22.00	2.10	3.70	3.00	7.1	870	83	146	119
SW28	c, f	0.026	0.12				2.20	4.6				85
SW29	f	0.013	0.19	4.90	0.82	3.10	1.20	14.2	366	61	231	90
SW30	f	0.021	0.2	5.20	0.38	0.62	0.54	9.8	254	19	30	26
SW31	f	0.007	0.036	1.30	0.07	0.14	0.09	5.5	197	10	21	14
SW32	f	0.016	0.03	0.90	0.16	0.26	0.23	1.9	58	10	17	15
SW33	f	0.021	0.019	1.10	0.10	0.23	0.15	0.9	53	5	11	7
SW34	f	0.017	0.038	1.50	0.13	0.29	0.18	2.3	89	8	17	11
SW36	f	0.022	0.049		0.20	0.32	0.28	2.2	0	9	14	13

Table SI.4, cont. Original surface sediment data used for BSAF estimates - Organic analytes.

station	biota	f - TOC	TBT	TPAH	PCB cong	PCB aro	PCB hom	toc-normalized TBT	TPAH	PCB cong	PCB aro	PCB hom
			ppm dry	ppm dry	ppm dry	ppm dry	ppm dry	ppm/toc	ppm/toc	ppm/toc	ppm/toc	ppm/toc
2231	c	0.013	0.015	0.69	0.08	0.38	0.12	1.2	53	6	29	9
2231	c	0.013	0.011	0.63	0.07	0.15	0.10	0.9	50	5	12	8
2240	m, e, f	0.011	0.0028	0.36	0.06	0.13	0.09	0.3	33	6	12	8
2241	f	0.003	0.0019	0.13	0.01	0.02	0.02	0.8	52	6	7	8
2243	c, f	0.005	0.0026	0.21	0.02	0.02	0.03	0.5	41	5	5	6
2243	c, f	0.006	0.0026	0.21	0.04	0.06	0.05	0.4	33	6	9	8
2244	f	0.006	0.0026	0.22	0.03	0.05	0.04	0.5	40	5	10	6
2244	f	0.005	0.0035	0.14	0.02	0.05	0.03	0.7	27	5	10	6
2433	c	0.007	0.0033	0.49	0.02	0.04	0.03	0.5	73	3	6	5
2433	c	0.007	0.0059	0.38	0.03	0.07	0.04	0.9	55	4	10	5
2440	c	0.016	0.031	3.10	0.13	0.28	0.18	1.9	191	8	17	11
2440	c	0.011	0.039	3.20	0.09	0.25	0.13	3.6	299	9	23	12
2441	c	0.011	0.0037	0.35	0.01	0.02	0.02	0.3	32	1	2	1
2441	c	0.013	0.0031	0.86	0.02	0.03	0.02	0.2	67	1	2	2

Table SI.5. Original data for individual bivalve samples - inorganics.
Contaminant levels in samples of soft tissues from clams (c) and mussels (m), as parts per million (ppm or mg/kg) dry weight (ppm wet / f-solids).

