Biological Evaluation

Continued Use of Puget Sound Dredged Disposal Analysis Program (PSDDA) Dredged Material Disposal Sites

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1 INTRODUCTION

As required by Section 7(c) of the Endangered Species Act of 1973 (16USC, 1531, et seq.) the U.S. Army Corps of Engineers is requesting informal Section 7 consultation for the transport and disposal of dredged material at the eight Puget Sound and Dredged Disposal Analysis (PSDDA) open-water disposal sites and for the Dredged Materials Management Program (DMMP) for the five-year period from 2010-2015. This Biological Evaluation (BE) for the program covers the threatened and endangered species found within the project's action area, which is primarily Puget Sound. The BE addresses the effects of transport, disposal, and disposal site management (including in some cases monitoring of biological and chemical inventories) . Excluded from this consultation are activities related to dredging, which are addressed through separate Section 7 consultations.

The DMMP manages dredged material disposal in three regions of the Pacific Northwest, including activities under the PSDDA program, as well as programs for Grays Harbor/Willapa Bay and the Lower Columbia River. The DMMP agencies include the Army Corps of Engineers, Seattle District (Corps); the Environmental Protection Agency, Region 10 (EPA); the Washington Department of Natural Resources (DNR); and Washington Department of Ecology (Ecology). The Corps serves as the lead agency for implementation of the program.

The DMMP manages the operation and monitoring of eight PSDDA open-water dredged material disposal sites in Puget Sound for use by both Federal and non-Federal entities for the disposal of acceptable dredged material. The five non-dispersive and three dispersive sites in Puget Sound were selected after examining existing literature and conducting physical and biological studies in order to locate dredged material disposal sites in areas where the least environmental and human use impacts would occur. The site selection process was documented in two program environmental impact statements prepared in 1988 and 1989 (PSDDA/FEIS 1988, 1989). The PSDDA program has also develop a management plan to determine whether dredged materials are acceptable for unconfined open-water disposal, and to evaluate effects of dredged material disposal at the eight selected sites since inception of the program (PSDDA/MPR 1988, 1989).

2 DMMP PROGRAM

2.1 Program Purpose and Objectives

The DMMP program (formerly called the PSDDA program) has allowed the DMMP agencies to eliminate the past system of independently planning dredged disposal activities within Puget Sound, to identify specific dredged disposal locations, and to implement regional planning. This is needed to responsibly carry out maintenance and new dredging of over 50 miles of navigable waterways, about 50 miles of port terminal shipping berths, and more than 200 small-boat harbors. Dredging is necessary to maintain the commercial and recreational services provided by these facilities, which play a vital role in the region's economic development and growth. Collectively there are over 34 port districts serving the region. The Puget Sound Dredged Disposal Analysis (PSDDA) Program focused on Puget Sound only. The geographic focus expanded to coastal Washington in 1995, and to the Washington side of the Columbia River in 1998. Therefore the program name was changed to Dredged Material Management Program (DMMP) in acknowledgement of the broader geographical focus. Throughout this BE PSDDA and DMMP may be used interchangeably.

The DMMP program goal is to provide publicly acceptable guidelines governing environmentally safe unconfined, open-water disposal of "clean" dredged material by both Federal and non-Federal entities, thereby improving consistency and predictability in the decision-making process. Public acceptability

involves consideration of a wide range of factors. Among these are technically sound evaluation procedures and practicability, which includes cost effectiveness.

The DMMP program has identified eight multi-user Puget Sound disposal sites, defined a consistent and objective procedure for evaluating the suitability of dredged material for disposal at those sites, and formulated site use management plans to monitor the effects of dredged material disposal. These management plans ensure adequate site use controls through application of an adaptive management framework, which allows the program to be altered based on the findings of the monitoring program.

2.2 Program Site Designation Process

A PSDDA site designation process conducted during the development of the 1988 and 1989 environmental impact statements resulted in the selection of three dispersive sites and five non-dispersive sites throughout Puget Sound (Figure 1). Non-dispersive disposal sites are areas where currents are low enough that dredged material is retained within the disposal site; dispersive sites have higher current velocities, so dredged material does not accumulate within the disposal site.

The number of sites selected balanced the need for ecologically safe disposal with the need for economically and logistically viable disposal options. The selection process evaluated sites based on currents, biological sensitivities, and human activities, which are discussed in detail in PSDDA/FEIS (1988) for Phase I sites and PSDDA/FEIS (1989) for Phase II sites. Selection factors included:

- navigation activities;
- recreational uses;
- cultural sites;
- aquaculture facilities;
- utilities;
- scientific study areas;
- point pollution sources;
- water intakes;
- shoreline land use designations;
- political boundaries;
- location of dredging areas;
- beneficial uses of dredged material;
- fish/shellfish harvest areas;
- threatened and endangered species;
- fish/shellfish habitat;
- wetlands, mudflats and vegetated shallows;
- bathymetry;
- sediment characteristics; and
- water currents.

Information on these factors were collected, mapped and overlain to identify areas of high and low resource value in Puget Sound. This allowed the agencies to identify areas between higher value resource areas where disposal siting would have a minimum conflict with ecological resources or human uses of Puget Sound. In addition, attempts were made to site disposal areas within 10 nautical miles (11.5 miles) of major dredging areas. After identifying these areas, additional constraints were included in the selection process.

For non-dispersive sites, these additional factors included:

- peak current speeds of less than 25 cm/sec to retain sediments within site boundaries,
- distance from shore (greater than 762 meters [2,500 feet]),
- site size for containment of the estimated volumes of dredged sediment to be disposed,
- distance from vulnerable biological resources (greater than 762 meters [2,500 feet]), and
- depth of water (where possible place site between 37 and 183 meters [120 and 600 feet]).

For dispersive sites, these additional factors included:

- current speeds in excess of 25 cm/sec for maximum dispersal of material,
- distance from shore not less than 1 nautical mile (1.2 miles),
- minimum water depth of 55 meters (180 feet) as a goal (not an absolute requirement), and
- locating sites so that the ultimate fate of the dispersed material will not have a significant adverse effect on natural resources.

Figure 1, Table 1, and Figures D-1 to D-8 (in Appendix D) illustrate the location of the eight PSDDA sites, their target and disposal zone boundaries, depths, and dimensions.

Figure 1. Approximate Location of Dispersive and Nondispersive PSDDA Dredged Material Disposal Sites in Puget Sound

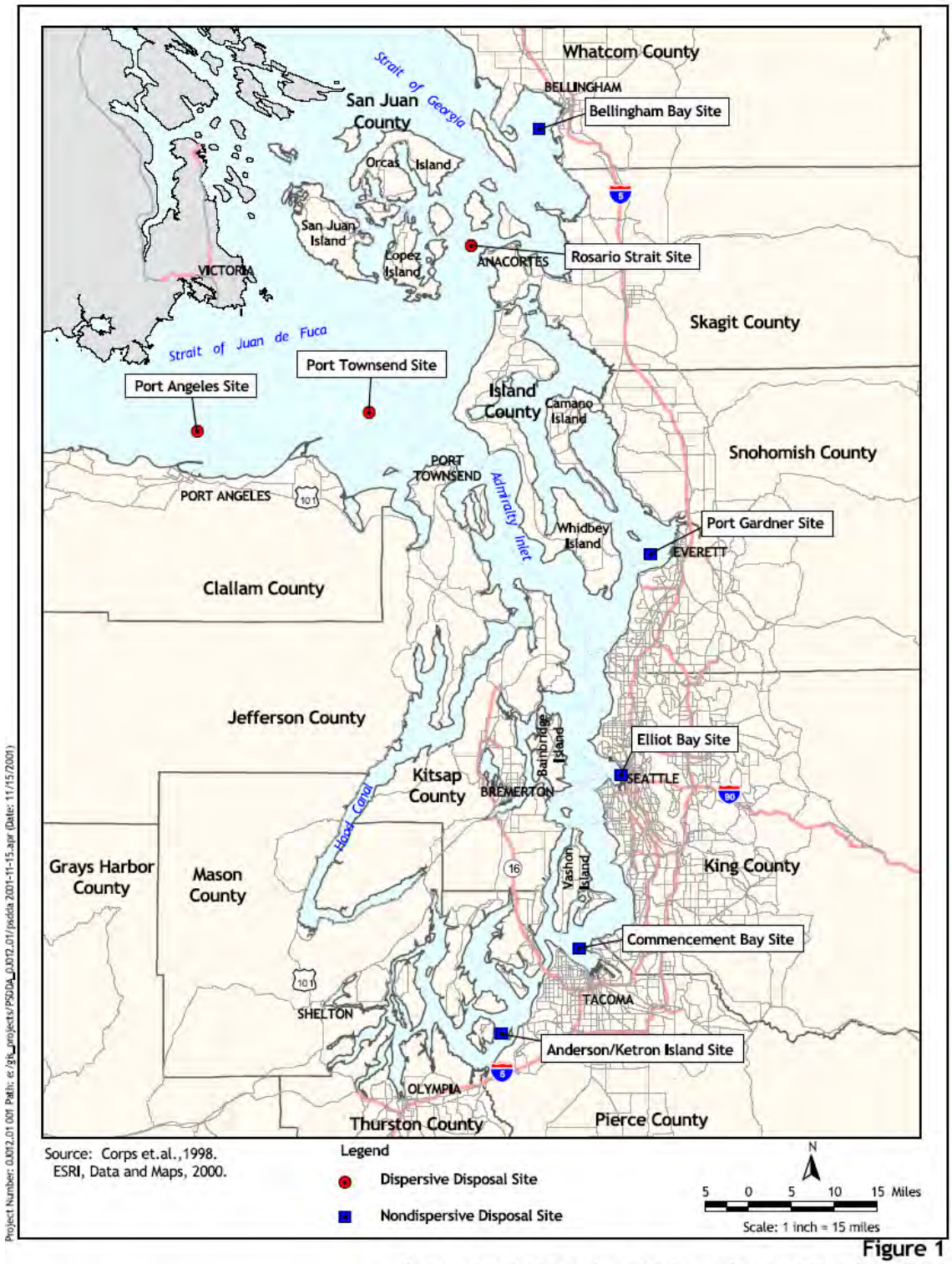

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Figure 1
Approximate Location of Dispersive and Nondispersive PSDDA Dredged Material Disposal Sites in Puget Sound

Table 1. PSDDA Disposal Site Characteristics

Site	Type	Area (acres)	Depth	Location (Lat Long NAD 83)	Disposal Zone Diameter [1]	Target Area Diameter[2]	Disposal Site Dimensions[3]	VTS/AIS[4]
Bellingham Bay	Non-Dispersive	260	96 ft (29 m)	Lat 48° 42.82' Long 122° 33.11'	1800ft (549 m) (circle)	1200ft(366 m)(circle)	3800 x 3800 ft (1158 x 1158 m) (circular)	VTS/AIS
Port Gardner	Non-Dispersive	318	420 ft (128 m)	Lat 47° 58.85' Long 122° 16.74'	1800 ft (549 m) (circle)	1200 ft (366 m) (circle)	4200 x 4200 ft (1280 x 1280 m) (circular)	VTS/AIS
Elliott Bay	Non-Dispersive	415	300-360 ft (91-110 m)	Lat 47° 35.91' Long 122° 21.45'[5]	1800 ft (549 m) (circle)	1200 ft (366 m) (circle)	6200 x 4000 ft (1890 x 1219 m) (tear drop shape)	VTS
Commencement Bay	Non-Dispersive	310	540-560 ft (165-171 m)	Lat 47° 18.145' Long 122° 27.815'[6]	1800 ft (549 m) (circle)	1200 ft (366 m) (circle)	4600 x 3800 ft (1402 x 1158 m) (ellipsoid)	VTS
Anderson Island	Non-Dispersive	318	442 ft (135 m)	Lat 47° 09.42' Long 122° 39.47'	1800 ft (549 m) (circle)	1200 ft (366 m) (circle)	4400 x 3600 ft (1341 x 1097 m) (ellipsoid)	VTS/AIS
Port Angeles	Dispersive	884	435 ft (133 m)	Lat 48° 11.67' Long 123° 24.94'	3000 ft (914 m) (circle)	None	7000 x 7000 ft (2134 x 2134 m) (circular)	VTS
Port Townsend	Dispersive	884	361 ft (110 m)	Lat 48° 13.61' Long 122° 59.03'	3000 ft (914 m) (circle)	None	7000 x 7000 ft (2134 x 2134 m) (circular)	VTS
Rosario Strait	Dispersive	650	97-142 ft (30-43 m)	Lat 48° 30.87' Long 122° 43.56'	3000 ft (914 m) (circle)	None	6000 x 6000 ft (1829 x 1829 m) (circular)	VTS

1. The disposal zone surrounds the target area within the disposal site.
2. The target area is the specified disposal compliance area within each site for the surface disposal/release of dredged material.
3. The disposal site is the bottom area that receives discharged dredged materials, encompassing and larger than the target area and disposal zone.
4. VTS = vessel traffic service; AIS = Automatic Identification System
5. Coordinates shifted 300 ft to southern corner of Target Area in 1991 following disposal site monitoring
6. Coordinates shifted in 2007 to Southeast corner of Target Area (http://www.nws.usace.army.mil/PublicMenu/documents/DMMO/CB-Site-Management-07-Clarification.pdf)

2.3 Program Suitability Determination Process

Only dredged material that has been determined to be "clean" enough for unconfined, open-water disposal can be discharged at the Puget Sound DMMP disposal sites. The process for determining if material is suitable for disposal at a PSDDA site is described in detail in the 2009 DMMP User's Manual (http://www.nws.usace.army.mil/PublicMenu/Menu.cfm?sitename=DMMO&pagename=Users_Manual). The process varies depending on whether the dredging project requires a new permit (figures 2 and 3). The typical Clean Water Act Section 404 and Section 401 permitting processes are intertwined with a second process, the dredged material evaluation process (Figure 4). The DMMP agencies document the suitability determination for each proposed dredging project in a memorandum for record, which provides the DMMP agencies consensus summary evaluation of all chemical and biological testing data relative to proposed dredged material suitability for unconfined-open-water disposal. The suitability determination is signed by all four cooperating agencies (Corps, EPA. Ecology, DNR). All suitability determinations are subsequently posted on the Corp's Dredged Material Management Office website (http://www.nws.usace.army.mil/PublicMenu/Menu.cfm?sitename=DMMO&pagename=SDM`S_BY_YEAR).

This evaluation process involves a four-tiered approach for the evaluation of sediments to be dredged in order to determine the suitability of sediments for unconfined, open-water disposal at sites in Puget Sound (Figure 5). This suitability analysis determines if sediments to be dredged have the potential to adversely affect biological resources. If, based on this analysis, materials are determined to be potentially adverse to biological resources, the material is considered unsuitable for DMMP Puget Sound open-water disposal and is disposed of by other means (e.g., disposal at Ecology-approved confined upland or nearshore disposal sites). A brief discussion of the tiered suitability evaluation follows.

Tier I analysis involves the review of existing sediment data, and site history including all potential sources (e.g., outfalls, spills, etc.) for sediment contamination (see pages 3-1 to 3-2 of DMMP Users Manual). If existing data are sufficient and indicate that sediments are removed from likely sources of contamination, the DMMP agencies may deem the sediments suitable, with no further testing required. If data are not sufficient, or there is some indication that sediments may contain contaminants (e.g., proximity to sources, spills, etc.), which may affect the quality of the aquatic environment, sediments would be chemically tested under Tier II for concentrations of both conventional parameters and chemicals of concern (Appendix A). The chemistry of the material to be dredged is typically evaluated for various smaller sub-areas within the area to be dredged. These subdivided areas within a dredge site are termed Dredged Material Management Units (DMMUs). A DMMU is the smallest area/volume within the project which can be dredged independently from other areas within the site. The methodology for determining the number and location of DMMUs for each dredging project and the number of samples to be collected within each DMMU are detailed in the DMMP User's Manual (Corps et al.; November 16, 2009).

The chemistry data are compared to established chemical guidelines (See Appendix A, and pages II-112 to II-130 in PSDDA EPTA for discussion on Apparent Effects Thresholds used to derive DMMP chemical guidelines) to assess whether additional biological testing under Tier III and Tier IV is necessary. If the Tier II analysis indicates that all chemical concentrations are below the Screening Level (SL), then no additional biological testing is necessary. The SL is the concentration level of specific chemicals below which there is no reason to believe that disposal of that material would result in unacceptable adverse biological impacts.

A Maximum Level (ML) has been defined for each chemical. The ML is a concentration above which there is reason to believe that the material would be unsuitable for unconfined, open-water disposal (EPTA, pages II-112 to II-130 at: http://www.nws.usace.army.mil/PublicMenu/documents/DMMO/epta_ph1ss.pdf). If

one or more chemical concentrations of sediments within a DMMU lie between the SL and ML, or if the concentration of one chemical is greater than the ML, but less than twice the ML, then that DMMU would be required to undergo standard biological testing under Tier III (solid phase bioassays) before a suitability determination can be reached (see pages 7-1 to 7-12 of DMMP Users Manual). If one chemical concentration is more than double the ML concentration, or if two or more chemicals exceed the ML within a DMMU, then those sediments would require biological testing using best-professional judgment, which also may include a Tier IV evaluation at the discretion of the DMMP agencies using Best-Professional-Judgment (BPJ). A Tier IV assessment is considered a special, non-routine evaluation that may be required by the DMMP agencies, which might include time-sequenced bioaccumulation or tissue analysis of organisms collected from the area to be dredged in order to determine concentrations of chemicals of concern, and/or a risk assessment (see pages 9-1 to 9-3 of DMMP Users Manual).

If chemical concentrations indicate that Tier III or Tier IV testing would be required, the discharger has the option of not continuing beyond Tier II, and accepting the decision that the material is not suitable for unconfined open-water disposal and must be disposed of at an Ecology-approved confined disposal site (e.g., confined upland or nearshore disposal).

In addition to comparison to the SL and ML concentration, the PSDDA sediment screening process also includes a Bioaccumulation Trigger (BT). The BT is the concentration of a chemical of concern, above which there is reason to believe there is potential for that chemical to be accumulated in the tissue of target organisms (see pages 8-1 to 8-8 of DMMP Users Manual). Traditional ecological effects of sediments are evaluated and compared statistically to reference values. Human health effects are evaluated against PSDDA guidelines for allowable tissue concentrations which are a combination of risk-based numbers and Food and Drug Administration action levels. Also see discussion in Appendix B (e.g., Biomagnifications effects of persistent organic pollutants in Southern Killer Whales, and Steller Sea Lions).