Station	bivalve	f- solids	As	Cd	Cr	Cu	Pb	Hg	Ni	Se	Ag	Zn
			ppm dry	ppm dry	ppm dry	ppm dry	ppm dry	ppm dry	ppm dry	ppm dry	ppm dry	ppm dry
NA06	c	0.147	20.4	0.218	2.24	15.65	4.35	0.109	2.59	2.72	0.259	116
NA06	c	0.151	17.2	0.219	2.25	14.57	5.43	0.093	2.45	1.32	0.344	119
NA06	c	0.128	21.1	0.438	2.27	17.97	3.91	0.125	2.66	2.34	0.414	164
NA06	c	0.159	18.9	0.233	2.39	15.09	3.33	0.164	2.96	1.89	0.189	113
NA06	c	0.167	19.8	0.305	1.50	13.77	3.47	0.108	2.22	1.80	0.156	144
NA11	c	0.155	20.6	0.232	1.68	10.32	2.39	0.077	2.52	1.94	0.329	97
NA11	c	0.148	17.6	0.189	1.55	12.16	1.89	0.095	1.82	1.35	0.277	108
NA11	c	0.131	21.4	0.191	1.37	12.21	2.29	0.130	2.14	2.29	0.321	107
NA11	c	0.155	23.9	0.335	2.19	16.77	3.42	0.116	2.52	2.58	0.465	129
NA11	c	0.147	17.7	0.367	2.45	12.93	3.33	0.109	2.45	1.36	0.252	122
NA12	c	0.14	20.0	0.143	1.43	12.14	2.14	0.143	2.29	2.86	0.143	86
NA12	c	0.132	19.7	0.273	1.97	15.15	2.35	0.114	2.73	2.27	0.235	129
NA12	c	0.152	17.1	0.204	1.71	9.87	1.97	0.086	1.97	1.32	0.178	112
NA12	c	0.147	19.7	0.238	2.18	11.56	2.52	0.095	2.52	2.72	0.211	116
NA12	c	0.142	18.3	0.197	1.34	16.90	2.68	0.099	2.04	1.41	0.352	127
NA19	m	0.197	15.2	0.376	6.09	81.22	6.60	0.122	9.64	3.05	0.609	102
NA20	c	0.162	18.5	0.179	1.54	10.49	2.53	0.105	2.59	1.85	0.136	117
NA20	c	0.136	16.2	0.169	1.99	11.76	2.79	0.125	2.50	1.47	0.140	110
NA20	c	0.158	20.3	0.222	2.34	12.66	3.48	0.133	3.16	1.27	0.139	114
NA20	c	0.147	17.0	0.197	2.04	9.52	2.52	0.116	2.59	1.36	0.150	109
NA24	m	0.2	15.0	0.310	2.70	48.50	4.55	0.100	5.50	3.50	0.430	80
SW04	c	0.146	26.0	0.295	5.21	55.48	13.01	0.158	3.29	2.05	0.397	315
SW04	c	0.142	26.8	0.387	3.45	35.21	11.97	0.148	4.44	1.41	0.204	218
SW04	c	0.152	20.4	0.243	3.49	26.32	8.55	0.125	2.30	1.32	0.224	178
SW04	c	0.153	23.5	0.203	1.18	16.99	4.58	0.105	2.42	1.31	0.183	124
SW04	c	0.149	24.2	0.181	2.82	30.87	7.38	0.128	2.55	2.01	0.161	141
SW08	c	0.148	17.6	0.149	2.23	21.62	5.41	0.176	1.96	1.35	0.108	101
SW08	c	0.12	23.3	0.242	2.92	26.67	11.67	0.133	2.42	nd	0.283	117
SW08	c	0.148	18.9	0.236	3.58	17.57	4.05	0.122	2.91	2.03	0.135	115
SW08	c	0.157	19.1	0.236	1.91	20.38	4.20	0.108	2.36	1.27	0.261	121
SW08	c	0.138	18.8	0.217	2.25	31.16	5.43	0.123	2.17	1.45	0.486	101
SW13	c	0.12	20.8	0.267	2.17	20.83	2.92	0.108	2.92	1.67	0.358	142
SW13	c	0.158	22.8	0.285	1.96	35.44	2.53	0.089	2.78	3.16	0.487	152
SW13	c	0.163	19.0	0.190	1.84	19.63	2.64	0.110	2.52	1.84	0.172	153
SW13	c	0.14	15.0	0.179	2.93	30.00	2.50	0.093	2.43	1.43	0.193	114
SW13	c	0.151	19.2	0.179	1.92	19.21	2.19	0.106	2.25	1.32	0.252	93
SW18	m	0.148	17.6	0.446	2.57	52.03	4.32	0.115	3.99	4.05	0.554	108
SW21	c	0.157	19.7	0.210	2.04	15.29	2.93	0.102	2.29	1.27	0.338	115
SW21	c	0.146	21.2	0.253	2.19	13.70	3.63	0.116	2.12	1.37	0.267	123
SW21	c	0.164	22.6	0.323	2.13	14.63	4.21	0.104	2.50	1.83	0.372	146
SW21	c	0.148	19.6	0.284	2.30	14.86	3.92	0.115	2.43	2.03	0.338	122
SW21	c	0.128	20.3	0.297	4.69	24.22	7.03	0.094	2.89	3.13	0.422	148

Table SI.5, cont. Original data for individual bivalve samples - Inorganics.

Station	bivalve	f-solids	As	Cd	Cr	Cu	Pb	Hg	Ni	Se	Ag	Zn
			ppm dry	ppm dry	ppm dry	ppm dry	ppm dry	ppm dry	ppm dry	ppm dry	ppm dry	ppm dry
SW27	m	0.187	15.5	0.326	2.67	44.39	4.33	0.096	3.69	3.74	0.439	96
SW28	c	0.157	17.8	0.229	1.27	11.46	2.23	0.121	2.55	1.27	0.178	115
SW28	c	0.143	18.9	0.196	1.26	11.19	2.73	0.119	2.24	nd	0.140	105
SW28	c	0.155	21.3	0.232	1.61	14.19	2.90	0.129	2.45	2.58	0.245	142
SW28	c	0.163	21.5	0.325	1.84	16.56	3.13	0.092	2.94	1.84	0.319	153
SW28	c	0.155	20.0	0.219	1.74	14.19	2.90	0.103	2.26	1.29	0.252	110
2231	c	0.152	20.4	0.211	2.11	9.21	1.58	0.145	2.04	1.97	0.145	99
2231	c	0.158	17.1	0.209	1.08	10.13	1.58	0.146	1.84	1.27	0.146	114
2231	c	0.153	18.3	0.144	1.37	7.84	1.63	0.131	2.42	1.31	0.137	92
2231	c	0.145	18.6	0.324	0.55	7.59	1.79	0.131	1.93	1.38	0.110	138
2231	c	0.165	20.6	0.188	1.88	9.70	1.82	0.164	2.00	1.82	0.206	103
2240	m	0.178	9.6	0.292	4.33	24.72	2.98	0.073	3.43	3.65	0.472	73
2243	c	0.138	16.7	0.181	2.25	9.42	2.39	0.130	2.32	1.45	0.275	109
2243	c	0.151	21.2	0.185	1.72	12.58	1.52	0.113	2.19	1.32	0.232	113
2243	c	0.143	21.7	0.196	2.10	13.99	2.03	0.126	3.01	2.80	0.231	105
2243	c	0.167	18.0	0.174	1.74	7.78	1.56	0.108	1.92	1.20	0.138	108
2243	c	0.158	24.1	0.253	2.47	14.56	2.53	0.089	2.78	1.27	0.411	114
2433	c	0.153	18.3	0.255	2.48	9.80	1.83	0.092	2.88	1.31	0.275	105
2433	c	0.158	17.7	0.241	1.90	9.49	1.58	0.082	2.78	1.27	0.234	95
2433	c	0.145	20.0	0.276	2.48	9.66	1.59	0.076	2.90	1.38	0.283	117
2433	c	0.148	18.9	0.216	2.36	12.16	1.76	0.061	2.50	1.35	0.345	88
2433	c	0.131	20.6	0.260	2.82	11.45	2.82	0.084	3.44	2.29	0.328	107
2440	c	0.131	19.8	0.206	3.66	12.21	3.82	0.145	3.44	3.05	0.282	107
2440	c	0.15	16.7	0.153	1.73	8.00	6.67	0.120	2.20	1.33	0.133	87
2440	c	0.112	19.6	0.223	1.70	10.71	3.39	0.134	2.68	2.68	0.223	116
2440	c	0.145	17.2	0.193	1.66	8.97	3.59	0.131	2.62	1.38	0.117	117
2440	c	0.136	17.6	0.213	1.99	12.50	3.82	0.103	2.79	1.47	0.485	125
2441	c	0.125	21.6	0.392	3.28	18.40	2.40	0.072	3.84	1.60	0.480	120
2441	c	0.125	20.8	0.376	3.52	19.20	2.24	0.080	4.64	nd	0.464	112
2441	c	0.124	21.0	0.484	2.82	21.77	2.26	0.081	3.55	0.81	0.540	137
2441	c	0.125	21.6	0.456	3.20	21.60	2.56	0.096	4.00	1.60	0.576	120
2441	c	0.132	20.5	0.402	3.03	20.45	2.73	0.091	3.56	0.76	0.492	152

Table SI.6. Original data for individual bivalve samples - Organics.

Contaminant levels in samples of soft tissues from clams (c) and mussels (m), as parts per million (ppm or mg/kg) dry weight (ppm wet / f-solids) and as lipid-normalized concentration (ppm dry / f-lipid dry).

Station	biota	f- solids	f - lipid dry	TBT ppm dry	TPAH ppm dry	PCB-Aro ppm dry	PCB-cong ppm dry	PCB-hom ppm dry	TBT/lipid ppm dry/lipid	TPAH/lipid ppm dry/lipid	PCB-aro/lipid ppm dry/lipid	PCB-cong/lipid ppm dry/lipid	PCB-hom/lipid ppm dry/lipid
NA06	c	0.147	0.035	0.109	1.701	0.449	0.374	0.544	3.08	48.08	12.69	10.58	15.38
NA06	c	0.151	0.028	0.212	1.788	0.457	0.265	0.384	7.44	62.79	16.05	9.30	13.49
NA06	c	0.128	0.023	0.242	1.484	0.516	0.156	0.219	10.69	65.52	22.76	6.90	9.66
NA06	c	0.159	0.045	0.239	2.013	0.579	0.434	0.629	5.35	45.07	12.96	9.72	14.08
NA06	c	0.167	0.037	0.246	1.916	0.575	0.347	0.497	6.61	51.61	15.48	9.35	13.39
NA11	c	0.155	0.039	0.097	1.290	0.303	0.174	0.245	2.46	32.79	7.70	4.43	6.23
NA11	c	0.148	0.036	0.074	1.554	0.331	0.162	0.223	2.08	43.40	9.25	4.53	6.23
NA11	c	0.131	0.021	0.092	1.298	0.282	0.168	0.237	4.29	60.71	13.21	7.86	11.07
NA11	c	0.155	0.031	0.123	1.484	0.355	0.181	0.258	3.96	47.92	11.46	5.83	8.33
NA11	c	0.147	0.041	0.082	1.429	0.313	0.177	0.259	1.97	34.43	7.54	4.26	6.23
NA12	c	0.14	0.036	0.129	1.714	0.157	0.114	0.157	3.53	47.06	4.31	3.14	4.31
NA12	c	0.132	0.032	0.114	1.667	0.167	0.114	0.159	3.57	52.38	5.24	3.57	5.00
NA12	c	0.152	0.030	0.086	1.579	0.230	0.112	0.158	2.89	53.33	7.78	3.78	5.33
NA12	c	0.147	0.035	0.129	1.701	0.333	0.156	0.218	3.73	49.02	9.61	4.51	6.27
NA12	c	0.142	0.041	0.062	1.761	0.218	0.120	0.162	1.52	43.10	5.34	2.93	3.97
NA19	m	0.197	0.061	0.477	1.269	0.508	0.426	0.558	7.83	20.83	8.33	7.00	9.17
NA20	c	0.162	0.033	0.136	3.086	0.210	0.148	0.216	4.15	94.34	6.42	4.53	6.60
NA20	c	0.136	0.036	0.191	1.985	0.213	0.125	0.176	5.31	55.10	5.92	3.47	4.90
NA20	c	0.158	0.029	0.171	2.848	0.253	0.082	0.120	5.87	97.83	8.70	2.83	4.13
NA20	c	0.147	0.029	0.109	2.789	0.170	0.150	0.211	3.81	97.62	5.95	5.24	7.38
NA24	m	0.2	0.075	0.375	2.300	0.700	0.550	0.750	5.00	30.67	9.33	7.33	10.00

Table SI.6, cont. Original data for individual bivalve samples - Organics.