Dispersive sites are located in areas of high bottom currents where dredged material placed at the site is expected to be rapidly transferred offsite. Tier I and II testing for dispersive sites is similar to non-dispersive sites. Generally, any chemical with a screening level exceedance would be subject to Tier III bioassay testing, where dispersive site bioassay interpretation guidelines would allow only a 10 percent absolute mortality (over reference sediments), as opposed to the 30 percent absolute mortality allowed for sediments which are being tested for disposal at non-dispersive sites. Accordingly, the more restrictive bioassay interpretation guidelines are used for testing sediments to be disposed of at dispersive sites to insure adherence to the Site Condition I Standard (PSDDA FEIS and EPTA: defines Site Condition I as “No adverse effects on biological resources due to Sediment Chemicals”, whereas the Site Condition II Standard is the applicable standard for non-dispersive sites: Site Condition II: “Minor adverse effects on biological resources due to sediment chemicals”).

Figure 2. Section 10/404 Regulatory Process (New Permit Required)

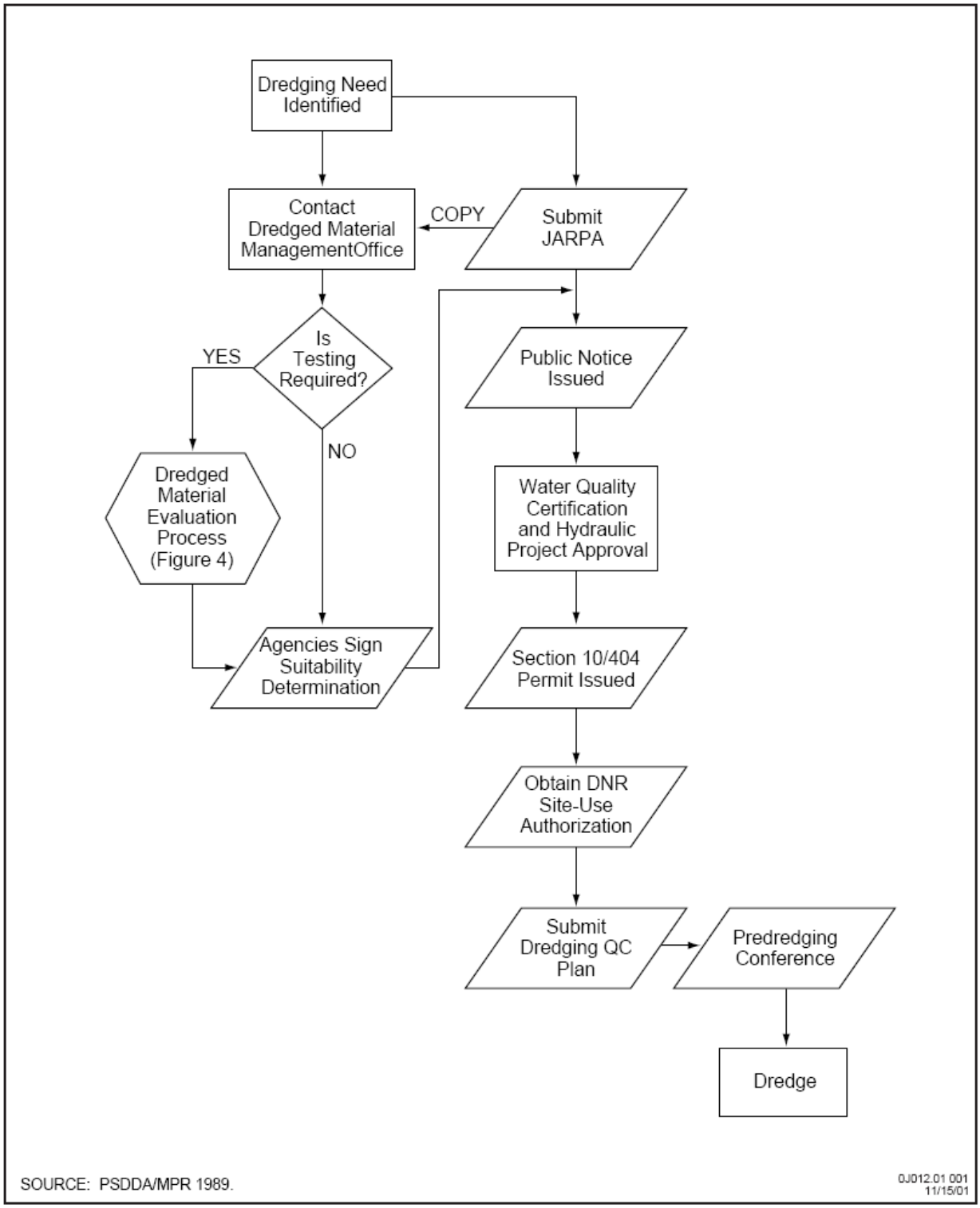


Figure 3. Section 10/404 Regulatory Process (New Permit Not Required)

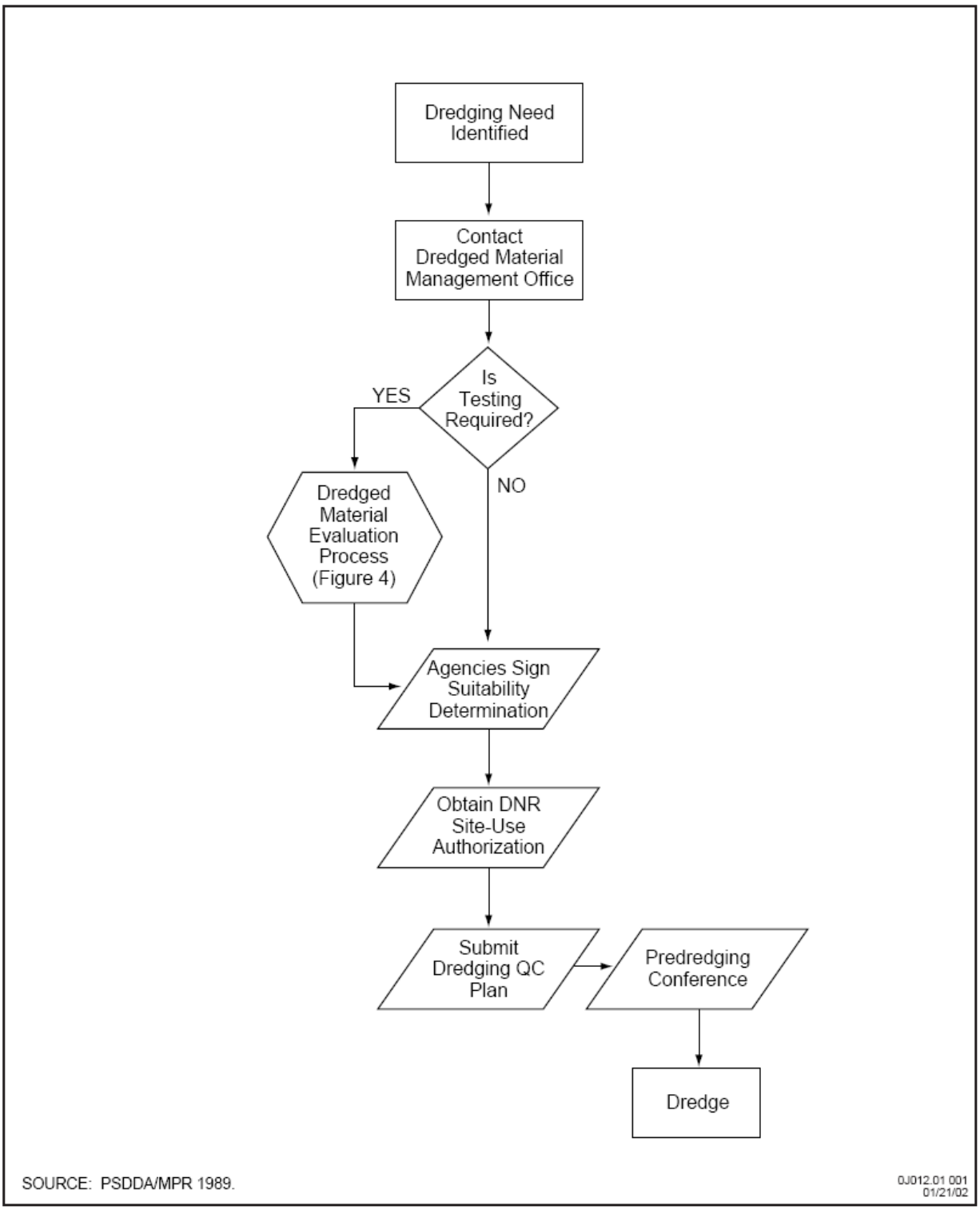


Figure 4. Dredged Material Evaluation Process

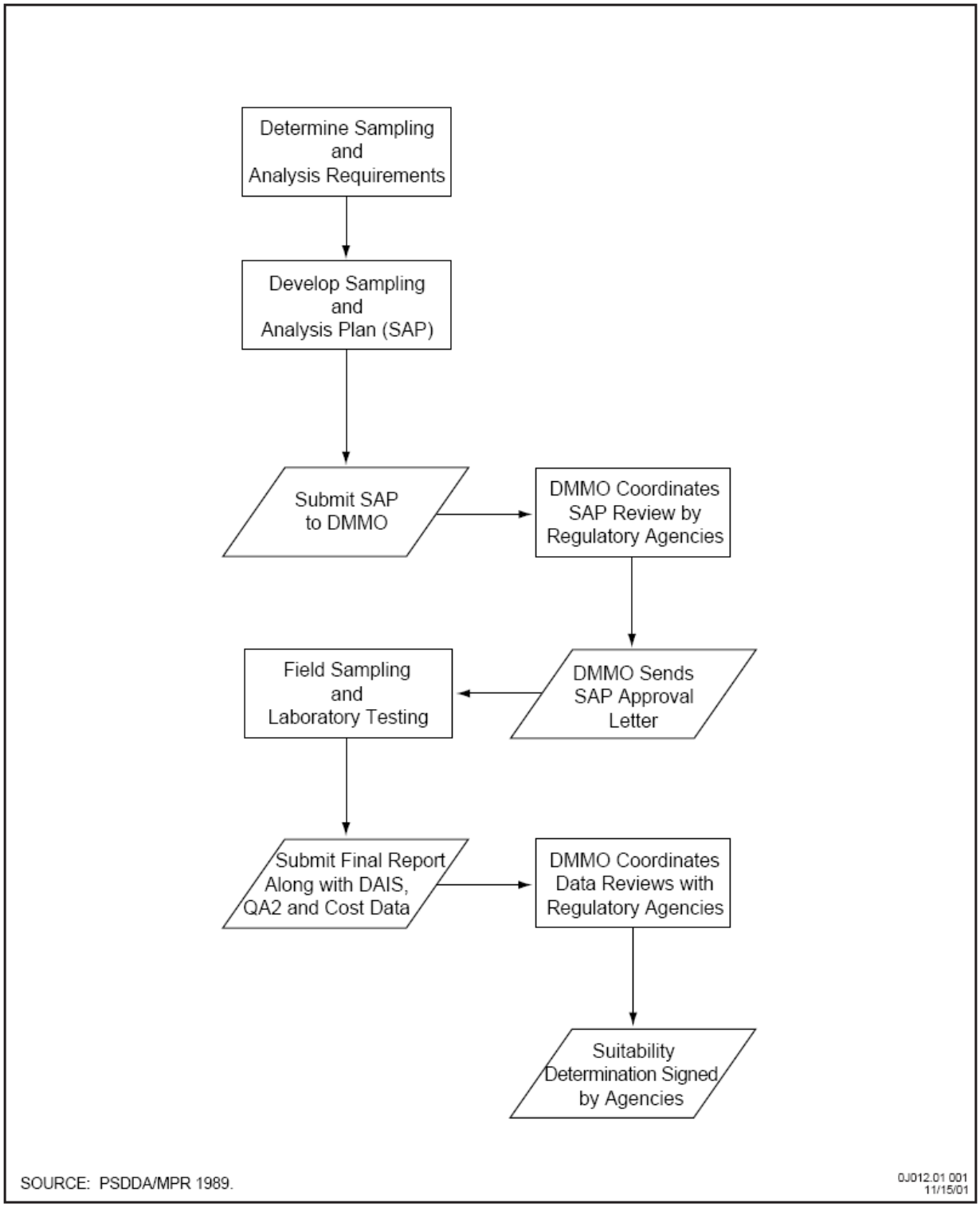
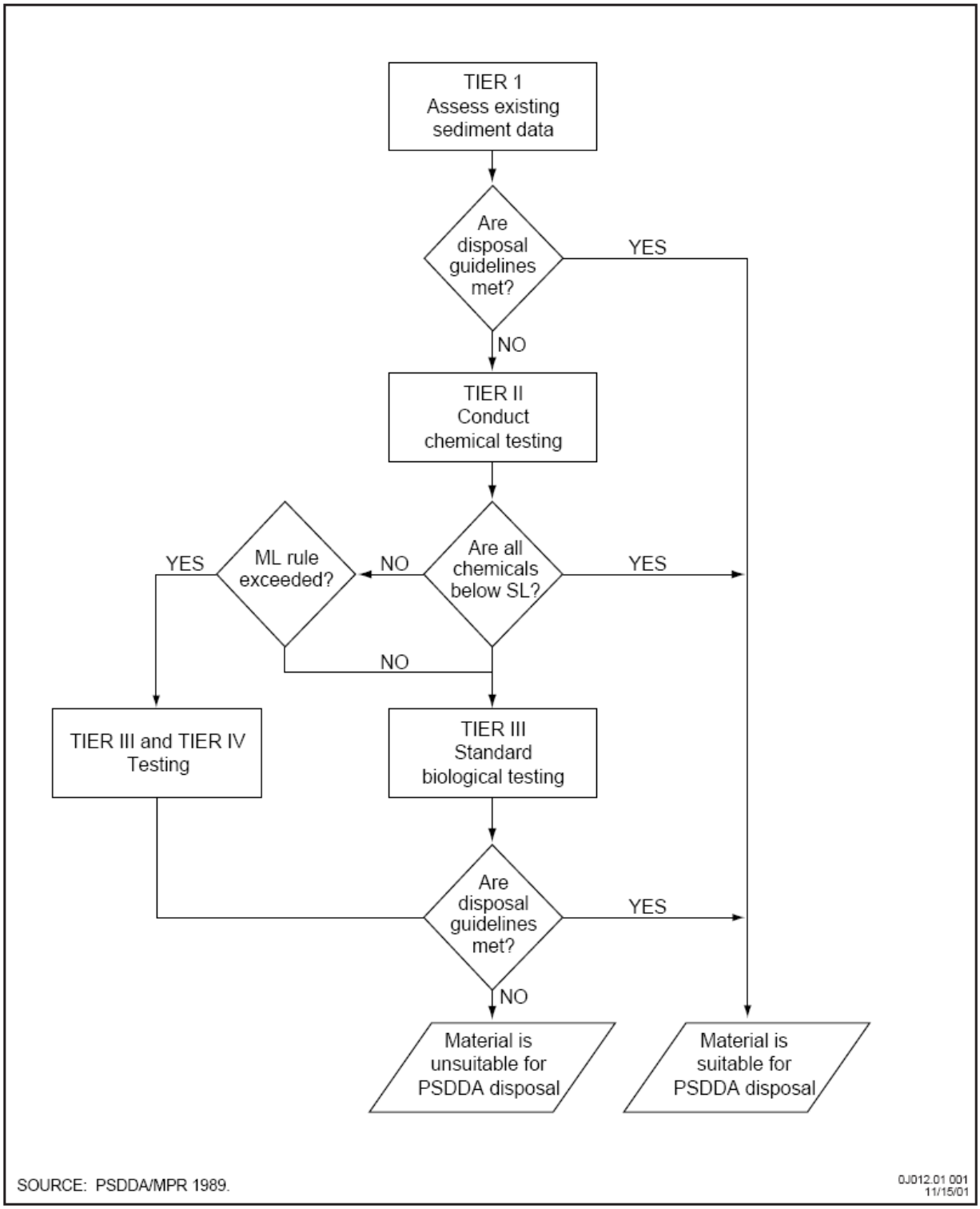


Figure 5. Tiered Testing Decision Diagram



2.4 Previous PSDAA Section 7 Consultations

As part of the 1988 and 1989 PSDDA environmental impact statements, biological assessments were prepared to evaluate the potential impacts of the program on species listed under the Endangered Species Act and occurring within Puget Sound at that time — bald eagles, several species of whales, and leatherback sea turtles. These previous biological assessments concluded that disposal activities at these sites are not likely to adversely affect bald eagles, whales or leatherback turtles because these species either do not occur in Puget Sound, are transient residents in the Sound, or are not likely to congregate or feed at the disposal sites.

3 DESCRIPTION OF THE PROPOSED ACTION

The activities considered in this biological evaluation are the transport of dredged material from a dredging site to a PSDDA disposal site; the disposal of material at a PSDDA disposal site; and the return of equipment to the dredging site. These same activities have occurred over the past 21 years, since the 1989 designation of PSDDA disposal sites.

Although dredging projects in Puget Sound are also required to comply with the Endangered Species Act (ESA), dredging activities are not considered in this biological evaluation. All dredging actions that generate material for open-water disposal at PSDDA sites require the issuance of a Section 10 and Section 404 permit (Clean Water Act). The issuance of a Section 10/404 permit is a Federal action requiring an ESA Section 7 consultation. Therefore, the potential effects of specific dredging activities on threatened and endangered species will be addressed in separate biological evaluations prepared by individual project proponents once specific future plans are known. Past and potential future disposal frequencies are addressed in Section 2.4 below.

The Corps of Engineers request that the term of the consultation resulting from this biological evaluation be five years. Disposal activities will occur concurrently with dredging projects. Since the timing of dredging activities is generally regulated by in-water work closure periods established to protect outmigrating juvenile salmon and bull trout during sensitive times in their life cycles, no additional ESA closure periods specifically for PSDDA sites are warranted. However, three of the eight PSDDA sites have closure periods for the protection of other marine resources/fisheries (see Table 2 below).

Table 2. PSDDA Site Closure Periods (non ESA)

Disposal Site	Disposal Site Closure Period	Reason
Port Townsend	September 1 to November 30	Fall shrimp closure
Port Angeles	September 1 to November 30	Fall shrimp closure
Bellingham Bay	November 1 to February 28	Crab/shrimp closure

3.1 Dredged Material Transport

The activity considered under this biological evaluation is the transport of dredged material from dredging site to disposal site, the disposal of the material, and the return of the equipment to the dredging site. Dredged material is generally transported to the disposal site by a tugboat pulling a bottom-dump (split-hull) barge. The barges can be of various sizes, with the ability to transport between 1,200 and 2,000 cubic yards (typically 1,500 cubic yards) of material each trip. The DMMP does not authorize use of Hopper Dredges in Puget Sound at DMMP sites. The number of barge discharges per day to a particular

site varies by project, but are typically two to five per day when projects are active (worst case example: 2007 Commencement Bay disposal = 1,324,254 cy, amounting to 897 bargeloads over 203 days between 8/22/2006 and 2/28/2007, average = 4.4 bargeloads/day). The distance traveled and the number of trips required varies depending on the location and extent of the dredging activity.