Station	biota	f- solids	f - lipid dry	TBT ppm dry	TPAH ppm dry	PCB-Aro ppm dry	PCB-cong ppm dry	PCB-hom ppm dry	TBT/lipid ppm dry/lipid	TPAH/lipid ppm dry/lipid	PCB-aro/lipid ppm dry/lipid	PCB-cong/lipid ppm dry/lipid	PCB-hom/lipid ppm dry/lipid
SW04	c	0.146	0.038	2.260	10.959	1.507	1.370	1.986	58.93	285.71	39.29	35.71	51.79
SW04	c	0.142	0.042	5.211	11.268	1.549	1.127	1.690	125.42	271.19	37.29	27.12	40.68
SW04	c	0.152	0.044	2.763	10.526	1.513	0.099	0.125	62.69	238.81	34.33	2.24	2.84
SW04	c	0.153	0.040	0.980	9.804	1.176	0.915	1.307	24.59	245.90	29.51	22.95	32.79
SW04	c	0.149	0.044	0.101	14.094	1.544	1.342	2.013	2.27	318.18	34.85	30.30	45.45
SW08	c	0.148	0.028	0.811	9.459	1.284	0.676	1.014	28.57	333.33	45.24	23.81	35.71
SW08	c	0.12	0.038	1.750	10.000	0.917	0.817	1.167	46.67	266.67	24.44	21.78	31.11
SW08	c	0.148	0.032	0.743	10.135	1.149	0.581	0.878	23.40	319.15	36.17	18.30	27.66
SW08	c	0.157	0.030	1.146	10.828	1.146	0.828	1.274	38.30	361.70	38.30	27.66	42.55
SW08	c	0.138	0.036	0.870	8.696	1.087	0.652	0.942	24.49	244.90	30.61	18.37	26.53
SW13	c	0.12	0.034	1.000	6.417	0.200	0.192	0.283	29.27	187.80	5.85	5.61	8.29
SW13	c	0.158	0.032	0.886	6.962	0.570	0.177	0.253	28.00	220.00	18.00	5.60	8.00
SW13	c	0.163	0.038	0.920	6.135	0.491	0.264	0.393	24.19	161.29	12.90	6.94	10.32
SW13	c	0.14	0.027	0.664	6.643	0.607	1.286	1.929	24.47	244.74	22.37	47.37	71.05
SW13	c	0.151	0.035	0.795	7.947	0.543	0.232	0.344	22.64	226.42	15.47	6.60	9.81
SW18	m	0.148	0.088	0.554	4.797	0.946	0.676	0.946	6.31	54.62	10.77	7.69	10.77
SW21	c	0.157	0.023	0.083	7.643	1.529	0.892	1.529	3.61	333.33	66.67	38.89	66.67
SW21	c	0.146	0.036	0.096	7.534	2.055	1.164	2.055	2.69	211.54	57.69	32.69	57.69
SW21	c	0.164	0.038	0.098	6.098	1.646	1.037	1.768	2.58	161.29	43.55	27.42	46.77
SW21	c	0.148	0.036	0.101	6.757	1.892	1.149	1.892	2.83	188.68	52.83	32.08	52.83
SW21	c	0.128	0.037	0.188	5.625	1.797	0.859	1.406	5.11	153.19	48.94	23.40	38.30
SW27	m	0.187	0.091	0.503	4.973	0.802	0.642	0.909	5.53	54.71	8.82	7.06	10.00
SW28	c	0.157	0.032	0.096	7.006	1.338	0.828	1.146	3.00	220.00	42.00	26.00	36.00
SW28	c	0.143	0.029	0.070	6.853	1.469	0.839	1.189	2.38	233.33	50.00	28.57	40.48
SW28	c	0.155	0.041	0.103	6.452	1.548	0.903	1.290	2.54	158.73	38.10	22.22	31.75
SW28	c	0.163	0.032	0.067	7.975	1.595	0.613	0.859	2.12	250.00	50.00	19.23	26.92
SW28	c	0.155	0.035	0.084	6.452	1.355	0.774	1.097	2.41	185.19	38.89	22.22	31.48

Table SI.6, cont. Original data for individual bivalve samples - Organics.

Station	biota	f- solids	f - lipid dry	TBT ppm dry	TPAH ppm dry	PCB-Aro ppm dry	PCB-cong ppm dry	PCB-hom ppm dry	TBT/lipid ppm dry/lipid	TPAH/lipid ppm dry/lipid	PCB-aro/lipid ppm dry/lipid	PCB-cong/lipid ppm dry/lipid	PCB-hom/lipid ppm dry/lipid
2231	c	0.152	0.041	0.023	0.724	0.138	0.099	0.138	0.56	17.74	3.39	2.42	3.39
2231	c	0.158	0.038	0.028	0.614	0.203	0.108	0.139	0.73	16.17	5.33	2.83	3.67
2231	c	0.153	0.026	0.017	0.784	0.150	0.078	0.105	0.65	30.00	5.75	3.00	4.00
2231	c	0.145	0.043	0.021	0.690	0.159	0.083	0.110	0.50	16.13	3.71	1.94	2.58
2231	c	0.165	0.030	0.027	0.606	0.115	0.067	0.091	0.92	20.41	3.88	2.24	3.06
2240	m	0.178	0.084	0.146	0.787	0.730	0.360	0.478	1.73	9.33	8.67	4.27	5.67
2243	c	0.138	0.019	0.021	0.652	0.167	0.101	0.130	1.12	34.62	8.85	5.38	6.92
2243	c	0.151	0.029	0.012	nd	0.199	0.106	0.139	0.41	nd	6.82	3.64	4.77
2243	c	0.143	0.035	0.032	0.455	0.126	0.105	0.133	0.92	13.00	3.60	3.00	3.80
2243	c	0.167	0.026	0.022	nd	0.168	0.003	0.003	0.84	nd	6.51	0.10	0.13
2243	c	0.158	0.034	0.008	nd	0.133	0.095	0.127	0.24	nd	3.89	2.78	3.70
2433	c	0.153	0.029	0.016	0.784	0.203	0.072	0.098	0.55	27.27	7.05	2.50	3.41
2433	c	0.158	0.023	0.023	0.759	0.177	0.089	0.120	1.00	32.43	7.57	3.78	5.14
2433	c	0.145	0.027	0.026	0.828	0.124	0.069	0.097	0.95	30.77	4.62	2.56	3.59
2433	c	0.148	0.028	0.024	0.743	0.142	0.088	0.128	0.86	26.19	5.00	3.10	4.52
2433	c	0.131	0.032	0.037	0.626	0.145	0.092	0.122	1.14	19.52	4.52	2.86	3.81
2440	c	0.131	0.028	0.107	5.038	0.374	0.244	0.366	3.78	178.38	13.24	8.65	12.97
2440	c	0.15	0.037	0.067	4.333	0.253	0.147	0.213	1.79	116.07	6.79	3.93	5.71
2440	c	0.112	0.036	0.125	4.554	0.286	0.143	0.196	3.50	127.50	8.00	4.00	5.50
2440	c	0.145	0.043	0.066	5.103	0.297	0.145	0.207	1.55	119.35	6.94	3.39	4.84
2440	c	0.136	0.033	0.088	5.000	0.272	0.154	0.213	2.67	151.11	8.22	4.67	6.44
2441	c	0.125	0.035	0.018	3.760	0.080	0.040	0.053	0.50	106.82	2.27	1.14	1.50
2441	c	0.125	0.030	0.012	0.512	nd	0.040	0.053	0.41	17.30	nd	1.35	1.78
2441	c	0.124	0.031	nd	2.339	nd	0.039	0.051	nd	74.36	nd	1.23	1.62
2441	c	0.125	0.034	0.012	0.800	nd	0.045	0.058	0.36	23.81	nd	1.33	1.74
2441	c	0.132	0.032	0.019	0.985	nd	0.033	0.042	0.60	30.95	nd	1.02	1.33

Table SI.7. Original tissue data for sand bass and eelgrass BSAFs - Inorganics.
Data for individual tissue samples as parts per million (ppm or mg/kg) dry weight (ppm wet / f- solids).

Sand bass whole bodies

Study area	f-solids	As	Cd	Cr	Cu	Pb	Hg	Ni	Se	Ag	Zn
		ppm dry	ppm dry	ppm dry	ppm dry	ppm dry	ppm dry	ppm dry	ppm dry	ppm dry	ppm dry
Reference	0.269	1.49	0.074	-	7.06	0.33	0.45	0.89	-	0.026	60
	0.256	1.56	0.117	-	2.89	0.15	0.27	0.82	-	0.031	55
	0.317	1.58	nd	-	2.97	0.50	0.44	0.91	-	0.032	54
	0.253	1.98	0.079	-	1.70	0.26	0.63	0.87	-	-	55
	0.293	1.71	-	-	2.32	0.30	0.34	0.92	-	-	44
NASSCO 1	0.256	1.56	-	-	2.27	0.55	0.47	0.78	1.17	-	47
	0.259	1.54	-	-	3.09	0.81	0.58	0.73	1.54	-	39
	0.238	2.52	0.084	-	8.82	0.59	0.76	1.05	1.68	0.084	67
	0.254	1.97	-	-	2.72	1.02	0.63	1.14	2.36	-	51
	0.243	2.06	-	-	3.00	0.74	0.70	1.23	2.06	-	62
NASSCO 2	0.251	3.59	0.080	-	9.56	1.83	0.80	1.31	1.20	0.096	60
	0.263	2.66	0.076	2.662	3.08	0.46	0.46	1.67	1.90	0.030	53
	0.318	2.20	0.063	-	1.89	0.47	0.54	0.63	1.26	0.069	44
	0.254	2.36	0.079	-	3.94	0.79	0.39	1.26	1.18	0.067	87
	0.25	2.80	nd	-	4.80	0.68	0.68	0.80	2.40	0.044	60
SWM 1	0.27	2.22	0.074	-	4.44	0.59	0.34	1.26	3.70	-	56
	0.244	2.05	0.164	-	2.21	0.98	0.57	0.82	2.87	-	53
	0.234	2.56	0.085	-	3.68	1.24	0.56	0.98	2.14	0.026	47
	0.252	2.38	0.079	1.587	7.54	1.35	0.68	1.31	1.98	0.044	64
	0.224	2.23	0.134	-	27.23	0.76	0.49	1.21	1.79	0.085	80
SWM 2	0.237	3.38	0.084	-	4.21	0.39	0.72	1.39	1.27	0.042	55
	0.241	2.07	0.041	-	4.98	0.62	0.54	0.87	-	0.046	46
	0.264	2.27	0.000	-	3.67	0.38	0.38	0.61	1.14	0.042	46
	0.285	2.81	0.070	-	11.58	0.74	0.49	0.74	1.05	0.144	46
	0.292	2.05	0.068	-	7.19	1.27	0.58	1.20	-	0.065	51

Eelgrass

Study area	f-solids	As	Cd	Cr	Cu	Pb	Hg	Ni	Se	Ag	Zn
		ppm dry	ppm dry	ppm dry	ppm dry	ppm dry	ppm dry	ppm dry	ppm dry	ppm dry	ppm dry
Reference	0.168	2.38	0.423	2.38	32	4.52	nd	2.80	-	0.77	173
NASSCO 1	0.155	3.87	0.774	9.68	194	19.35	0.129	3.87	-	1.61	348
SWM 1	0.155	5.48	0.774	18.06	206	24.52	0.258	6.45	-	1.48	355

Table SI.8. Original tissue data for sand bass and eelgrass BSAFs - Organics. Data for individual tissue samples as parts per million (ppm or mg/kg) dry weight (ppm wet / f- solids), as well as lipid-normalized (ppm dry / f-lipid dry).