Transport of the barge to and from the disposal sites is not generally a concern with regard to potential physical effects on salmon, coastal pelagic, and groundfish species or habitat. Some dredged material may possibly be lost overboard on the way to the disposal sites either by being blown overboard, sloughing, or leaking. Concern has been expressed that windborne, spilled, or leaking dredged material entering the water column during transport could in some way delay or otherwise affect freshwater entry of returning adult salmon or have deleterious effects on pelagic and groundfish species. The negligible potential for this outcome is reviewed in the following discussion.

Mechanical dredging operations are performed to achieve an economical load that will result in some overflow of dredged material within the allowable dilution zone. The determination of an economical load is made in the field, based on the consistency of the dredged material and the safe load capacity of the transport barge. Sometimes the dredged material dewaters quickly, allowing the load to be mounded along the centerline axis of the barge. If the dredged material contains fines and high water content, mounding is not feasible and appropriate freeboard is maintained on the confinement bulkhead (sideboards) to prevent spillage. When the barge capacity is reached, the deck area outside the perimeter bulkhead of either deck or bottom dump barges is inspected for accumulated sediment. Spilled sediments are flushed overboard with water in the dilution zone at the dredging site to provide safe access for the dredge crew and to prevent the materials from being lost overboard in transit from the dredging site to the disposal site.

The potential for effect from windborne sediments is minimal. The type of sediments that can typically be mounded on a barge (and thus would be most exposed to wind) are either more granular (contain little fine or organic material, would be relatively inert, and pass quickly through the water column) or are very cohesive (clay). More claylike sediments generally contain a high moisture content, which would resist windborne transport. The amount of time between loading and discharge of dredged materials at the disposal site is relatively short (hours), which gives finer material little time to dry (become less cohesive) during the transport process. Thus, potential for windborne transport of these types of materials is minimal.

The potential for sloughing or leaking of dredged material from barges during the transport of material to the disposal sites is minimized by the design of modern barges (sideboards on the deck and seals on the bottom dump doors) and the typical operation practices of the contractors (loading practices and deck cleaning for crew safety and access, as required, prior to leaving the dilution zone). If any significant leaking is noted, the contractor must correct the situation before leaving the dredging dilution zone. Thus, the potential for significant sloughing or leaking of dredged material is minimal.

Although there is always potential for a fuel spill, this possibility is extremely small. The number of trips and distance traveled by the tugs and barges is minimal compared to the vast number of commercial vessels sailing on Puget Sound. Therefore, the incremental effect of the noise generated by the tug hauling the barge to and from the disposal sites is considered to be insignificant. The loading sandy or smaller-grained material onto a barge generates relatively low sound levels, based on the observations of work crews--a search of the literature failed to find any reference to the impulse noise generated by the loading of sand into a barge. Similarly, no reference could be found of the noise levels caused by the opening of a center-dump barge under the water surface to release the load of sediment. Intuitively, it would seem that the noise would be relatively less than other activities in dredging areas, such as the sound of the tug engines, and is thus a negligible addition to the ambient noise levels surrounding the

disposal area. Furthermore, the disposal operation is short-lived (less than one minute), and is unlikely to occur while a killer whale is in the vicinity. Therefore, this potential noise effect is considered to be discountable.

3.2 Disposal Activities

3.2.1 Dispersive Sites

Dredged material disposed at the dispersive sites are dispersed relatively quickly by the strong currents at these locations. Disposal occurs from the barge as the barge is being towed through the disposal site. The disposal sites were sized on the assumption that a barge is towed at an average speed of 3 knots and the load is completely dumped in 10 minutes. Dispersive site disposal zones (the area on the surface where dredged material is released) were sized based on the predicted horizontal spread of a single dump of dredged material.

Based on modeling conducted as part of the PSDDA site selection process (Phase I PSDDA DSSTA, pages II-29 to II-46), a disposal event based on a single **1,500 cy bottom-dump barge** disposal in 122 meters (400 feet) of water with a current speed of 50 cm/sec (1 knot) would result in a horizontal spread of 610 meters (2,000 feet) down current of the dump spot, and 303 meters (1,000 feet) to either side. For the dispersive site, 914-meter (3,000-foot) diameter disposal zones were established. Based on the projected spread, the disposal site dimensions were set at 1,829 meters (6,000 feet) diameter for the Rosario site, and 2,134 meters (7,000 feet) diameter for the Port Townsend and Port Angeles sites.

3.2.2 Non-Dispersive Sites

Dredged material disposal activities at the non-dispersive sites are conducted to maintain the dispersion of dredged material in the 600-foot radius target zone. Disposal occurs from the barge as the barge is being towed through the disposal site at the minimum speed necessary to maintain control. All dredged material disposal tugs are required to record and report when and where the doors on the barge are opened and closed to ensure that all disposal occurs within the target zone. In addition, the DNR keeps a record of all disposal track lines that each barge traveled during the dumping using DGPS.

The behavior of discharged material at non-dispersive sites was modeled as part of the original site selection process (PSDDA/DSSTA, 1989). The models showed that material separated from the jet (because of turbulent shear or collapse) and settled to the bottom within the disposal site boundary within a 305-meter (1,000-foot) radius of the drop point. The depth of the deposits estimated from a single 1,500 cy barge load of dredged material (e.g., from the modeling studies) on the bottom varies from about 0.8 cm in the center of the disposal mound, to about 0.1 cm near the edges of the mound.

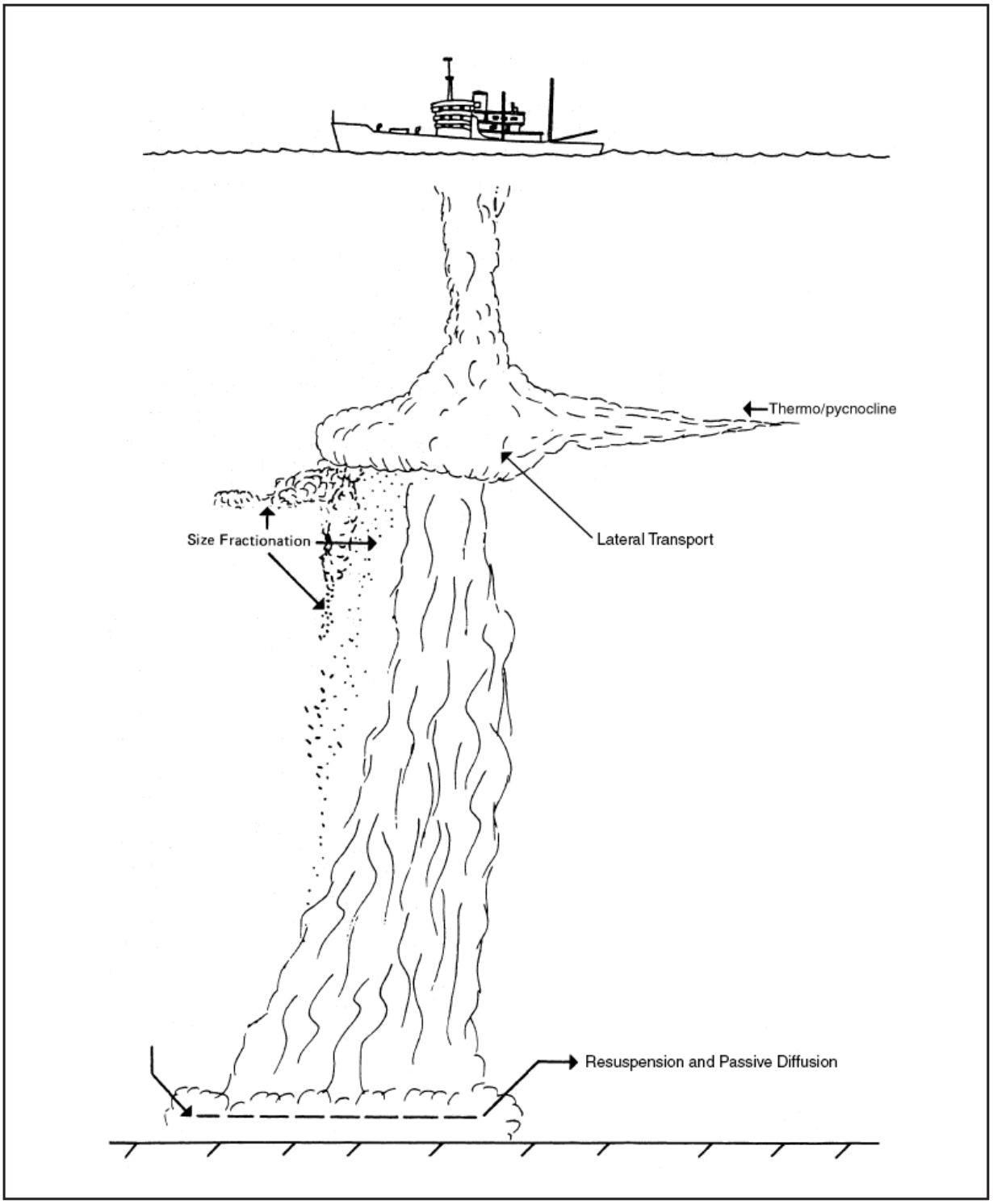
3.3 Disposal Mechanisms

As part of the PSDDA site selection analysis, the Corps conducted extensive numerical modeling simulations using the Disposal from an Instantaneous Dump (DIFID) model (Trawle and Johnson 1986). The model evaluated the fate and dispersal of dredged material of varying composition discharged from barges into waters of varying depth and current speed (PSDDA/MPR 1988, 1989). A schematic representation of a discharge event is presented in Figure 6.

Changes in the form and behavior of an instantaneous discharge of dredged material from a barge during its descent through the water column are generally described by the Corps (1986) and Pequegnat (1983). The descent from an instantaneous discharge from a moving split-hull barge is similar in some regards and can generally be divided into three phases according to the physical forces that act on the material as

it descends through the water column to the bottom. These phases are convective descent, dynamic collapse, and passive diffusion.

Figure 6. Schematic Representation of the Fate of Dredged Material during Disposal



SOURCE: Adapted from Pequegnat 1983.

3.3.1 Convective Descent

During convective descent, the discharged material descends through the water column as a dense, well defined fluid-like jet. The consistency and behavior of the jet depends on the characteristics of the dredged material, moisture content, cohesiveness, size composition (e.g., silt, clay, sand, gravel), and the equipment used to dredge the material (clamshell, cutterhead, hopper/drag-arm). Material previously discharged at PSSDA sites has been of highly variable character, and a wide range of dredged material type can be expected in future disposal activities. Dredging within Puget Sound is almost entirely performed using clamshell dredges and require use of bottom-dump barges, which release the consolidated dredged material below the water surface through the split-hull barges. Clamshell dredges keep the dredged material relatively consolidated and minimize the percent moisture content (PMC).

All other things being equal, the PMC will determine the amount of dredged material that will initially reach the bottom, the amount of time it takes to initially reach the bottom, the area of the bottom it covers, the direct and immediate potential impact on the pelagic water column and bottom, and the effects of the environment on the dredged material (resuspension and transport). Where the initial PMC is low, as with clamshell dredging, the transit time of the material is sufficiently brief that the influence of any currents in transporting the material laterally is minimal (Pequegnat 1983). In modeling conducted by the Corps (PSDDA/FEIS 1988, 1989), transit time of the material to the bottom in 122 meters (400 feet) of water is on the order of 30 seconds after the discharge is initiated.

As the material descends to the bottom, large volumes of water are entrained in the jet, which expands the diameter of the jet as it approaches the bottom. The Corps (1986) estimated that the diameter of the jet as it makes contact with the bottom in 122 meters (400 feet) of water would be approximately 76 meters (250 feet). As a result of several factors, including turbulent shear, some material is separated as it descends, and settles to the bottom at a slower rate. This rate is determined by material density (size fractionation). Lateral transport of this material has been a concern in the discharge of sediments that contain contaminants. However, this is not a critical issue for the present analysis because the material discharged at PSDDA sites will have been evaluated thoroughly for suitability for disposal. To be suitable, the sediments must not contain unacceptable concentrations of chemicals of concern.

3.3.2 Dynamic Collapse

The dynamic collapse phase occurs as the material collides with the bottom or when the material encounters a water layer with greater ambient density (thermocline or pycnocline). As the jet material collapses, the material spreads out in all directions as a density/momentum-driven surge. The behavior of discharged material at both dispersive and non-dispersive sites was modeled as part of the original site selection process (PSDDA/DSSTA, 1989).

For dispersive sites, the models showed that material impacts the bottom within the disposal site boundary. An estimated 90% of material is deposited within a 457-meter (1,500-foot) radius of the disposal location. The initial depths of the deposits on the bottom were calculated to vary from 2.2 to 0.73 cm in water depths of 61 to 122 meters (200 to 400 feet).

For non-dispersive sites, the models showed that material separated from the jet (because of turbulent shear or collapse) and settled to the bottom within the disposal site boundary within a 305-meter (1,000-foot) radius of the drop point. The depth of the deposits on the bottom varies from about 0.8 cm in the center of the disposal mound, to about 0.1 cm near the edges of the mound.

The concentration of suspended solids, as well as the extent and duration of their presence in the water column, is of concern because of potential effects on biota. As expected, effects caused by suspended

solids vary in concentration and duration depending on the type of material discharged and environmental conditions. The material to be discharged is loaded into bottom-dump barges with a clamshell dredge, which maximizes the cohesiveness of the material compared to other dredging methods. As such, the material tends to clump when discharged. This minimizes loss from the jet to the surrounding water and resuspension once it contacts the bottom. Various estimates have been made to characterize the loss of material to surrounding waters (Corps 1986). Studies have generally concluded that from 1 to 5% of the disposed material is lost from the jet to the water column during descent. However, monitoring has demonstrated that this material settles rather quickly (within 1 hour). Please see Section 4.1.1 for additional discussion regarding the behavior of sediments in the water column during and after disposal events.

3.3.3 Diffusion of Disposed Material by Currents

This process is not a major factor at non-dispersive sites because current velocities at the sites are too low to initiate movement of the material. The dispersive sites are located in areas where bottom currents are swift enough to completely disperse discharged dredged material out of the disposal site.

The three dispersive sites have mean current speeds greater than 40 cm/sec. Several field studies were performed and numerical models were created to evaluate the transport of dredged material from dispersive sites, based on current speeds. These studies/models indicated that at all three sites a small amount of dredged material would initially accumulate on the bottom after a discharge event, but then complete erosion of the material would likely occur over a single flood or ebb tide.

Bathymetric monitoring of the Rosario Strait site in 1991, 1994, 1999, and 2009 confirmed that dredged material is rapidly dispersed and no accumulations of dredged materials have occurred at that site since the 1989 baseline survey. In 2000 no disposal activities occurred, with only 10,419 cy in 2001, 500 cubic yards in 2002, and 38,223 cubic yards of dredged material in 2003. A sharp increase in disposal occurred in 2004 with 230,747 cy, 150,921 cy in 2006, and 188,580 cy in 2009 (Table 4). The Rosario Strait site was subsequently monitored in 2009 and it confirmed that there has been no mounding of material at this site. The other two dispersive sites have not been monitored since their baseline surveys because of the relatively low site use and low volumes of material disposed at these sites over the past 21 years (Table 4).

Transport of dredged materials by currents can occur through relatively large distances. The direction and distance of transport varies for each site and depends on the stage of the tide during which the material is disposed. PSDDA/DSSTA (1989) evaluated far field dispersion using a variety of methods including observation of Lagrangian drifters and numerical simulations (Crean 1983). The studies anticipated wide dispersal of the material because of the strong currents at the sites.

The currents at the Rosario Strait site, with net current speeds of 10 to 30 cm/sec and peak speeds of 100 cm/sec, were estimated to transport suspended material up to 10 miles a day. The prevailing current flow would tend to disperse suspended material southward from the Rosario Strait site. Mean current speeds at the Port Townsend site are between 30 and 50 cm/sec, with peak speeds of 75 to 100 cm/sec. The east/west movement of the material depends on the tide, with net speeds reaching 10 miles per day. At these speeds, the prevailing currents could move suspended sediment to the mouth of Admiralty Inlet in 1 day or to Vancouver Island in 2 days. No field data exist for the Port Angeles site, but the peak current speeds are estimated at about 125 cm/sec with an east/west trajectory. Resuspended material transported in the bottom currents would predominately move eastward over time, entering the Strait of Georgia via Haro Strait and Puget Sound via Admiralty Inlet.

3.4 Site Usage

Table 3 details cumulative discharges to the eight PSDDA sites since their designation in 1989-1990 through 2010. The cumulative volumes are depicted in terms of the relative site capacity, as well as estimated time to exceed that volume. Over 16 million cubic yards of dredged material has been disposed at the 8 sites over the past 21 years. The Commencement Bay, Elliott Bay, Port Gardner, and Rosario Strait sites are the most heavily used of the PSDDA sites, with an average of 92,000 to 381,000 cubic yards disposed at each per year.

Table 4 details post dredging volumes at each site. Dredging volumes over the past 2 – 3 years provide a general trend and a rough idea of how much material would be disposed of at the PSDDA sites over the next few years. Please see detailed discussions of each disposal site in sections 4.2 and 4.3.

Table 3. Twenty-One Year (1989-2010) PSDDA Site Use Summary

Nondispersive Disposal Site	Cumulative Volumes (CY)	Average Volume Per Year (CY/YR)	15-Year Predictions MPR Phase I/II (CY)	Percent of 15-Year Prediction	Estimated Time to Exceed Site Capacity (Years) [1]
Port Gardner (1989-2010)	3,143,183	142,872	8,243,000	38.1	41
Elliott Bay (1989-2010)	2,720,743	123,670	10,525,000	25.9	50.8
Bellingham Bay (1990-2010)	78,883	3,756	1,181,500	6.7	2,375
Commencement Bay (1989-2010)	8,012,385	364,199	3,929,000	203.9	2.7[2]
Anderson/Ketron Island (1990-2010)	140,543	6,693	785,000	17.9	1,324
SUBTOTALS:	14,095,737	641,190	24,663,500	57.2	N/A
Dispersive Disposal Site	**Cumulative Volumes (CY)**	**Average Volume per Year (CY/YR)**	**15-Year Predictions MPR Phase I/II (CY)**	**Percent of 15-Year Prediction**	**Estimated Time to Exceed Site Capacity (Years) [3]**
Rosario Strait (1990-2010)	1,932,259	92,012	1,801,000	107.3	N/A
Port Townsend (1990-2010)	55,528	2,644	687,000	8.1	N/A
Port Angeles (1990-2010)	22,344	1,064	285,000	7.8	N/A
SUBTOTALS:	2,010,631	95,720	2,773,000	72.5	N/A
GRAND TOTALS:	16,105,868	736,911	27,436,500	58.7	N/A

1. Site capacity estimated in Phase II Disposal Site Selection Technical Appendix for non-dispersive sites is approximately 9,000,000 cubic yards, therefore (Site Capacity – Cumulative Volume)/average annual disposal volume = Estimated Time to Exceed Site Capacity **from** 1988 EIS.
2. Estimate based on average disposal volumes over first 21 years, but site based on current and estimated future site use is expected to exceed 1988 EIS site capacity within the next 2.6 years. After NEPA/SEPA review, new site volume ceiling is now 23 million cubic yards.
3. Actual site capacity for dispersive sites is not limited, assuming complete dispersal of dredged material off site.