Sand bass whole bodies

Location	f-solids	f-lipid	TBT	PCB-hom	PCB-aro	PCB-con	TPAH	TBT	PCB-hom	PCB-aro	PCB-con	TPAH
		dry	ppm dry	ppm dry	ppm dry	ppm dry	ppm dry	ppm/lipid	ppm/lipid	ppm/lipid	ppm/lipid	ppm/lipid
Reference	0.269	0.041	0.082	1.71	1.45	1.49	-	2.00	41.8	35.5	36.4	-
	0.256	0.059	0.034	1.84	1.13	1.60	-	0.59	31.3	19.3	27.3	-
	0.317	0.069	0.030	2.02	1.48	1.70	-	0.44	29.1	21.4	24.5	-
	0.253	0.075	0.024	1.78	1.15	1.50	-	0.32	23.7	15.3	20.0	-
	0.293	0.075	0.033	2.90	1.91	2.46	-	0.44	38.6	25.5	32.7	-
NASSCO 1	0.256	0.125	0.021	5.08	2.38	4.30	-	0.17	40.6	19.1	34.4	-
	0.259	0.054	0.042	5.41	8.11	4.63	-	0.79	100.0	150.0	85.7	-
	0.238	0.038	0.046	1.72	2.90	1.51	-	1.22	45.6	76.7	40.0	-
	0.254	0.071	0.146	3.31	2.87	2.87	-	2.06	46.7	40.6	40.6	-
	0.243	0.058	0.160	1.93	2.55	1.69	-	2.79	33.6	44.3	29.3	-
NASSCO 2	0.251	0.036	0.135	2.99	1.99	2.59	-	3.78	83.3	55.6	72.2	-
	0.263	0.068	0.209	2.43	2.13	2.05	-	3.06	35.6	31.1	30.0	-
	0.318	0.044	0.101	2.04	1.89	1.76	-	2.29	46.4	42.9	40.0	-
	0.254	0.016	0.213	1.54	0.94	1.30	-	13.50	97.5	60.0	82.5	-
	0.25	0.040	0.148	2.96	1.60	2.56	-	3.70	74.0	40.0	64.0	-
SWM 1	0.27	0.148	0.032	1.93	2.07	1.63	-	0.22	13.0	14.0	11.0	-
	0.244	0.033	0.258	1.07	1.68	0.94	-	7.88	32.5	51.3	28.8	-
	0.234	0.085	0.141	2.74	5.56	2.31	-	1.65	32.0	65.0	27.0	-
	0.252	0.103	0.063	3.02	2.78	2.54	-	0.62	29.2	26.9	24.6	-
	0.224	0.063	0.152	1.61	8.04	1.34	-	2.43	25.7	128.6	21.4	-
SWM 2	0.237	0.093	0.101	1.81	2.36	1.56	-	1.09	19.5	25.5	16.8	-
	0.241	0.041	0.087	3.65	4.02	3.11	-	2.10	88.0	97.0	75.0	-
	0.264	0.072	0.182	3.26	2.58	2.77	-	2.53	45.3	35.8	38.4	-
	0.285	0.077	0.123	2.04	1.72	1.68	-	1.59	26.4	22.3	21.8	-
	0.292	0.034	0.137	1.58	1.44	1.34	-	4.00	46.0	42.0	39.0	-
Eelgrass data												
Reference	0.168	<0.006	-	0.021	0.030	0.016	-					
NASSCO 1	0.155	<0.006	-	0.103	0.048	0.071	0.903					
SWM 1	0.155	<0.006	0.02	0.071	0.123	0.052	2.645					

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Wildlife Risk-Based Sediment Screening Levels for the Shipyard Sediment Site

The Carlsbad Fish and Wildlife Office (CFWO) prepared Technical Memorandum CFWO-EC-TM-04-01 to assist CFWO staff in identifying sites in San Diego Bay that may pose a potential risk to Fish and Wildlife Service trust resources due to the presence of pollutants in sediments (provided in the Appendix for Section 34). The Technical Memorandum presents the results of initial efforts by CFWO to develop risk-based screening levels for San Diego Bay sediments including details on the process and data used to develop the levels. While the Regional Board clearly understands that these levels are intended for screening purposes only, the 7-step process used by CFWO in deriving the levels is considered applicable for development of site-specific, risk-based sediment screening levels for the Shipyard Sediment Site.

Based on the Tier II wildlife risk assessment results, as discussed in Section 25, the Regional Board determined that ingestion of prey caught within all four assessment units at the Shipyard Sediment Site poses a theoretical risk to the aquatic-dependent wildlife receptors of concern (excluding the sea lion). The chemicals in prey tissue posing a risk include benzo[a]pyrene (BAP), total polychlorinated biphenyls (PCBs), copper, lead, mercury, and zinc. Risk-based sediment screening levels for the Shipyard Sediment Site were developed for these contaminants using CFWO's 7-step process.