Table 4. Disposal Site Use Summary Over Twenty-two Years of DMMP Management.

Dredging Year*	Puget Sound Disposal Site Cumulative Volumes (cubic yards)								
	Commencement Bay	Elliott Bay	Port Gardner	Bellingham Bay	Ketron Island	Rosario Straits	Port Townsend	Port Angeles	Dredging Year Totals
	Nondispersive	Nondispersive	Nondispersive	Nondispersive	Nondispersive	Dispersive	Dispersive	Dispersive	
1989	6,648	4,097							10,745
1990		129,542	992,074						1,121,616
1991	10,900	12,000	17,261			566,694			606,855
1992		230,241				43,850			274,091
1993		17,282	109,500	32,883	10,197	176,486	22,642		368,990
1994		132,770	236,749			57,010			426,529
1995	290,857	93,412	143,510		8,677	25,250			561,706
1996	460,684	95,302	121,246	44,800		205,500		22,344	949,876
1997		18,982	102,531						121,513
1998	693,540	110,465		1,200		53,000	4,000		862,205
1999	140,319	414,794				140,761	1,986		697,860
2000	893,776	360,577							1,254,353
2001	265,867	557,340	248,965			10,419			1,082,591
2002		133,270	45,919						179,189
2003	710,675					38,223			748,898
2004	1,205,993	15,602			5,772	230,747			1,458,114
2005	949,399	77,838			8,180	23,847			1,059,264
2006	811,000	3,801	722,185			150,921			1,687,907
2007	1,324,254	24,250	4,400		10,407	20,970	10,996		1,395,277
2008	214,858	172,999	17,393		97,310				502,560
2009	18,803	20,133	10,450			188,580	6,856		244,822
2010	14,812	96,046	371,500				9,048		491,406
Totals:	8,012,385	2,720,743	3,143,183	78,883	140,543	1,932,258	55,528	22,344	16,105,868
AVG Vol./yr	364,199	123,670	142,872	3,756	6,693	92,012	2,644	1,064	736,911

* Dredging Year: 16 June through June 15th of following year (overlaps 2 Calendar years)

3.5 Conservation Measures

A number of measures and procedures inherent in the Dredged Material Management Program (DMMP) act in combination to minimize the potential for impacts to listed species in Puget Sound. These include:

- consolidation of dredged material disposal sites to minimize the area and locations affected by dredged material disposal;
- siting of dredged material disposal sites in areas of relatively low habitat value or low use by biota (distance offshore, depth, areas with low known resource value);
- consideration of beneficial-use disposal sites for appropriate dredged material;
- timing of dredging and disposal events to avoid overlap with sensitive migration or life history periods of listed species;
- using dredged material testing protocols to ensure the suitability of materials for unconfined, open-water discharge;
- sequencing of disposal (cleanest suitable material last) to manage sediment quality objectives;
- conducting site monitoring activities (physical, chemical and biological) to determine if unacceptable impacts are occurring at disposal sites;
- performing annual review of monitoring results; and
- adaptively managing sites by the DMMP agencies in light of the above.

4 ACTION AREA AND PROJECT AREAS

4.1 Action Area

Given the wide distribution of PSDDA sites, the distances associated with transport of dredged material from dredging sites to the disposal sites, and the sizeable dispersal zones for material discharged at the dispersive sites, the action area for this biological evaluation is defined as Puget Sound, including the Georgia Strait and the Strait of Juan de Fuca. Individual project areas are the specific disposal sites and their associated waters. Each of the eight sites is described in the following sections.

4.2 Non-Dispersive Sites

4.2.1 Commencement Bay Site

The Commencement Bay disposal site is located approximately 0.65 nautical miles (0.75 mile) west of Brown's Point. The site is elliptical, covering 310 acres with dimensions of 1,402 by 1,158 meters (4,600 by 3,800 feet). The Commencement Bay site is generally located in waters 165 to 171 meters (540 to 560 feet) deep. The center of the site is now around 439 feet deep due to twenty-one years of disposal. In June 2007 the DMMP agencies adjusted the disposal site coordinates 565 feet southeast of the initial site center coordinates within the target area to dampen future mounding from disposal as an adaptive site management action.

Sediment grain size is small in this depositional area. Currents near the bottom move predominantly in a southern direction and are less than 25 cm/second, not fast enough to resuspend sediments (PSDDA/FEIS 1988).

Initial pre-disposal benthic infauna biomass at the Commencement Bay site was dominated by large polychaetes (67%), bivalve mollusks (28%), and crustaceans only constituting 5% of the biomass. The Benthic Resources Assessment Technique analysis for this area indicated that four benthic feeding

strategy groups of fish were heavily using the area, primarily represented by Dover sole and English sole (PSDDA/FEIS 1988). Bottom trawl studies in 1986 indicated that Dover sole, English sole, and ratfish were the most abundant bottom fish at the Commencement Bay site. Trawling conducted in 2007 at previously studied transects reconfirmed the generally low abundances of bottom fish noted during the 1986 site designation studies, with 2007 evaluations depicting English sole averaging 4.2 fish/hectare and Slender sole averaging 4.9 fish/hectare.

A post-disposal evaluation of this site in 1996 indicated that dredged material remained onsite. Dredged material at the site perimeter was <0.5 cm thick. Sediment testing at the site indicated that there was some small increase in lead sediment concentrations at one perimeter station, with several metals (copper, mercury, silver, and zinc) also increasing at one perimeter station. However, overall sediment quality was improved in 1996 over 1995 levels, and the biological effects guideline of "minor adverse effects" (e.g., Site Condition II; EPTA, page 2-111; also see definition in Section 2.3) was not exceeded (SAIC, 1995, 1996).

Monitoring at the Commencement Bay disposal site during 2001 documented a wider spread of dredged material than originally envisioned during the site selection/designation process (SEA, 2001). The DMMP agencies closed the site pending evaluation of the offsite impacts, which showed no chemical and biological impacts (e.g., no toxicity, no depressions in benthic infauna taxa) within the expanded dredged material footprint. Additional sampling conducted verified that the benthic community was not impacted outside the disposal site. The site was eventually re-opened in July 2002 after all additional site investigations and modeling studies were completed, and after the DMMP agencies provided assurances to Pierce County Shoreline Board on the management actions adopted by the DMMP agencies, which included close monitoring of all disposal activity at the Commencement Bay disposal site. The DMMP agencies are currently evaluating further site management recommendations that could include expanding the current site boundaries and relocating the current disposal zone coordinates to minimize the mound height.

Additional monitoring in 2003, 2004, and 2007 further documented that the dredged material was not impacting the benthic community and that sediment quality remained high and met the site management objectives (SAIC, 2003, 2004, 2007). The monitoring during 2003 and 2004 showed that the dredged material footprint extended outside the disposal site perimeter, in general similar to that observed in 2001, but not extending as far north. However, monitoring in 2007 following disposal of 1.3 million cubic yards of material showed the dredged material generally within the disposal site and perimeter line, and under the site management compliance limit (< 3 cm of dredged material at Perimeter Line).

Because of the relatively high disposal at the Commencement Bay site between 1995 and 2008 (Table 4), and the projected volumes of other relatively large DMMP construction/maintenance dredging projects currently going through the permitting process for disposal at this site, the DMMP agencies elected to conduct a NEPA/SEPA review of the reauthorization of the Commencement bay site. The DMMP agencies initiated a NEPA/SEPA evaluation in 2007 to evaluate the disposal site's ability to accommodate a volume ceiling up to 23 million cubic yards to accommodate long term regional disposal needs as part of the Pierce County Shoreline Permit process. This resulted in a NEPA/SEPA Supplemental Environmental Impact Statement (SEIS) (http://www.nws.usace.army.mil/PublicMenu/Menu.cfm?sitename=DMMO&pagename=CB_SEIS) – a supplement to the 1988 EIS– which re-evaluated the purpose and need for this site, and evaluated the existing site relative to site capacity and site management. The draft NEPA SEIS went out for a 45-day public interest review in April 2009. The Final NEPA SEIS with minor revisions went out for a 30-day "Wait Period" in August 2009. The SEPA compliance review was completed on October 23, 2009. The Record of Decision Amendment to the SEIS was completed and signed by the Seattle District Commander on February 12, 2010, and by the EPA Regional Administrator on February 17, 2010. The

Corps and EPA issued a joint Public Notice (40 CFR 230.80) for the Reauthorization of the Site on February 19, 2010.

The SEIS evaluated two action alternatives and a no-action alternative. The preferred alternative included an adaptive management mound dampening strategy that expands the site volume ceiling up to 23 million cubic yards. The effects of adaptive management - by periodic shifting of the disposal coordinates within the existing target zone (i.e., a 1,200 ft diameter circle around the site center) are depicted in Figure 7. In June 2007, the DMMP agencies implemented a provisional coordinate shift 565 feet southeast of the site center, and the selected Alternative 2 (preferred alternative) in the SEIS adopted this provisional 2007 shift as well as implemented two additional coordinate shifts at 13 million cubic yards (mcy) to the southwest, and one additional coordinate shift at 18 mcy to the northeast corner of the target zone. Table 5 depicts the past, present, and future coordinates for disposal at this site as described above. Figure 8 depicts the effect of coordinate shifts on mound height for the two action alternatives, and Figure 9 depicts the existing and predicted mound configurations, as a result of adaptive management coordinate shifts for the two action alternatives evaluated in the SEIS, and the predicted effects on mound height growth without additional coordinate shifts. It illustrates that active management can significantly reduce mound height growth for the preferred alternative. (Note that the DMMP agencies evaluated the likely future disposal site mound configuration and mound height for two potential alternatives in the SEIS with MDFATE. Data used in MDFATE to predict SEIS alternatives was repeatedly field validated with two bathymetric (2001 and 2003) and two Multibeam bathymetric (2006 and 2007) surveys (see Appendix D to 2009 SEIS)).

Appendix A to the SEIS provides a comprehensive summary of DMMP adaptive management, and 20 years of post-disposal monitoring at the Commencement Bay site compared to the pre-disposal baseline monitoring condition, and demonstrates compliance with the DMMP site management objectives. The site has generally received clean sediments from Blair Waterway, with approximately 97% of the sediments coming from Blair Waterway dredging projects.

Table 5. Commencement Bay Disposal Site Coordinates (past, present and future) for Preferred Alternative Evaluated in Site Reauthorization 2009 SEIS

DMMP Coordinates	Disposal Site Volume (million cubic yards)	Latitude (N)	Longitude (W)
Site Center (1988-2007)	0 – 7.8 mcy	47 degrees 18.21 minutes N	122 degrees 27.91 minutes W
SE corner of Target Zone (2007-present)	7.8 – 13 mcy	47 degrees 18.145 minutes N	122 degrees 27.815 minutes W
SW corner of Target Zone	13 – 18 mcy	47 degrees 18.143 minutes N	122 degrees 28.004 minutes W
NE corner of Target Zone	18 – 23 mcy	47 degrees 18.277 minutes N	122 degrees 27.816 minutes W

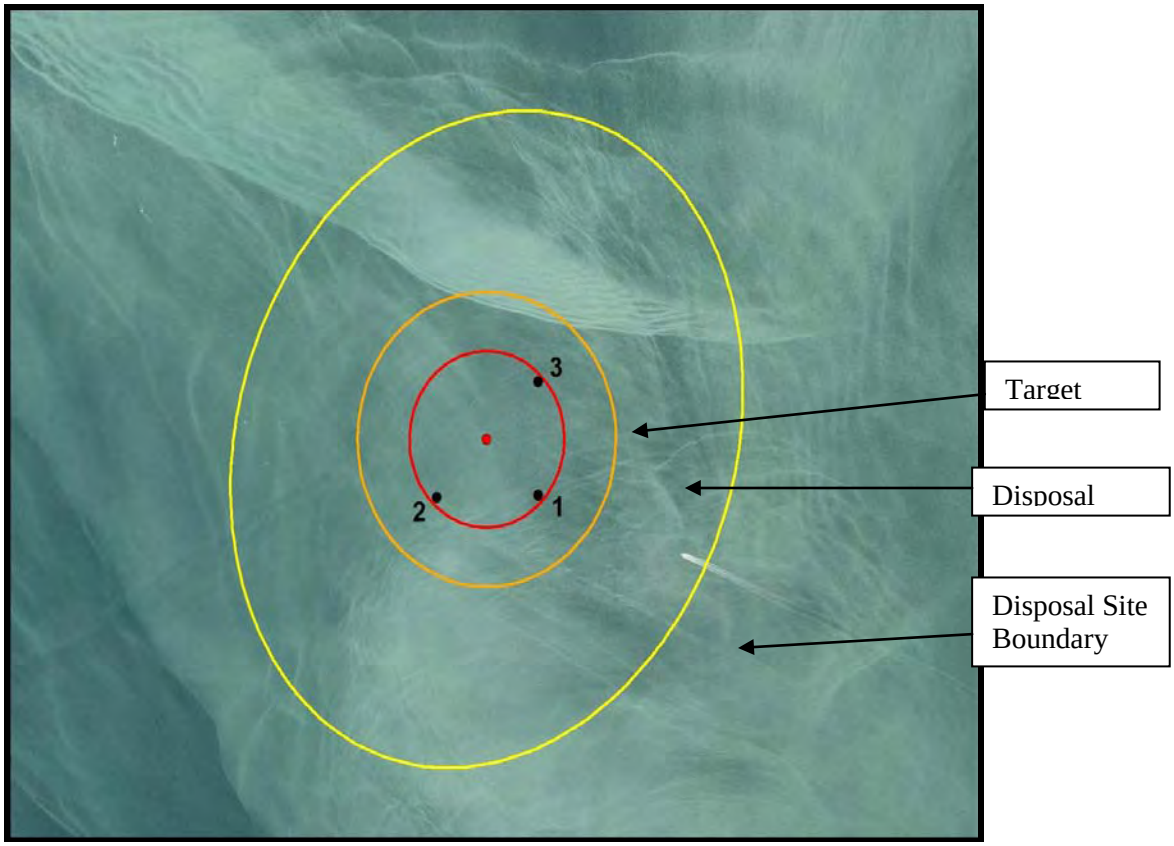


Figure 7. Commencement Bay Disposal Site Disposal Coordinates: Past, Present, Future
Site Center coordinates (1988-2007), (1) SE Coordinates (2007 – present), (2) SW Coordinates (cumulative volume of 13 mcy – 18 mcy); (3) NE Coordinates (cumulative volume of 18 mcy – 23 mcy)

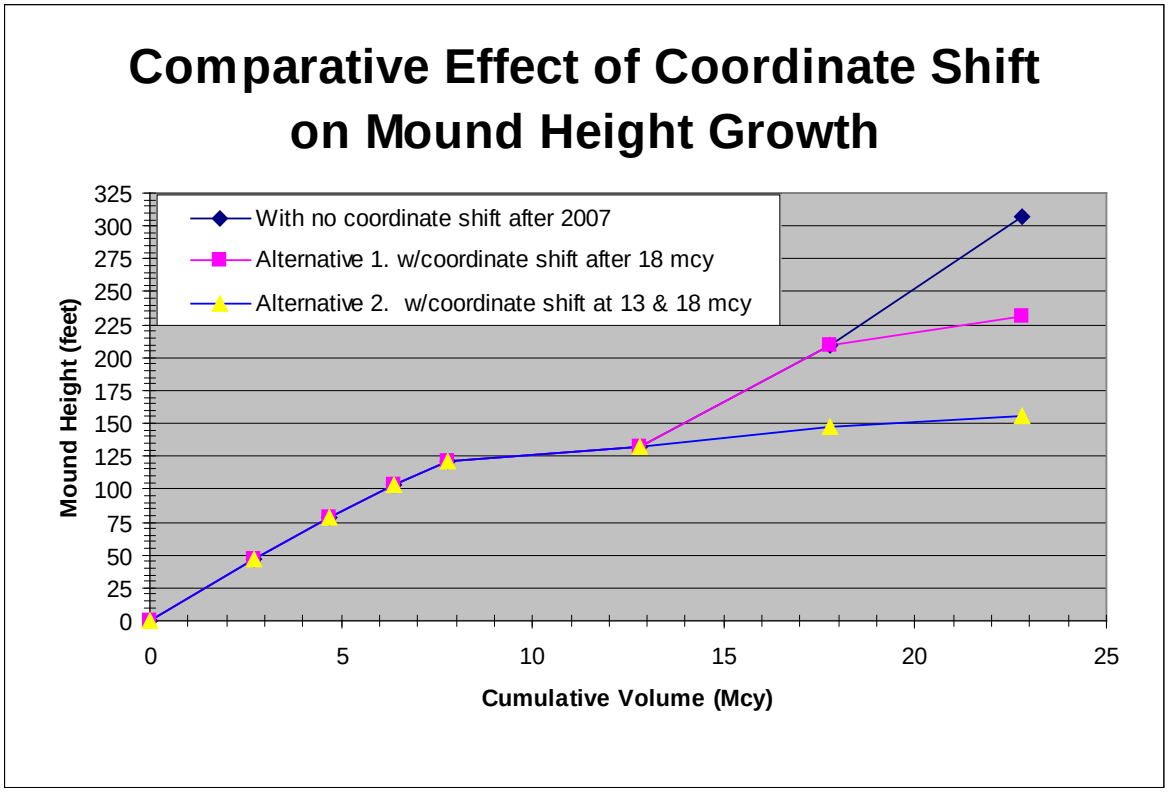


Figure 8. Comparative Effect of Coordinate Shift on Mound Height Growth for two Alternatives evaluated in SEIS.

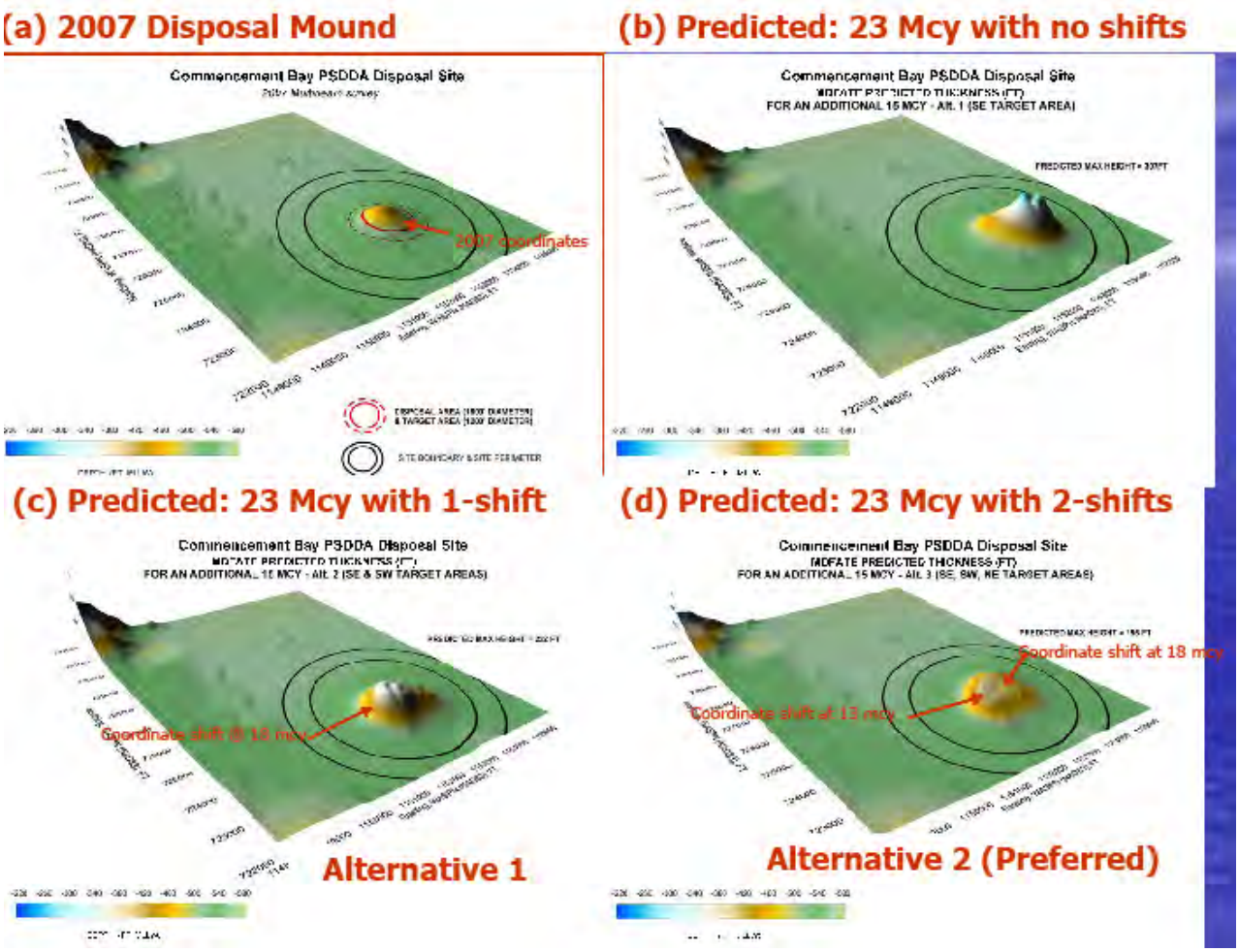


Figure 9. Commencement Bay Site Alternatives (a) Comparative analysis of the existing site, (b) predicted 307 ft mound with 23 mcy with no additional coordinate shifts beyond 2007, (c) Alternative 1: site with 1 additional coordinate shift at 18 mcy, (d) Alternative 2 (Preferred): site with 2 additional coordinate shifts at 13 mcy and 18 mcy after a cumulative disposal volume of 23 mcy.

4.2.2 Elliott Bay Site

The Elliott Bay site is located near the mouth of the Duwamish River, about 0.74 nautical miles (0.85 mile) from Harbor Island. The site is egg-shaped with dimensions of 1,890 by 1,219 meters (6,200 by 4,000 feet), covering an area of 415 acres. The depth of the site is 91 to 110 meters (300 to 360 feet).

The peak current speed on the bottom at the site is less than 15 cm/second, well below the 25 cm/second threshold required to resuspend fine sediments. The direction of currents is variable in Elliott Bay, although a study by McLaren and Ren (1994) documented that sediment transport in Elliott Bay occurs in a clockwise gyre. Elliott Bay sediments are generally very fine-grained material. The inner bay sediments vary from 9 to 12% clay with the highest percentage at the greatest depths. Chemicals of concern including PCBs, PAHs, metals, organic compounds, copper, lead, zinc, cadmium, arsenic, and mercury are commonly found to be elevated in Elliott Bay (PSDDA/FEIS 1988).

The **i**nitial pre-disposal benthic infauna**l survey** at the Elliott Bay site indicated benthos are dominated by large polychaetes and bivalve mollusks. Polychaetes make up 51%, mollusks 39%, and crustaceans only 4% of the biomass. The Benthic Resources Assessment Technique analysis for this area indicated that

four benthic feeding strategy groups of fish were utilizing the benthos within the site and vicinity, primarily represented by Dover sole and English sole (PSDDA/FEIS 1988).

Post-disposal evaluation of this site in 1992, 2000, and 2002 indicated that dredged materials remained onsite, and that the thickest layers were in the center of the target zone. Sediment testing at the site indicated that the concentration of chemicals of concern is well below the allowable "minor adverse effects" level and predominantly below screening levels. Comparative pre-disposal and post-disposal onsite sediment quality monitoring has shown that metals and PAH concentrations have dropped significantly due to dredged material disposal. The DMMP agencies conducted a special monitoring survey in 2005 at onsite stations to evaluate only sediment chemistry following disposal of material determined to be suitable for open-water disposal from the CERCLA early action cleanup in East Waterway. The results of this monitoring noted slightly elevated PCB concentrations at one onsite station, but all chemicals were in compliance with the site management objectives. Overall, monitoring has confirmed that there are no indications of adverse environmental effects beyond the boundary of the disposal site (SAIC, 1992, 2000, 2002).

The disposal of 414,794 cubic yards of dredged material on-site in DY99 prompted a Full Monitoring in 2000 (SAIC, 2000). In addition to meeting the goals of all monitoring efforts, the 2000 monitoring at Elliott Bay was also designed to address concerns related to dredged material disposal at PSDDA sites and the listing of Puget Sound Chinook and Bull Trout as threatened under the Endangered Species Act (ESA) of 1973 (SAIC, 2001). The tests used for ESA concerns included 45-day bioaccumulation tests using *Macoma* and *Nephtys* for sediment and tissue. Physical, chemical, and biological analyses were conducted at up to 61 sampling locations. The results of the 45 day bioaccumulation test showed accumulation of silver, copper, lead, antimony, zinc, mercury, and TBT relative to reference sediments, but no levels exceeding human health standards. The Co-planar PCB analysis of tissue samples from the bivalve *Macoma* and polychaete *Nephtys* showed that uniformly low PCB contamination was observed in the onsite sediments and tissue samples and demonstrated that PCBs were not a concern for either endangered species passing through the site or benthic feeding demersal flatfish species that may be foraging at the disposal site.

Dioxin concentrations in offsite sediments averaged 8.7 pptr (Table 5), whereas observed dioxin concentrations in infaunal benthic tissue, in English sole, and Dungeness crab were generally comparable to observations at other non-dispersive disposal sites (Table 6).

4.2.3 Port Gardner Site

The Port Gardner disposal site is located 2 nautical miles (2.3 miles) west of the Everett Harbor. The 318-acre site is circular with a diameter of 1,219 meters (4,000 feet). The depth of this site is 128 meters (420 feet). The site is relatively flat, with slopes of less than 0.3 meter (1 foot) over a horizontal distance of 61 meters (200 feet).

Currents are weak at this depositional site and move predominantly northward to westward. Pre-disposal sediment at the site was predominantly medium and fine silt with greater than 15% clay. Sediments along the south and east ends were coarser, ranging from fine to very fine sand (PSDDA/FEIS 1988).

Benthic infauna at the Port Gardner site are dominated by large polychaetes and bivalve mollusks. Large numbers of juvenile ophellid polychaetes were also observed in 1986. Benthic biomass averaged 36 g/m^2, with polychaetes making up 50%, bivalves 42%, and crustaceans only 2.4% of the biomass. The Benthic Resources Assessment Technique analysis for this area indicated that four benthic feeding strategy groups of fish were foraging on benthos within the site and vicinity, primarily represented by Dover sole and English sole (PSDDA/FEIS 1988).

Post-disposal evaluation of this site in 1994, and 2006 indicated that dredged material remained onsite. Dredged material was thickest at the center of the target zone and tapered to about 5 cm thick at the edge. Sediment testing at the site indicated that the concentration of chemicals of concern was well below the allowable "minor adverse effects" level and generally below screening levels and SQS (PSDDA 1996, SAIC 2006). The Port Gardner site was used sparingly between 1994 and 2005, but had 722,185 cy in 2006, which triggered a full-monitoring assessment during 2006 (Table 4). The monitoring results confirmed that the dredged material was distributed within the disposal site, and that all chemicals were below Washington State Sediment Quality Standards (SQS), and no indication of onsite toxicity or that sediment chemistry is increasing due to disposal of dredged material. Evaluation of tissue chemistry in the sea cucumber (*Molpadia intermedia*) detected only low concentrations, and no evidence that tissue concentrations of bioaccumative chemicals were increasing over predisposal baseline conditions.

Dioxin concentrations in offsite sediments averaged 4.1 pptr (Table 5), whereas observed dioxin concentrations in infaunal benthic tissue, in English sole, and Dungeness crab were generally comparable to observations at other non-dispersive disposal sites (Table 6).

4.2.4 Bellingham Bay Site

The Bellingham Bay site is approximately 3.5 nautical miles (4 miles) south-southwest of the city of Bellingham, and 1.2 nautical miles (1.4 miles) west of Post Point. The site depth is about 29 meters (96 feet) MLLW. The site is circular with a diameter of 1,158 meters (3,800 feet), and the area of the site is 260 acres. This is the shallowest of the non-dispersive disposal sites.

The Bellingham Bay site is located in a low-energy depositional environment. Pre-disposal sediment conditions included a predominance of silt with 18 to 20% clay. Sediments contained a large quantity of organic material, had BOD_5 concentrations of 2,000 to 2,500 mg/kg of sediment, greater than 8% volatile solids, and about 70% water (PSDDA/FEIS 1989).

Benthic studies at the Bellingham Bay site during July 1987 described a community that was dominated by two taxonomic groups, principally the bivalve Axinopsida serricata, and polychaete worms of the families Terribellidae, Maldanidae, Onuphidae, and Chaetopteridae. Bivalve biomass constituted 61% and polychaetes constituted 21% of the biomass in the top 5 cm of sediment at the site. Crustacean biomass was relatively insignificant throughout the Bellingham Bay study area, constituting less than 3% of the community biomass in the top 5 cm of sediment, and generally less than 1% of the community biomass below 5 cm. (PSDDA/FEIS 1989).

Of the fish found at depths greater than 20 meters (66 feet), longfin smelt were the most numerous in Bellingham Bay (Donnelly et al. 1988) and would probably be the species of greatest importance to salmonids. Juvenile and adult longfin smelt are abundant in the area at times and could be preyed on by adult salmon. These fish were not considered a major predator in the Benthic Resources Assessment Technique (BRAT) analysis (PSDDA/FEIS 1989) and feed on plankton rather than the benthos. Effects of dredged material disposal on longfin smelt and other forage fish would be primarily through burying of epibenthic crustaceans that may be prey for these fish (Simenstad et al. 1979). Pacific herring and sandlance prey predominantly on pelagic copepods and would not be significantly affected by changes in the benthic and epibenthic community.

Post-disposal evaluation of this site in 1993 indicated that dredged materials remained onsite, and that most of the material was in thin layers (<10 cm thick). Sediment testing at the site indicated that the concentration of chemicals of concern was well below the allowable "minor adverse effects" level (Site

Condition II = Nondispersive Site Management Standard; EPTA, PSDDA EIS) and was generally less than the screening levels (PSDDA 1994).

This disposal site has had no disposal since 1998 (Table 4), and the site is currently deactivated pending renewal of the shoreline permit. Dioxin concentrations in offsite sediment averaged 6.9 pptr (Table 5), whereas dioxin concentrations observed in infaunal benthic taxa tissue, and in English sole, starry flounder, and Dungeness crab were comparable or generally lower than the other nondispersive disposal sites (Table 6).

4.2.5 Anderson/Ketron Island Site

The Anderson/Ketron site is located approximately 3 nautical miles (3.5 miles) west-southwest of the town of Steilacoom, midway between Anderson and Ketron Islands. This oval-shaped site is approximately 1,341 by 1,097 meters (4,400 by 3,600 feet), covering 318 acres. The site is 135 meters (442 feet) deep (MLLW).

Although current speeds at depths 15 meters (49 feet) or more above the bottom at the Anderson/Ketron site are at or greater than the critical speed for fine sediment transport (about 25 cm/sec), bottom conditions indicate that this is a depositional site (PSDDA/FEIS 1989). Pre-disposal sediment conditions indicated the sediment grain size was predominantly medium to very fine sand with 4 to 8% clay at the north and south ends. Higher organic content and finer grain size covered much of the area. Sediments contained volatile solids of less than 1% to 4% (PSDDA/FEIS 1989).

The benthic infauna at the Anderson/Ketron site was somewhat different from the other non-dispersive sites in that it had a smaller biomass percentage of mollusks (13%) and a greater biomass percentage of crustaceans (44%). Polychaetes (47%) dominated the benthic infauna biomass. The predominant demersal fish at the site were English sole, Pacific tomcod, and slender sole.

This disposal site has been used only infrequently (seven disposal actions over 21 years) with only a relatively small quantity of material being disposed (total = 140,543 cy). Post-disposal monitoring in Spring 2005 at the Anderson/Ketron disposal site, documented compliance with the DMMP site management objectives, and these site monitoring results are now the new baseline for future site evaluations. The chemistry measured within the disposal site and at perimeter stations were generally below screening levels and SQS levels, on-site sediments were evaluated through toxicity testing and no toxicity was expressed.

Dioxin baseline sediment concentrations (Table 5) and benthic infaunal dioxin tissue concentrations and English sole and Dungeness crab tissue concentrations (Table 6) were comparable to benthic taxa observed at other non-dispersive sites, whereas offsite sediment concentrations averaged 3.6 pptr. The DMMP agencies conducted a special dioxin evaluation at the site following the placement of 97,000 cy of federal material from the Olympia Harbor project (2008). The post-disposal monitoring results demonstrated that the onsite dioxin concentrations were comparatively lower than the 2005 values (3.1 pptr (in 2005) versus 1.1 pptr (in 2008)) and offsite dioxin concentrations were either equal to or lower than the 2005 values.

4.3 Dispersive Sites

4.3.1 Rosario Strait Site

The Rosario Strait site is located approximately 1 nautical mile (1.2 miles) south of Cypress Island, northwest of Shannon Point on Fidalgo Island. The disposal zone is a 457-meter (1,500-foot) circular area that is centered at Latitude N 48° 30.87' and longitude W 122° 43.56'. The disposal site is circular with a 1,829-meter (6,000-foot) radius. The average depth of the site is 37 meters (120 feet).

The seafloor at the Rosario Strait site is composed of coarse-grained sediments, rocks and cobble, typical for areas which experience strong current flows. The currents at the Rosario Strait site have a net speed of 10 to 30 cm/sec, with peak speeds of 100 cm/sec. The prevailing single layer current flow would tend to disperse suspended material southward from the Rosario Strait site. Bathymetric post-disposal monitoring of the Rosario Strait site in 1991, 1994, and 1999 showed that the material did not accumulate on site and was readily dispersed. There was no net accumulation of dredged material compared to the predisposal baseline condition.

Biota at the Rosario Strait site are typical for higher energy environments, with epibenthic organisms dominating rather than infaunal organisms. Abundance and diversity of invertebrates collected by rock dredge at the site were low. Species at stations located in and near the disposal site included non-pandalid shrimp and sea urchins. Dungeness crabs, rock crabs, and pandalid shrimp were not found at the site. Current and bottom conditions made it difficult to sample for bottomfish, and fishes captured are not necessarily representative of fishes in the area. During the siting studies, ringtail snailfish and incidental Dover sole, Pacific sandlance, sculpin, smooth alligatorfish and other snailfishes were captured at the site. Pelagic species which inhabit waters near the site include juvenile Pacific herring, Pacific sand lance, northern anchovy, surf smelt and longfin smelt. Although these forage fishes occur in the area, the site is located away from spawning beaches. Adults and juveniles of all five species of Pacific salmon may occur in the vicinity of the site as they migrate to and from the ocean. Other pelagic species which may occur in the vicinity of the site include steelhead, cutthroat trout and bull trout.

This site is the most frequently used dispersive site in Puget Sound, with a net cumulative volume of 1,932,758 cy over the past 21 years (Table 4), and yearly average disposal volume of 92,036 cy.

4.3.2 Port Townsend Site

The Port Townsend site is located approximately 12 nautical miles (13.8 miles) northwest of Port Townsend. The disposal zone is a 457-meter (1,500-foot) circular area that is centered at Latitude N 48° 13.61' and longitude W 122° 59.03'. The disposal site is circular with a 2,134-meter (7,000-foot) radius. The average depth of the site is 110 meters (361 feet). The substrate at the site is a mixture of sand, gravel and shell.

Mean current speeds at the Port Townsend site are between 30 to 50 cm/sec, with peak speeds of 75 to 100 cm/sec. The east/west movement of the material is dependent on the tide, with net speeds reaching 10 miles per day. At these speeds, the prevailing currents could move suspended sediment to the mouth of Admiralty Inlet in one day, or to Vancouver Island in two days.

Biota at the Port Townsend site are typical for higher energy environments, with epibenthic organisms dominating rather than infaunal organisms. Common biota included pandalid shrimp, scallops and sea urchins. Twelve demersal fish species were caught during the PSDDA siting studies. The most abundant commercial species included Dover sole, rex sole, Pacific cod, and walleye pollock and arrowtooth flounder. Pelagic species which inhabit waters near the site include juvenile Pacific herring, Pacific sand

lance, northern anchovy, surf smelt and longfin smelt. Although these forage fishes occur in the area, the site is located away from spawning beaches. Adults and juveniles of all five species of Pacific salmon may occur in the vicinity of the site as they migrate to and from the ocean. Other pelagic species which may occur in the vicinity of the site include steelhead, cutthroat trout and bull trout.