Step 1 – Identify receptors of concern.

As discussed in Section 25, fish-eating marine birds and mammals, mollusk-eating birds, and sea grass-eating reptiles were identified as important groups of aquatic-dependent wildlife that could be at risk due to exposure to chemicals in prey species at the Shipyard Sediment Site (Exponent, 2003). Six species have been identified as suitable representative receptors for assessing potential risk to these groups as approved by the Natural Resource Trustee Agencies (U.S. Fish and Wildlife, Department of Fish and Game, and National Oceanic and Atmospheric Administration). The six species are shown below. These receptors were selected based on characteristics such as their presence at the site, feeding habits, known adverse effects from exposure to bioaccumulative contaminants, the availability of ample life history information in the literature, and federal or state listings of species as threatened or endangered.

Receptor	Scientific Name	Representative of	Comments
California least tern	*Sterna antillarum brownie*	Marine birds that may feed on small fish	Federal and California listed endangered species
California brown pelican	*Pelecanus occidentalis californicus*	Marine birds that may feed on small- to medium-sized fish	Federal and California listed endangered species
Western grebe	*Aechmophorus occidentalis*	Diving marine birds that may feed on small fish	
Surf scoter	*Melanitta perspicillata*	Diving marine birds that may feed on mollusks	
California sea lion	*Zalophus californianus*	Marine mammals that may feed on medium-sized fish	
East Pacific green turtle	*Chelonia mydas agassizii*	Marine reptiles that may feed on sea grasses	Listed as threatened wherever found and listed as endangered in Florida and on the Pacific coast of Mexico

Step 2 – Identify basic approaches for developing sediment cleanup levels.

Combine benchmark toxicity values (i.e., daily contaminant dose rates, mg/kg-day) with literature-based exposure factors to establish contaminant concentrations in the receptor's diet (mg/kg in the diet). Then, use locally-derived (i.e., Shipyard Sediment Site) biota-to-sediment accumulation factors (BSAFs) to back-calculate from the contaminant concentration in the diet to a corresponding cleanup level in sediment.

Step 3 - Develop equations for calculating cleanup levels.

For organics:

$$ppm_{sed} = TRV / [(\text{sediment ingestion rate}) + (BSAF)(\text{f-lipid/f-toc})(\text{food ingestion rate})$$

For inorganics (and organics for herbivorous receptors):

$$ppm_{sed} = TRV / [(\text{sediment ingestion rate}) + (BSAF)(\text{food ingestion rate})$$

Step 4 – Identify literature-based benchmark toxicity values.

The TRVs that were used to calculate the sediment screening levels are those presented in Technical Memorandum CFWO-EC-TM-04-01.

Chemical	Birds		Mammals	
	Low TRV (mg/kg-day)	High TRV (mg/kg-day)	Low TRV (mg/kg-day)	High TRV (mg/kg-day)
Copper	2.3	52.3	2.67	632
Lead	0.014	8.75	1.0	241
Mercury	0.007 (n*), 0.021 (p*)	0.018	0.018*	0.27
Zinc	17.2	172	9.6	411
Benzo[a]pyrene	--	--	1.31	32.8
PCBs	0.09	1.27	0.36	1.28

* TRV-L is substituted with NOAELs derived from the same studies as those used by EPA Region 9 BTAG, but using different uncertainty factors to address concerns about Service trust resources. The NOAELs are recommended by USFWS (Zeeman, 2003). Two values are recommended for avian receptors, one for piscivorous birds (p), such as terns and pelicans, and the other for non-piscivorous birds (n) such as scoter.

Step 5 – Select literature-based wildlife exposure factors.

Sediment screening levels are computed using equations that incorporate assumptions about how much food and sediment each species ingests per day from the area of concern. The following food ingestion and sediment ingestion rates are those presented in Technical Memorandum CFWO-EC-TM-04-01.

Receptor	Food Ingestion Rate (kg_{food}/kg_{BW}-d) dry weight	Sediment Ingestion Rate (kg_{sed}/kg_{BW}-d) dry weight
Surf Scoter	0.0757	0.0038
Western Grebe	0.0743	0.0037
Least Tern	0.2492	0.0050
Brown Pelican	0.0812	0.0016
Sea Lion	0.0238	0.00048
Green Turtle	0.0047	0.00024

Step 6 – Derive biota-to-sediment accumulation factors (BSAFs) for sediments from the Shipyard Sediment Site.

The following NASSCO and Southwest Marine BSAFs are those presented in Attachment B of Technical Memorandum CFWO-EC-TM-04-01. Bivalve BSAFs are provided in Tables B6 and B7, demersal fish BSAFs are provided in Table B10, and eelgrass BSAFs are provided in Table B13.