This site has been used infrequently over the past 21 years, with a cumulative disposal volume of 53,647 cy (Table 4).

4.3.3 Port Angeles Site

The southern border of the Port Angeles site is located approximately 4 nautical miles (4.6 miles) north of Port Angeles (Figure 1 and Figure B-3 in Appendix B). The disposal zone is a 457-meter (1,500-foot) circular area that is centered at latitude N 48° 11.67' and longitude W 123° 24.94'. The disposal site is circular with a 2,134-meter (7,000-foot) radius. The average depth of the site is 133 meters (435 feet). The substrate at the site is a sand/gravel mix with some shell.

No field data for currents exist for the Port Angeles site; however, the peak current speeds are estimated at about 125 cm/sec, with an east/west trajectory. Resuspended material transported in the bottom currents would predominately move eastward, over time probably entering the Strait of Georgia via Haro Strait, and Puget Sound via Admiralty Inlet.

Shrimp were seasonally abundant at the Port Angeles site. Other common invertebrates included scallops and sea urchins. Commercially important fishes caught during the PSDDA siting study included English sole, Dover sole, quillback rockfish and walleye pollock. Pelagic species that inhabit waters near the site include juvenile Pacific herring, Pacific sand lance, northern anchovy, surf smelt and longfin smelt. Although these forage fishes occur in the area, the site is located away from spawning beaches. Adults and juveniles of all five species of Pacific salmon may occur in the vicinity of the site as they migrate to and from the ocean. Other pelagic species that may occur in the vicinity of the site include steelhead, cutthroat trout and bull trout.

This disposal site has only been used once during the past 21 years, with a single project disposal volume of 22,344 cy in 1996.

4.4 PSDDA Site Monitoring

4.4.1 Dispersive Site Monitoring

Dispersive sites are located in areas of high bottom currents where dredged material placed at the site is expected to be rapidly transferred offsite. This precludes practical monitoring for chemically-induced biological effects. Consequently, the dispersive sites are only monitored for physical conditions at the site. To determine if material is remaining at the site or dispersing, baseline and post-disposal monitoring of these sites is conducted.

The surveys consist of using precision vertical soundings to detect mounding of dredged material within the target parameter. During the baseline and post-disposal phases of monitoring, soundings are made over continuous transects which are spaced 100 meters (328 feet) apart, and begin and end 100 meters outside the target area. The baseline and post-disposal soundings are then compared to determine if there is mounding of dredged material within the target area. Baseline studies of the dispersive sites were performed in 1989 (PTI Environmental Services 1989), and three post-disposal bathymetric surveys were

conducted at the Rosario Strait disposal site in 1991, 1994, and 1999, and demonstrated that no accretion of material within the disposal site has occurred.

4.4.2 Non-Dispersive Site Monitoring

Monitoring for non-dispersive sites consists of more rigorous evaluations to determine if the deposited material remains onsite; if the site conditions are being met; and if biological resources are being affected. Monitoring data forms the basis for the annual review of the need for changes in the evaluation procedures and site management plans. The frequency of post-disposal monitoring events varies by site and disposal volume. PSDDA's initial monitoring framework envisioned that monitoring would be more frequent initially, and be reduced through time as monitoring validated adherence to the site management objectives. The initial trigger for either full or partial monitoring was placement of 150,000 cubic yards at a site. In 1996, the trigger was increased to 300,000 cubic yards. In 2002, the DMMP agencies established a volume trigger of 500,000 cy to initiate monitoring at the Commencement Bay site, Elliott Bay site, and the Port Gardner site. A 300,000 cy volume trigger remains in effect for initiating monitoring at the Bellingham Bay site and the Anderson/Ketron Island disposal site. The monitoring involves the collection of physical, chemical and biological data at and near the site. Three types of post-disposal monitoring events are distinguished in the PSDDA monitoring framework:

Full Monitoring - Mapping of the disposal site is accomplished through the use of a sediment vertical profiling system (SVPS), which determines the depth and spread of dredged material. Box core benthic samples and SVPS photos are used to provide quantitative and qualitative information on benthic infaunal conditions onsite and offsite. Chemical monitoring is used to evaluate the concentrations of chemicals of concern present on and off the site, and whether or not they are present in concentrations that could cause unacceptable adverse impacts. Biological monitoring includes toxicity bioassays to assess onsite-dredged material. Additionally, offsite benthic communities are evaluated by a comparison of baseline data and post-disposal data along a gradient to determine if unacceptable impacts from dredged material disposal are occurring. Monitoring parameters evaluated include sediment chemistry, sediment bioassays, infaunal tissue chemistry, and infaunal abundance.

Partial Monitoring - For material with no or few Screening Level (SL) exceedances, less rigorous site monitoring occurs. Partial monitoring includes bathymetric mapping of the site and use of a SVPS to determine the depth of dredged material and sediment dispersal. The SVPS is also used to provide information on general benthic conditions onsite and offsite. Partial monitoring also includes collection of sediment at and near the site for analysis of chemicals of concern. No quantitative biological information (box cores) is collected during partial monitoring events.

Tiered Monitoring – Only a portion of the samples are analyzed to verify that deposited material is staying on-site and that site conditions are met. If analysis of samples indicates that there may be unacceptable impacts offsite, the archived samples are analyzed to determine if biological resources are being affected.

Baseline monitoring of the non-dispersive sites was conducted in 1988 (Phase I sites) and 1989 (Phase II sites) to document existing conditions and for use as a benchmark for post-disposal monitoring studies. Details of baseline studies are provided in PTI Environmental Services (1988, 1989). The types of samples collected as part of the baseline studies included sediment chemistry, toxicity (bioassays), field collected tissue chemistry, and benthic infauna.

4.4.3 Post-Disposal Monitoring Events

All five nondispersive sites have had post-disposal surveys. To date, the DMMP agencies have conducted 23 post-disposal monitoring surveys at nondispersive sites including:

- 7 full monitoring events (Port Gardner – 1990, 2006; Elliott Bay - 1992 and 2000; Commencement Bay – 2001, 2007); and Anderson/Ketron Island – 2005
- 5 tiered-full monitoring events (Port Gardner – 1994, 2010; Elliott Bay – 2002; Commencement Bay – 1995, 2003);
- 2 partial monitoring events (Elliott Bay – 1990 and Bellingham Bay – 1993)
- 2 tiered-partial monitoring events (Commencement Bay – 1996, 2004
- 7 special surveys (side-scan survey at Bellingham Bay - 1993; side-scan survey at Elliott Bay - 1995; and SPI survey at Commencement Bay – 1998; Elliott Bay – 2005 (onsite chemistry); Commencement Bay – 2005 (SPI and Phenol special study); and
- 4 bathymetric surveys at Commencement Bay – 2001, 2004, 2006, 2007 (e.g., 2006 and 2007 were Multibeam bathymetric surveys)

Based on PSDDA site monitoring data to date (including physical mapping, onsite and offsite chemistry, sediment toxicity, offsite infaunal bioaccumulation, and offsite benthic community structure data), dredged material disposal is not causing adverse impacts at or adjacent to the nondispersive sites. The Commencement Bay site is included in these results. During 2001 monitoring, a thin dredged material footprint was observed beyond the site boundary, and extensive monitoring was conducted (after the site was closed for one-year) to fully evaluate and document that there was no evidence of contamination, toxicity, or benthic community impacts. PSDDA/DMMP evaluation procedures, as evidenced by 20 years of monitoring results appear to have adequately protected the environmental conditions at all the disposal sites.

5 EFFECTS ANALYSIS

This first portion of the effects analysis focuses on the general impacts of usage of PSDDA disposal sites, while species-specific discussions follow in Section 7. The broader discussion in this section largely focuses on effects relevant to anadromous salmonids, but the sub-section on prey and trophic structure addresses potential impacts on the food chain and is therefore applicable to marbled murrelets and Steller sea lion as well.

The following evaluation is loosely based upon the NMFS Matrix of Pathways and Indicators (NMFS 1996), which is a set of guidelines designed to facilitate and standardize the determination of effects of projects/actions on listed anadromous salmonids. The NMFS matrix, along with a similar USFWS matrix developed for bull trout, was developed for freshwater environments and is not directly applicable to estuarine and marine waters. The following discussion is therefore organized around a set of modified pathways and indicators. Several pathways/indicators routinely included in evaluations for marine and estuarine waters were excluded from this analysis because they are not relevant to the deep-water PSDDA sites (e.g., shoreline and riparian conditions, refugia). Since numerical criteria for habitat functionality (e.g., between 50 and 57° F = properly functioning water temperature) are currently unavailable for estuarine and marine waters, this evaluation is qualitative rather than quantitative in nature.

5.1 Water Quality

5.1.1 Turbidity

5.1.1.1 Transport Activities.

The potential for overboard sloughing or leaking of dredged material from barges during the transport of material to the disposal sites is minimized by the design of modern barges (sideboards on the deck and seals on the bottom dump doors) and the typical operation practices of the contractors (loading practices and deck cleaning prior to leaving the dilution zone). If any significant leaking is noted, the contractor must correct the situation before leaving the dredging dilution zone. If an unnoticed leak were to occur, it would result in a small trailing plume, which would be spatially insignificant in relation to the movements of listed species (i.e., potential for an animal to contact this material in the water column would be negligible). Additionally, the prop wash from the tug boat would likely cause enough turbulence to quickly disperse the small amount of sediment. Therefore, significant sloughing or leaking of dredged material during transport to a PSDDA disposal site is unlikely.

The potential for winds to carry sediments from a transport barge to the water column is also small. The types of sediments that can typically be mounded on a barge (and thus would be most exposed to wind) are either granular or very cohesive and clay-like. Granular sediments contain little fine or organic material, would be relatively inert, and would pass through the water column very quickly. More claylike sediments generally have a high moisture content, which would resist windborne transport. The amount of time between loading and discharge of dredged materials at the disposal site is relatively short (hours), which gives finer material little time to dry and become less cohesive during the transport process. Thus, the potential for windborne transport of these types of materials is minimal.

5.1.1.2 Disposal Activities.

Disposal of dredged material will result in elevated turbidity levels. During monitoring at other disposal sites across the country, maximum concentrations of suspended sediments observed during disposal activities were less than 1,000 mg/l (Pequegnat 1983). Truitt (1986) found that very little suspended sediment persists near the surface or midwater during dredged material disposal during a capping demonstration project in Duwamish Waterway. As Figure 10 demonstrates, the highest concentrations tend to occur in near-bottom waters, and are typically much lower (less than 200 mg/l) in mid and upper water depths.

Turbidity levels generally return to ambient conditions rather quickly, and relatively little material is separated from the jet as it descends into the water column when a clamshell dredge has been used (as described in Section 2.3.1). PSDDA/DSSTA (1989) evaluated the transport and duration of suspended sediment in the water column following a generic disposal event at the dispersive sites. At the end of 1 hour, calculations indicated that suspended sediment traveled 1,097 meters (3,600 feet). Concentrations associated with this loss of sediment from the jet were approximately 0.25 mg/l, which is approximately one-quarter of the ambient concentration. After 6 hours (one ebb or flood tide), the material was calculated to have traveled 6,584 meters (21,600 feet) and the concentration of suspended solids was reduced to 0.0007 mg/l. Figure 10 illustrates the relatively short duration of elevated suspended sediment concentrations in the water column at a non-dispersive site. As the graph illustrates, total suspended sediments at the middle and upper depths remained elevated for about 12 minutes.

Turbidity studies cited in Pequegnat (1983) found that lethal concentrations of suspended sediments for adult marine organisms were an order of magnitude or higher than maximum suspended sediment concentrations observed in the field during dredging and disposal operations. In addition to the effects

caused by decreased visibility for behaviors such as feeding and homing, territoriality, and avoidance responses, potential sub-lethal effects of increased suspended sediment concentrations on salmonids include: biochemical stress responses (elevated plasma glucose and cortisol levels), impaired osmoregulatory capacity, gill flaring (a response to gill irritation equivalent to a cough), impaired oxygen exchange due to clogged or lacerated gills, and reduced tolerance to infection.

Duration of suspended sediments, timing of the event, and particle size and shape have been shown to influence the potential affect of increased turbidity on Pacific salmon juveniles, but there is little specific information on thresholds of physical, physiological, or behavioral tolerances for particular species. It is unknown what threshold of turbidity might exist that serves as a cue to fish to avoid light reducing turbidity. The primary determinate of risk level for a particular species is likely to lie in the spatial and temporal overlap between the area of elevated turbidity, the degree of turbidity elevation, the occurrence of the fish, and the options available to the fish for carrying out the critical function of their particular life-history stage (Nightingale and Simenstad 2001).

Laboratory experiments like those cited above have yielded some information on the response of fish to elevated suspended sediment concentrations, but application of this information is difficult given the often conflicting results attributable to variations in experimental design. For example, some mortality of Chinook and coho smolts occurred over short-duration exposures to suspended sediment levels from 500 mg/l to 1,400 mg/l (Newcombe and MacDonald 1991). LeGore and Des Voigne (1973) conducted 96-hour bioassays on juvenile coho salmon using re-suspended Duwamish River sediments. Acute effects were not observed at suspended sediment concentrations up to 5 percent (28,800 mg/l dry weight), and then only after prolonged exposure. This concentration is well above that measured during disposal operations.

For short-term exposures (<4 days) to sub-lethal concentrations (14,400 mg/l), osmoregulatory capacity of salmonids is not impaired (Servizi 1990). Sockeye have been shown to exhibit gill damage at exposures of 3,100 mg/l over 96 hours (Servizi 1990). Biochemical responses and gill flaring appear to be reversible, as recovery occurs when the stressor is removed or the fish escapes the plume. However, if the stress is chronic, a metabolic cost may be incurred (Servizi 1990). Exposure to suspended sediment loads in the range of 2,000 to 4,000 mg/l caused a temporary elevation in plasma cortisol concentration, but this response was considered moderate when compared to fish exposed to handling stress and confinement (Redding et. al. 1987).

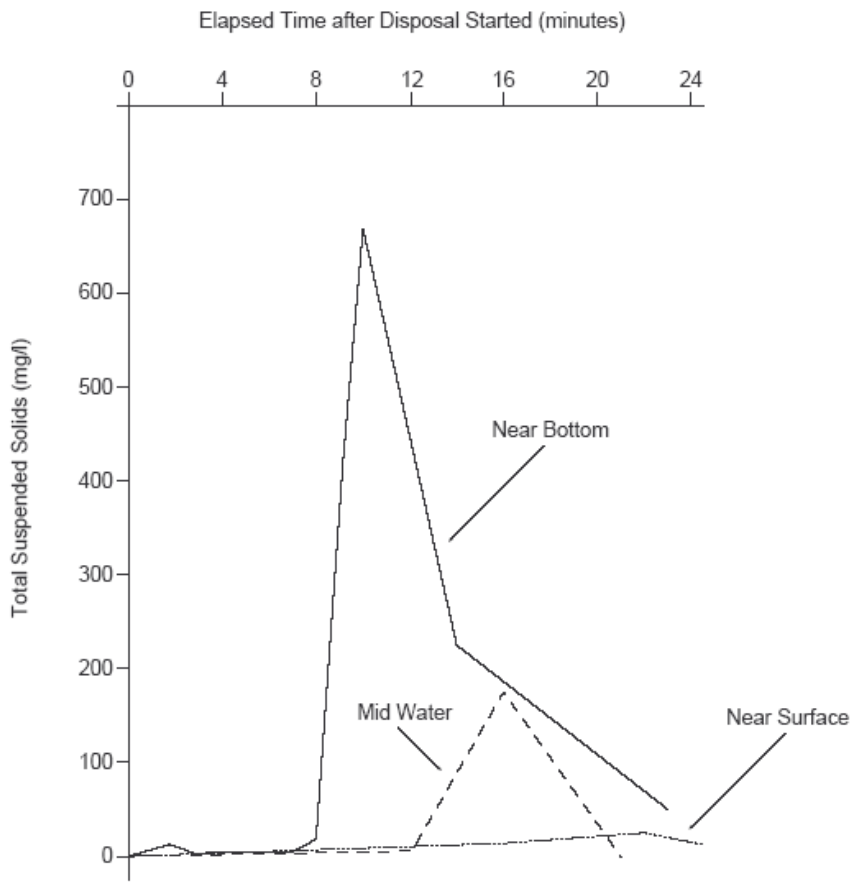
Bioassay-type tests generally measure an endpoint, often mortality, under conditions dissimilar to those organisms encounter in the field. Dose-response relationships measured under laboratory conditions tend to simulate a worst case scenario for motile organisms, which can often avoid unsuitable conditions (Clarke and Wilber 1999). Under most scenarios, fish and other motile organisms encounter localized suspended sediment plumes for exposure durations on a temporal scale of minutes to hours (Clarke and Wilber 1999). Testing protocols utilizing brief exposure periods and representative sediment periods would better clarify the actual hazards (Servizi 1990). A few generalizations can be taken from this collection of research, however. Smolts are the life history stage most sensitive to elevated turbidity. For this reason, dredging work closures periods are implemented to avoid dredging and disposal operations during juvenile salmon outmigration periods. It is also clear that the turbidity levels generally associated with disposal operations are not high enough to cause acute physiological injury to adult fish.

Effects of increased suspended sediment concentrations on salmonids may also include reduced foraging success and deterrence from migratory paths. Increased turbidity levels could affect the feeding success of marbled murrelets and Steller sea lions as well. Sediment suspended at the surface or midwater would be more likely to affect foraging than sediments dispersed on or near the bottom for all these species, except perhaps the Steller sea lion. Almost all pelagic juvenile and yearling Chinook salmon captured in

Puget Sound by Beamish et al. (1998) were collected at a depth of 30 meters (98 feet) or less. Most Chinook salmon caught off the east and west coasts of Vancouver Island by Taylor (1969) were found at depths of 73 meters (240 feet) or less. Recent acoustic telemetry work in Puget Sound indicates that bull trout frequent shoreline areas and are infrequent migrants across deep waters (Goetz et al. 2004). One char monitored with a depth tag as part of the Goetz et al. (2004) study tended to spend most its time at depths of 5 to 10 meters, with mid-day migrations to deeper waters (less than 25 meters). All but two of the disposal sites are located in areas more than 90 meters (295 feet) deep; the Rosario Strait site is located at a depth of 30-43 meters and the Bellingham Bay site is located at a depth of 29 meters. The potential for turbidity associated with dredged material transport and disposal to affect salmonid migratory paths is addressed in Section 4.3 below.

Disposal activities will temporarily degrade this indicator during and immediately following discharge events, but will maintain existing conditions over the long term. The available evidence summarized above indicates that suspended sediment concentrations sufficient to cause adverse effects would be limited in extent. Dredging and disposal operations will degrade water quality on a localized and temporary basis, neither over the long term nor throughout the entire action area. Adult salmonids are expected to avoid these areas readily, while juveniles would be less able to avoid such areas. Therefore, timing restrictions are in place to reduce the potential for exposure of fish at sensitive life stages. This will reduce impacts to a discountable level.

Figure 10. Time Series of Total Suspended Solids at Three Depths during Dredged Material Disposal



SOURCE: Truitt 1986 in Corps 1986.

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5.1.2 Dissolved Oxygen

Anaerobic sediments create an oxygen demand when suspended in the water column, which decreases dissolved oxygen levels. Given the rapid descent of material dredged by a clamshell dredge and the generally well-mixed nature of waters within the action area, disposal activities are not likely to lead to appreciable reductions in dissolved oxygen in the mid and upper portions of the water column. Conditions would be degraded in a localized area on a short-term basis, but would be maintained over the long term.

At the non-dispersive disposal sites, reductions in dissolved oxygen levels would be expected to be larger and more persistent in the lower portion of the water column. However, monitoring of experimental disposal sites in Elliott Bay during and up to 9 months after disposal showed no significant long-term impacts to water quality (PSDDA/FEIS 1988). Impacts to salmonids associated with degradation of dissolved oxygen levels near any mounds of dredged material are not expected to occur since pelagic juveniles and adults have a distribution higher in the water column. At the dispersive sites, oxygen-demanding materials would be rapidly diluted and any decrease in dissolved oxygen content in the water would be un-measurable.

5.1.3 Chemical Contamination

Sediment-bound contaminants associated with suspended sediments may dissolve in the water column and result in impacts to water quality. However, sediments are rigorously tested for chemicals of concern and potential for biological effects before they are determined to be suitable for disposal at PSDDA sites. It should be noted that the effects testing is focused on assessing benthic impacts, and not necessarily tied to protecting fish directly. The disposal sites were selected to minimize impacts to commercial invertebrate and fish resources. Any exposure to contaminants would be either avoided by fish moving through the disposal site, or of a very short duration in the water column following disposal. Dredged material that contains higher levels of contaminants is disposed at Washington Department of Ecology approved confined disposal sites in upland or nearshore areas. Therefore, exposure of listed species to significant levels of contaminants is not expected.

Nutrients in sediments released to the water column when materials are discharged could affect phytoplankton production. However, any such effect would be small, temporary, and would not affect the overall productivity of the action area. Considering the nutrient inputs to nearshore waters from rivers, any changes in primary productivity would be unmeasurable.

5.1.4 Dioxin Regulation in Puget Sound

As part of an effort to gather dioxin data at all Puget Sound non-dispersive disposal sites, the DMMP agencies collected dioxin/furan baseline data at the Commencement Bay, Elliott Bay, and Bellingham Bay sites in 2007. These data complemented dioxin data previously collected at the Port Gardner site in 2006, and the analysis of archived sediment and benthic infaunal tissue samples collected at the Anderson/Ketron Island site during 2005 monitoring. The analysis of the Anderson/Ketron Island samples for dioxin/furans was triggered in 2006 after dioxin reason-to-believe issues surfaced for the Olympia Harbor Federal/Port Navigation and operation and maintenance project in lower Budd Inlet.

These data were used in part to develop an interim regulatory approach for dioxins. During the 2007 monitoring effort at Commencement Bay, sediment and tissue samples were collected and analyzed. Additionally, the DMMP agencies agreed to conduct special dioxin/furan sampling efforts at Elliott Bay

and Bellingham Bay disposal sites for sediment and tissues. Special efforts were made to collect representative benthic infaunal species at each disposal site for dioxin analysis. This effort also included conducting near site trawling with a 7.6 meter Otter Trawl to collect representative demersal fishes, targeting samples of English Sole for dioxin analysis, and Dungeness crab meat and hepatopancreas samples for dioxin/furans analyses. These analyses consisted of 3 composited analyses each of representative demersal flatfish species and crab samples (e.g., 5 crabs per analysis and 5 whole fish per analysis).

Table 5(a) summarizes the onsite and offsite dioxin in sediments, as the total Toxic Equivalence Quotients (TEQ) summed for all 17 congeners of dioxin/furan using the 2005 World Health Organization Toxic Equivalency Factors (TEFs) for all five non-dispersive sites. These analyses show that the order from highest to lowest dioxin/furan TEQ's was Elliott Bay > Bellingham Bay > Port Gardner > Anderson/Ketron Island > Commencement Bay.

The DMMP agencies have published a proposed revised Puget Sound interim framework for interpreting dioxin data for open-water disposal (http://www.nws.usace.army.mil/PublicMenu/Menu.cfm?sitename=DMMO&pagename=Dioxin_Guidelines). The background based approach proposed was based on an extensive 3-year interagency/stakeholder process, which also included establishing a non-urban background dioxin standard based on a 2008 Puget Sound interagency cooperative investigation sponsored by Region 10 EPA (http://www.nws.usace.army.mil/PublicMenu/Doc_list.cfm?sitename=DMMO&pagename=Bold_survey). The public comment period closed on 30 June 2010. The proposed guidelines follow, and following consideration and evaluation of comments received, standards will be promulgated upon a determination by the heads of the DMMP agencies and the Puget Sound Partnership.

Dispersive Site Management Objective: 4 pptr (parts per trillion, dry-weight) 2,3,7,8-tetrachloro-p-dibenzodioxin toxicity-equivalents (TEQ) will be defined as the Site Management Objective for all dispersive disposal sites in Puget Sound. This value is based on an upper bound estimate of the distribution of dioxin in sediments from non-urban areas of Puget Sound 1.

Dispersive Dredged Material Suitability Guideline: The Dredged Material Suitability Guideline is the maximum dioxin concentration allowed in any single Dredged Material Management Unit (DMMU). For dispersive sites, this guideline is set equal to the Dispersive Site Management Objective of 4 pptr TEQ. Other dioxin concentrations can be approved on a case-by-case basis, if demonstrated to be consistent with the anti-degradation provisions in the Sediment Management Standards (SMS) rule.

The currently in-place interim framework for Puget Sound specific non-dispersive sites directs a project-specific comparison of dioxin/furan concentrations in project dredged material to the disposal site background, outside the boundary of the disposal site. The site-specific guidelines for the five Puget Sound non-dispersive disposal sites are depicted in Table 5 (a), and specify the following:

Nondispersive Sites. a comparison of dioxin in test sediments to disposal-site background, defined using disposal site-specific monitoring data, which include an offsite maximum concentration, and an offsite average concentration.

Dioxin concentrations in any given DMMU may not exceed the site specific maximum
Average dioxin concentrations (weighted to the volume of each DMMU) cannot exceed the site-specific mean offsite concentration.

Dispersive Sites: No DMMU may exceed a suitable reference area. (An example reference area is shown in Table 6.)

Table 6. Interim Dioxin Guidelines utilized to evaluate Projects within DMMP*

(a) Puget Sound Nondispersive Site Offsite Interim Guidelines				
Disposal Site	Mean	Maximum	Range	n = # of stations
Anderson/Ketron Island	3.6	6.8	1.7 – 6.8	n = 7
Commencement Bay	2.4	5.2	0.86 – 5.2	n = 10
Elliott Bay	8.7	12.2	4.0 – 12.2	n = 11
Port Gardner	4.1	5.2	3.1 – 5.2	n = 9
Bellingham Bay	6.9	10.5	4.3 – 10.5**	n = 9
(b) Puget Sound Dispersive Site Interim Guidelines				
Samish Bay Reference: 2.44				

* dioxin concentrations expressed in pptr-dry weight-TEQ
** mean excludes benchmark station BBB01 located near the Georgia Pacific Outfall with 22 pptr-dry-weight-TEQ

Table 7 summarizes the dioxin/furan invertebrate and flatfish tissue data collected during 2007 at the Commencement Bay site, Elliott Bay site, and the Bellingham Bay site. It also includes archived tissue samples analyzed at the Anderson/Ketron Island site in 2006, and tissue data collected at the Port Gardner site during 2006 monitoring previously discussed. Additionally, the Puget Sound Ambient Monitoring Program (PSAMP) provided the DMMP with Dungeness Crab and English Sole samples from their monitoring efforts in Nisqually Reach during 2007. These samples were collected from the vicinity of the Anderson/Ketron Island site in order to supplement the DMMP's efforts to evaluate dioxin in tissues from this location.

Dioxin/furan tissue data have been collected for six polychaete species, three bivalve species, Dungeness crab (meat and hepatopancreas), and two species of flatfish (English Sole, and Starry Flounder). English sole was the only sampled species that was collected at all five sites. Dioxin/furan concentrations in English Sole (whole body) ranged from 0.69 ppt-TEQ to 0.29 pptr-TEQ. Dungeness Crab samples were collected at four sites. No crabs were found at the Commencement Bay site, which is consistent with the 1986 siting resource studies. Edible meat concentrations in crab ranged from 0.46 pptr-TEQ at the Anderson/Ketron Island site to 0.09 pptr-TEQ at the Bellingham Bay site. Crab hepatopancreas concentrations ranged from 13.5 pptr-TEQ at the Anderson/Ketron Island site to 2.04 pptr-TEQ at the Port Gardner site.

If implemented, the revised new interim dioxin guidelines currently being considered, would result in effects on listed species, and habitat that would be even less than the existing dioxin guidelines in place over the past three years.

Table 7. Dioxin/Furan Tissue Concentrations (pptr-TEQ*) in the Vicinity of DMMP Nondispersive Disposal Sites (after SAIC, 2008b)

Taxa	Anderson/Ketron Island	Commencement Bay	Elliott Bay	Port Gardner	Bellingham Bay
BENTHIC:					
Annelids:					
Capitellidae					0.37 (0.21 – 0.59), n = 8
Glyceridae		0.38 (0.26 - 0.56), n = 7	0.94 (0.31 – 2.51), n = 8		0.40 (0.19 – 0.61), n = 2
Maldanidae		0.35 (0.23 - 0.43), n = 4	0.49 (0.42 – 0.53), n = 3		
Nephtys sp.				0.13 (0.09 - 0.16), n = 9	
Spiondae					0.21 (0.16 – 0.25), n = 3
Travisia sp.		0.85 (0.66 - 1.07), n = 4	0.66, n = 1	0.42 (0.36 - 0.60), n = 9	
Bivalves:					
Compsomyax sp.	0.07 (0.05 - 0.13), n = 3	0.08 (0.06 - 0.09), n = 2			0.07 (0.06 – 0.083), n = 5
Yoldia sp.	0.47, n = 1				
Macoma sp.	0.14, n = 1				0.12 (0.09 – 0.14), n = 3
Dungeness Crab *(Cancer magister)*					
(Meat)	0.46 (0.214 - 0.716), n = 3		0.18, n = 1	0.19 (0.18 - 0.19), n = 3	0.09 (0.07 – 0.11), n = 3
(Hepatopancreas)	13.5 (11.5 - 14.9), n = 3		5.55, n = 1	2.04 (1.7 - 2.8), n = 3	2.6 (1.7 – 3.3), n = 3
English Sole (*Parophrys vetulus*) (whole body)	0.29 (0.172 - 0.345), n = 3	0.66 (0.49 - 0.92), n = 3	0.69 (0.41 – 1.03), n = 3	0.44 (0.28 - 0.57), n = 3	0.29, n = 1
Starry Flounder (*Platichthys stellatus*) (whole body)					0.10 (0.07 – 0.146), n = 3

*Undetected congeners of dioxin/furan were summed at ½ detection limits; Table entries show mean concentration, range (in parenthesis); number of observations (n)

5.2 Sediment

5.2.1 Physical Characteristics

At the non-dispersive PSDDA sites, changes in sediment character (e.g., percent silt, clay, sand, gravel) have occurred since usage of the sites began 21 years ago. In addition to temporary impacts to benthic fauna from burial, changes in sediment character can affect the structure and productivity of benthic communities within the disposal site.

The monitoring results at Port Gardner in 1994, and 2006, and at the four other non-dispersive sites indicated that all the site management objectives were generally met. Site management objectives (PSDDA Site Management Technical Appendix) are evaluated at all five non-dispersive sites by evaluating 3 broad monitoring questions, and 6 testable hypotheses as depicted in Table 8. The DMMP updated the existing Environmental Monitoring Plan in 2007 (http://www.nws.usace.army.mil/PublicMenu/documents/DMMO/Updated_Environmental_Monitoring_Plan_-_Final_-_January_2007.pdf). In the few cases where benthic taxa depressions were noted at transect stations (hypothesis 6), similar observations were also noted in the same benthic major taxa at benchmark stations outside the direct influences of dredged material disposal. The monitoring results also confirmed that there were no unacceptable adverse effects on biological resources immediately offsite due to dredged material.

Monitoring of benthic fauna just outside the Elliott Bay site in 1992 verified that there were no adverse environmental effects beyond the boundary of the disposal site (PSDDA 1994). The abundance of major benthic taxa at the transect stations was similar to the abundances measured during baseline studies.

Questions	Hypothesis	Monitoring Variable	Interpretive Guideline	Action Item when exceeded*
No.1 Does the deposited dredged material stay onsite?	**1.** Dredged material remains within the site boundary?	Sediment Profile Imagery (SPI) Onsite & Offsite	Dredged material > 3 cm at the perimeter stations	Further assessment is required to determine full extent of dredged material deposit.
	2. Chemical concentrations do not measurably increase over time due to dredged material disposal at offsite stations.	Sediment Chemistry Offsite	Washington State Sediment Quality Standards and Temporal Analysis	Post-disposal benchmark station chemistry is analyzed and compared with appropriate baseline benchmark station data.
No. 2 Are the biological effects conditions for site management exceeded at the site due to dredged material disposal?	**3.** Sediment chemical concentrations at the onsite monitoring stations do not exceed the chemical concentrations associated with PSDDA Site Condition II guidelines due to dredged material disposal	Sediment Chemistry Onsite	Onsite chemical concentrations are compared to DMMP maximum levels.	PSDDA agencies may seek adjustments of disposal guidelines and compare post-disposal benchmark chemistry with appropriate baseline benchmark station data.
	4. Sediment toxicity at the onsite stations does not exceed the PSDDA Site Condition II biological response guidelines due to dredged material disposal.	Sediment Bioassays Onsite	DMMP Bioassay Guidelines (Section 401 Water Quality Certification)	Benchmark station bioassays are performed (if archived after monitoring) and compared with baseline benchmark bioassay data.
No. 3 Are unacceptable adverse effects due to dredged material disposal occurring to biological resources offsite?	**5.** No significant increase due to dredged material disposal has occurred in the chemical body burden of benthic infaunal species collected down current of the disposal site	Tissue Chemistry Transect	Guideline values Metals: 3x baseline conc. Organics: 5x baseline conc.	Compare post-disposal benchmark tissue chemistry with baseline benchmark tissue chemistry data.
	6. No significant decrease due to dredged material disposal has occurred in the abundance of dominant benthic infaunal species collected down current of the disposal site.	Infaunal Community Structure Transect	Guideline values Abundance of major taxa < 1/2 baseline macrobenthic infaunal abundances	Compare post-disposal benchmark benthic data with baseline benchmark data.

Table 8. DMMP Nondispersive Site Monitoring Framework

Full monitoring at the Commencement bay site in 1995, 2001, 2003, and 2007 confirmed that benthic resources were not being impacted outside the site boundary by disposal of clean dredged material. Moreover, the results for 2001 and 2003 indicated that taxa specific abundances actually increased from the baseline abundances for all taxonomic groups (polychaetes, crustacean, mollusks). Apparent reductions in specific benthic taxa abundance (arthropods and mollusks) in 2007, were attributable to area wide changes to benthic community structure, and not due to dredged material disposal. Benthic Community structure observed during Sediment Profile Imagery Surveys have consistently shown high benthic habitat values and evidence that benthic taxa are generally not being physically displaced by disposal of clean dredged material throughout most of the disposal site. Sediment Profile Images (SPI) have generally documented Climax Stage III communities throughout the site (Figure 11), which indicate that benthic infaunal taxa are generally able to recover from individual disposal events, when the dredged material cover is less than 10 cm during each incremental disposal as documented by the presence of

Stage I / III Communities (Figure 12). Even after a cumulative volume of 8 million cubic yards at this site, the benthic community structure continues to exhibit a healthy, robust structure.

Pioneer Community ⟶ Climax Community

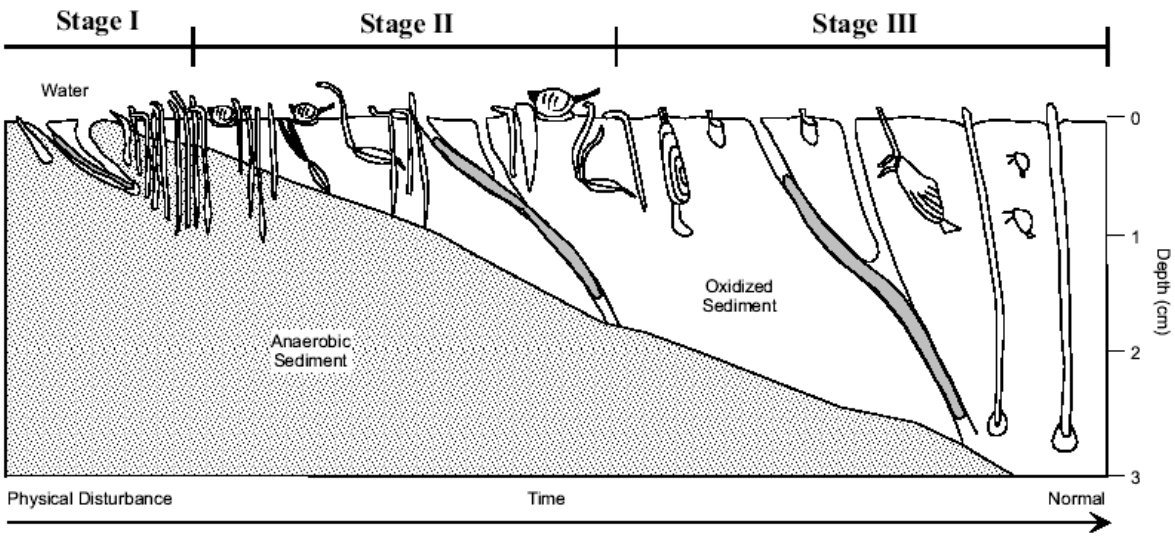


Figure 11. Idealized Development of Infaunal Successional Stages (after Pearson and Rosenberg, 1978)

Changes in sediment characteristics have not occurred at the dispersive sites since materials do not mound, and are quickly dispersed. The preponderance of material disposed of at the most used dispersive site, the Rosario Strait site, is clean sand from the Swinomish River and clean fine-textured sediment from Squalicum Waterway in Bellingham Harbor (no material from Squalicum Waterway disposed since 2004). Three bathymetric surveys conducted in 1991, 1994, 1999, and 2009 verified that no material has accumulated on the bottom within the disposal site, due to the highly dispersive environment.