Bivalve BSAFs for inorganic analytes ($kg_{sediment}/kg_{tissue}$)

	Cu	Pb	Hg	Zn
NASSCO mean	0.14	0.05	0.19	0.42
SWM mean	0.09	0.03	0.11	0.28
SY Sediment Site mean	0.12	0.04	0.15	0.35

Bivalve BSAFs for organic analytes (kg_{toc}/kg_{lipid})

	f-lipid/f-toc	TPAH	PCB Congeners	PCB Aroclors	PCB Homologs
NASSCO mean	2.50	0.27	0.38	0.40	0.37
SWM mean	2.21	0.27	0.40	0.41	0.42
SY Sediment Site mean	2.355	0.27	0.39	0.405	0.395

Demersal fish BSAFs for inorganic analytes ($kg_{sediment}/kg_{tissue}$)

	Cu	Pb	Hg	Zn
NASSCO mean	0.019	0.009	0.660	0.194
SWM mean	0.021	0.007	0.427	0.109
SY Sediment Site mean	0.02	0.008	0.5435	0.1515

Demersal fish BSAFs for organic analytes (kg_{toc}/kg_{lipid})

	f-lipid/f-toc	TPAH	PCB Congeners	PCB Aroclors	PCB Homologs
NASSCO mean	2.902	--	3.379	2.144	2.689
SWM mean	3.154	--	0.690	0.688	0.526
SY Sediment Site mean	3.028	--	2.0345	1.416	1.6075

Eelgrass BSAFs for inorganic analytes ($kg_{sediment}/kg_{tissue}$)

	Cu	Pb	Hg	Zn
NASSCO mean	2.016	0.365	0.538	1.834
SWM mean	0.733	0.235	0.187	1.086
SY Sediment Site mean	1.3745	0.3	0.3625	1.46

Eelgrass BSAFs for organic analytes (kg_{toc}/kg_{lipid})

	f-lipid/f-toc	TPAH	PCB Congeners	PCB Aroclors	PCB Homologs
NASSCO mean	not done	0.282	0.591	0.242	0.607
SWM mean	not done	0.117	0.038	0.056	0.035
SY Sediment Site mean	not done	0.1995	0.3145	0.149	0.321

Step 7 – Develop sediment cleanup levels.

Risk-based sediment screening levels were developed for the chemicals in prey tissue posing a theoretical risk to the receptors of concern (identified in Section 25) using the equations provided in Step 3 above. The screening levels are shown in the table below and the calculations are attached.

Receptors	Primary Contaminant Drivers (1)	Risk-Based Sediment Screening Levels for Shipyard Sediment Site (mg/kg dry weight)	
		Low TRV-based	High TRV-based
Brown Pelican	Lead	6.22	3,890
	Mercury	0.15	0.39
	Total PCB Aroclors	0.26	3.63
	Total PCB Congeners	0.18	2.53
Least Tern	Lead	2.0	1,250
	Zinc	402	4,020
	Total PCB Aroclors	0.08	1.18
	Total PCB Congeners	0.06	0.83
Sea Lion	NONE	Not Applicable	Not Applicable
Surf Scoter	Copper	184	4,180
	Lead	2.05	1,280
	Benzo[a]pyrene	See Footnote (2)	See Footnote (2)
Western Grebe	Lead	3.26	2,040
	Total PCB Aroclors	0.28	3.94
	Total PCB Congeners	0.20	2.75
Green Turtle	Lead	8.48	5,300

(1) The primary contaminant driver(s) listed for each receptor of concern are those identified in Section 25.

(2) Risk-based screening levels for benzo[a]pyrene (BAP) could not be calculated because there are no BAP toxicity reference values available for birds.

Aquatic Dependent Wildlife Risk-Based Screening Levels for the Shipyard Sediment Site (ppm dry-weight)

	TRV-low (mg/kg-day)	TRV-high (mg/kg-day)	Sediment Ingestion Rate (kg/kg_{BW}-day)	Food Ingestion Rate (kg/kg_{BW}-day)	BSAF (unitless)	f-lipid/toc (unitless)	Low TRV-based Cleanup Level (mg/kg dry-weight)	High TRV-based Cleanup Level (mg/kg dry-weight)
Brown Pelican								
Lead	0.014	8.75	0.0016	0.0812	0.008	--	6.22E+00	3.89E+03
Mercury	0.007	0.018	0.0016	0.0812	0.5435	--	1.53E-01	3.94E-01
Total PCB Aroclors	0.09	1.27	0.0016	0.0812	1.416	3.028	2.57E-01	3.63E+00
Total PCB Congeners	0.09	1.27	0.0016	0.0812	2.0345	3.028	1.79E-01	2.53E+00
Least Tern								
Lead	0.014	8.75	0.005	0.2492	0.008	--	2.00E+00	1.25E+03
Zinc	17.2	172	0.005	0.2492	0.1515	--	4.02E+02	4.02E+03
Total PCB Aroclors	0.09	1.27	0.005	0.2492	1.416	3.028	8.38E-02	1.18E+00
Total PCB Congeners	0.09	1.27	0.005	0.2492	2.0345	3.028	5.84E-02	8.25E-01
Sea Lion								
NONE	--	--	--	--	--	--	Not Applicable	Not Applicable
Surf Scoter								
Copper	2.3	52.3	0.0038	0.0757	0.115	--	1.84E+02	4.18E+03
Lead	0.014	8.75	0.0038	0.0757	0.04	--	2.05E+00	1.28E+03
Benzo[a]pyrene	Not Available	Not Available	0.0038	0.0757		--	#VALUE!	#VALUE!
Western Grebe								
Lead	0.014	8.75	0.0037	0.0743	0.008	--	3.26E+00	2.04E+03
Total PCB Aroclors	0.09	1.27	0.0037	0.0743	1.416	3.028	2.79E-01	3.94E+00
Total PCB Congeners	0.09	1.27	0.0037	0.0743	2.0345	3.028	1.95E-01	2.75E+00
Green Turtle								
Lead	0.014	8.75	0.00024	0.0047	0.3	--	8.48E+00	5.30E+03