Any impacts to benthic infauna resulting from changes in sediment character at the disposal sites would not have a measurable effect on salmonids because they do not typically feed or otherwise utilize habitats at the depths of the disposal sites. Food web relationships are addressed further in Section 4.4 below.

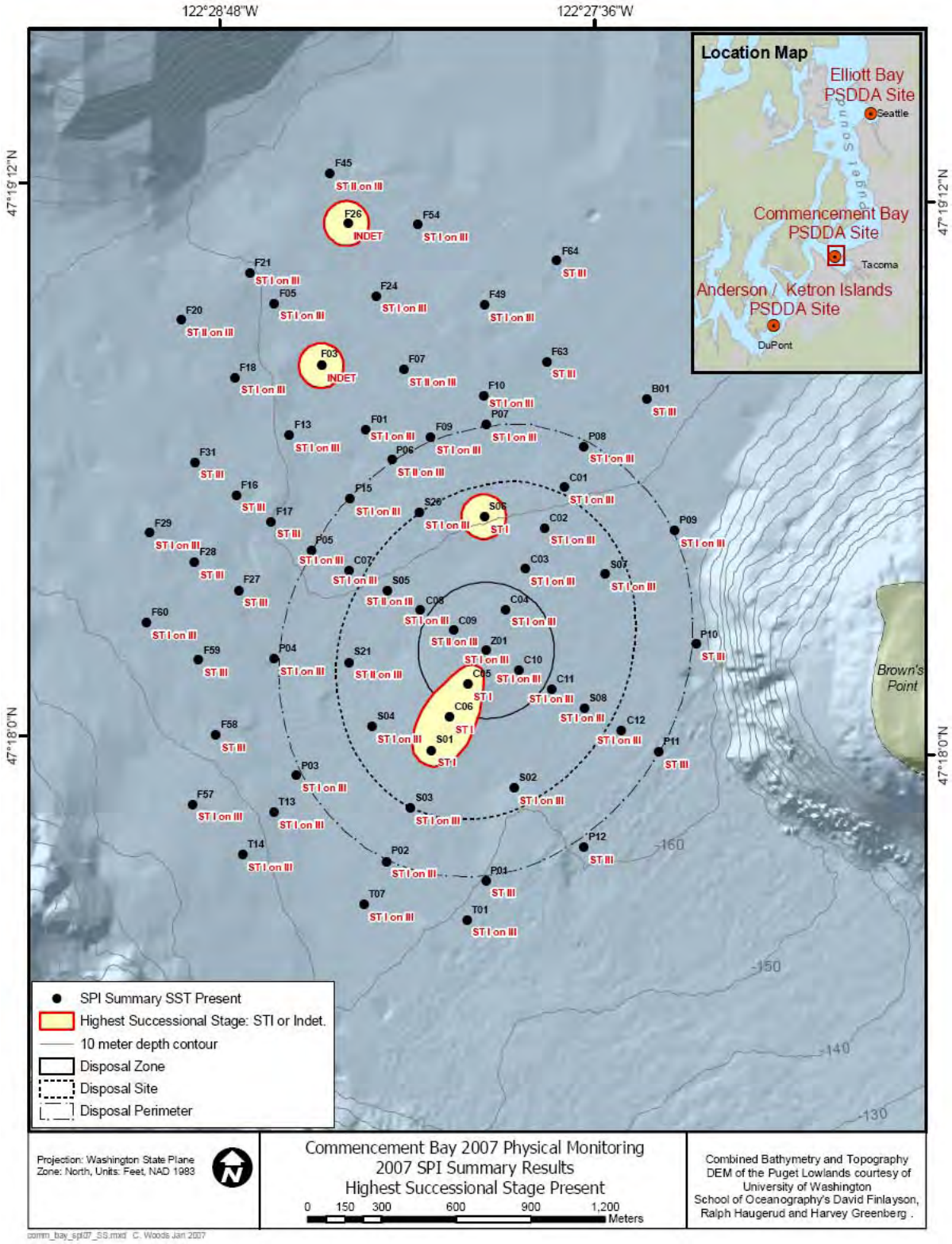


Figure 12. Commencement Bay 2007 monitoring results depicting Infaunal Successional Stage Distribution (after SAIC, 2008a)

5.2.2 Chemical Contamination

The PSDDA program includes rigorous chemical testing of sediments to determine if they are suitable for unconfined, open-water disposal. Only sediments that have passed rigorous chemical (and sometimes biological) testing are discharged to PSDDA sites. Effects to listed species resulting from contamination of discharged sediments would be extremely unlikely to occur.

5.3 Habitat Conditions

The operation of tugboats used to transport dredged material to the PSDDA sites would increase ambient noise levels along the immediate travel route. Impacts of any sound disturbance would likely result in temporary, short-range displacement of animals rather than injury. Degradation would be insignificant due to the short time noise levels would increase in a given area and the minor nature of the increase. Due to the deep waters in which dredging and disposal activities occur, prop-wash from tug boats would have no effects on bathymetry in the action area.

Disposal activities will have no effect on current patterns, salinity levels, temperatures, or water column stratification within the action area. Bathymetry would not be affected at the dispersive sites, but would be altered at the non-dispersive sites. In open-water environments near the disposal sites, salmonids primarily occupy mid- to upper-level pelagic waters. As such, bathymetric changes resulting from disposal would have no effect on habitat attributes utilized by these species.

It is unlikely that the small amounts of dredged material discharged to action area waters during the transport of material to the disposal site would affect physical navigation cues used by adult salmonids. Likewise, disposal events at the PSDDA sites are localized enough and generally far enough from the mouths of major spawning rivers to have little potential for effect on salmonids migratory paths. Adult salmon use a variety of mechanisms to navigate from the open ocean to their natal spawning grounds (Pearcy 1992). Return from the open ocean and coastal migration are thought to involve the use of either magnetic or celestial cues. As adult salmon approach the estuaries of their natal streams, Percy suggests that they rely more on a number of “navigational landmarks” for orientation, possibly including salinity, temperature, currents and bathymetry. At some point during the nearshore migration, olfaction becomes the dominant navigational cue to guide salmon upstream. Small amounts of dredged material in the water column would not affect these navigation cues, with the possible exception of visual orientation and olfaction. As described in Section 5.1.1.2, any dredged material leaking from a transport barge would be extremely small in quantity and would be quickly dispersed. The highest concentrations of material (up t o 700 mg/l) separated from a disposal jet and transported laterally at the thermocline/pycnocline or subject to size fractionation would disperse in about 12 minutes (Truitt, et al). If a salmon did come into contact with any dredged material, it would likely be subject to visual or olfactory effects for a matter of seconds to minutes, which would be insignificant in relation to the myriad of other naturally variable conditions affecting these senses.

5.3.1 Mound height effects on circulation patterns and habitat

Mound height effects on circulation pattens in Commencement Bay were addressed in the recently completed Supplemental Environmental Impact Statement (SEIS) for the Commencement Bay Disposal Site Reauthorization (http://www.nws.usace.army.mil/PublicMenu/Menu.cfm?sitename=DMMO&pagename=CB_SEIS), where circulation modeling found little discernable impact from a predicted 155-foot mound after 23 million cubic yards of dredged material (see bottom of page 98 of SEIS). The existing mound height in Commencement bay is 122 feet, and is estimated at 43 feet at the Elliott bay site, and is estimated at less than 50 feet at the Port Gardner disposal site. The mound heights at the two least used sites, the Anderson/Ketron Island and Bellingham bay sites are estimated to be less than 5 feet in height. Therefore,

based on the evaluation of circulation effects at the Commencement bay site, the effects of mound height on tidal currents, species, and habitat at all the non-dispersive sites are expected to be negligible.

5.4 Prey and Trophic Structure

The DMMP program (formerly the PSDDA program) was developed to minimize potential effects on the physical, chemical, and biological characteristics of disposal sites. The selection of both dispersive and non-dispersive sites was based on an evaluation of benthic resources at candidate sites in order to minimize the potential for effects to important prey resources. Analytical procedures, collectively called the Benthic Resources Assessment Technique (BRAT), were used to estimate the relative amount of trophic support that a given benthic habitat provides to fishes (Lunz and Kendall 1982, Clarke and Lunz 1985). Results of the BRAT analyses were used to help determine final site selections.

Large planktonic crustaceans (e.g., calanoid copepods and euphausiids) and forage fish (e.g., sand lance, surf smelt, Pacific herring) are critical links in the action area's trophic structure. These salmonid and marbled murrelet prey resources are pelagic, with no links to the deep-water benthic habitats affected by disposal operations. Therefore, water column turbidity effects to pelagic prey resources are the primary impact pathway and are the focus of the remainder of this analysis.

Increased turbidity levels are not expected to significantly affect phytoplankton productivity in the action area for a couple of reasons. As discussed in Section 4.1.1, the portion of disposal plumes resulting in the greatest turbidity increase would be located in near-bottom waters. Phytoplankton production typically occurs in the upper portion of the water column where increases in turbidity are expected to be highly localized and temporary (on the order of minutes (see Truitt, et al)). Any reduction in phytoplankton productivity resulting from disposal-related turbidity would be small-scale relative to the large size of the action area and expected to return to pre-project conditions within days. The action area is highly dynamic, with the project sites surrounded by unaffected waters, which could serve as a source for new plankton populations. Phytoplankton have rapid replication times, so that populations can double in a day; they can generally mature to reproductive life stages within 3 days and can remain viable for days to weeks (Little 2000).

While the impacts of dredged material disposal on benthic communities are relatively well studied and understood, impacts on zooplankton have been studied less and are poorly understood. This lack of research is partly due the technical difficulties (e.g., representative sampling, need for in situ work, the subtlety of anticipated effects, and the differentiation of those effects from other anthropogenic effects) associated with studying this type of impact (Segar 1990). However, laboratory studies reviewed by Clarke and Wilber (1999) indicate that crustaceans do not exhibit detrimental responses at dosages within the realm of suspended sediment conditions associated with disposal activities; crustaceans have been shown to tolerate high suspended sediment concentrations (up to 10,000 mg/l) for durations on the order of two weeks. The high variability in zooplankton distribution and abundance would further limit the scale of potential impacts. The localized area of effect and low frequency of disposal events would result in insignificant impacts on zooplankton.

Forage fish are an important and abundant fish species in Washington, significant as an intermediate step in the marine food web between zooplankton and larger fish/seabirds. Disposal activities will not affect the intertidal and shallow subtidal spawning habitats of forage fish.

Effects to planktonic prey organisms and forage fish are expected to be discountable.
Increased turbidity in the vicinity of the sites immediately after a disposal event could cause a temporary and localized decrease in phytoplankton productivity or cause mortality of pelagic fish eggs, larvae, and

zooplankton. However, the disposal sites lack components (e.g., physical habitat structure, tidal currents) that would attract or concentrate plankton or fish. These organisms are widely distributed throughout Puget Sound, so the localized, short-term, and infrequent disposal of dredged materials would not substantially affect populations of these organisms over the entire action area nor impact their availability as food for listed species.

6 INTERRELATED AND INTERDEPENDENT EFFECTS

The dredging activities that generate material for disposal at the PSDDA sites are interrelated to the proposed action. Interrelated effects associated with dredging operations will occur within portions of the action area, but far removed from the individual PSDDA site project areas where most disposal impacts will occur. Therefore, interrelated actions will not increase the size of disposal impacts to a level where take would occur. Because all interrelated dredging projects would require federal authorization in the form of a Clean Water Act Section 404 permit, each dredging project or groups of projects (maintenance dredging programs) would undergo Section 7 consultation independently.

7 CUMULATIVE EFFECTS

The Corps knows of no other non-Federal actions that are reasonably certain to occur that may adversely affect a listed, proposed, or candidate species within the action area. As described in Section 2 and Section 5, all dredging projects that generate material for disposal at PSDDA sites require a Federal permitting action. Tables 3 and 4 in Section 2.4 detail what is currently known about past disposal actions at each disposal site over the sixteen years of implementation. It is likely that future disposal actions are likely to follow this pattern. It is anticipated that relatively heavy use of the Commencement bay disposal site is anticipated over the next five years due to large construction projects currently in the regulatory review pipeline from the Port of Tacoma. The material is largely clean native material coming from the Blair Waterway.

Monitoring results verify that during the first 21 years of operation of the PSDDA sites, the program management plan has been effective in protecting the environment from unacceptable adverse impacts. Continued use of the PSDDA management and monitoring program is expected to allow continued safe and publicly acceptable disposal of dredged materials. Therefore, no significant cumulative effects to listed species are anticipated.

8 EVALUATION OF PROJECT IMPACTS ON AFFECTED SPECIES

8.1 Puget Sound Chinook Salmon

The Puget Sound evolutionarily significant unit of Chinook salmon (*Oncorhynchus tshawytscha*) was listed as a threatened species in March 1999.

8.1.1 Distribution and Timing

The distribution and timing of Chinook salmon in Puget Sound are determined by life stage (i.e., adult or juvenile), race type (i.e., ocean type or stream type), size/age of juveniles, and location of natal stream.

For “ocean type” fish, adults are generally present in Puget Sound only as they pass through on the way to their spawning streams. Migrating adults may follow the shoreline (PSDDA/FEIS 1989), and milling of adults near the mouth of spawning streams may occur prior to entry (PSDDA/FEIS 1988). Juvenile

Chinook salmon rear extensively in the estuarine and pelagic areas of Puget Sound (Simenstad et al. 1982; Beamish et al. 1998). Initially, they tend to follow shorelines and are associated with structures (PSDDA/FEIS 1988, 1989; Anderson 1990). They move into deeper water as they become larger. Although some may remain in Puget Sound for a year or more, most are present in the Sound for only for a short time (i.e., a few months) before they complete their outmigration to the Pacific Ocean.

Peaks of juvenile Chinook salmon in the estuary areas of Puget Sound occur in June for most populations. They apparently disperse to deeper nearby marine areas when they reach approximately 65-75 mm in fork length (Healey 1982; Simenstad et al. 1982). The amount of time spent in the estuary is dependent on size at downstream migration and growth in the estuary. Dispersal from the estuarine areas is relatively rapid. Average length of estuarine residence for Chinook salmon in the Nanaimo River estuary was about 20 to 25 days (Healey 1980).

Fraser River, British Columbia Chinook stocks are the most prominent Chinook stock on the coast and once they enter saltwater they do not have northward migration, but are found at all life-stages in southern BC, from the Queen Charlotte Islands to Oregon and Puget Sound. Beamish et al. (1998) collected Chinook salmon in pelagic areas of Puget Sound during spring, summer, and fall 1997 using large rope trawls. Ocean age-1 fish predominated trawl catches in April/May, whereas ocean age-0 fish predominated catches in July and September. Lengths of ocean age-0 and age-1 Chinook salmon (respectively) averaged 89 and 249 mm in April/May, 129 mm and 323 mm in July, and 164 and 390 mm in September. Almost all fish in both age groups were caught at a depth of 30 meters (98 feet) or less. Immature Chinook salmon captured off the east and west coasts of Vancouver Island were mostly captured at depths between 57 and 73 meters (187 and 240 feet), indicating a primarily mid-pelagic vertical distribution (Taylor 1969 in Groot and Margolis 1991). Based on troll sampling in the Strait of Juan de Fuca evaluated by Argue (1970), maturing Chinook salmon were typically shallower than older immature fish with the highest rate of capture between 20 and 37 meters (66 and 121 feet). Little information is available on the vertical distribution of resident blackmouth. However, since they pursue the same types of prey (herring, sandlance, krill and different pelagic stages of crab), their vertical distribution is likely also mid-pelagic.

8.1.2 Migratory Pathways

Puget Sound Chinook salmon juveniles and returning adults could potentially pass through the dispersive disposal sites between their natal spawning streams and either the west coast of Vancouver Island or Georgia Strait. The literature indicates that “stream type” Chinook are common in the Georgia Strait during the spring and early summer of their first ocean year, and “ocean type” Chinook are most abundant during the summer and fall of their first ocean year (Healy 1980). Adult Chinook salmon enter the straits in mid-April (spring-run) and between mid-July and September (summer and fall run). However, both juveniles and adults tend to travel close to shore and migrate directly and rapidly between the ocean and their natal stream. Therefore, presence within areas influenced by dredged material disposal by Chinook salmon would be very transitory. Blackmouth could occur in Rosario Strait and the Straits of Juan de Fuca throughout the year.

8.1.3 Foraging and Food Web Relationships

Juvenile Chinook salmon use both their natal, freshwater streams and estuarine wetlands of Puget Sound for early rearing. The amount of time juveniles spend in estuarine areas is dependent upon their size at downstream migration and rate of growth. Juveniles disperse to deeper marine areas when they reach approximately 65-75 mm in fork length (Simenstad et al. 1982). While residing in upper estuaries as fry, juvenile Chinook have an affinity for benthic and epibenthic prey items such as amphipods, mysids, and cumaceans. As the juveniles grow and move to deeper waters with higher salinities, this preference

changes to pelagic items such as decapod larvae, larval and juvenile fish, drift insects, and euphausiids (Simenstad et al. 1982).

The primary prey items for larger juveniles, blackmouth, and returning adult Chinook salmon in Puget Sound include Pacific herring (Clupea harengus pallasi), sandlance (*Ammodytes hexapterus*), and krill (euphausiids) (WDF 1981, Healey 1991; Beamish et al. 1998). Because these three prey organisms are also planktivores, they represent critical links between Chinook salmon and phytoplankton/zooplankton in the trophic structure of Puget Sound.

8.1.4 Evaluation of Project Impacts

Potential effects to Chinook salmon due to continued operations of the PSDDA dispersive and non-dispersive, unconfined, open-water disposal sites are insignificant. This determination is supported by numerous factors.

First, Chinook salmon may occur in areas of disposal activities however, their presence would be minimal and coincidental because there are no features at the sites that would cause Chinook salmon to congregate.

Second, should a Chinook salmon coincidentally be present in the disposal area during a discharge event, it could experience a short period of non-lethal discomfort due to high suspended sediments in the water column. The period during which sediments in the water column are elevated is relatively short (approximately 12 minutes in midwater areas studied by Truitt [1986a, 1986b]) and localized. Fish would migrate from the area affected by the discharge and recover relatively quickly from the discomfort.

Third, the potential for toxic effects of contaminants released from discharged sediments is minimal. Sediments are determined to be suitable for discharge through a series of physical, chemical and biological testing procedures that have been subject to thorough review by the regulating agencies and the public. A white paper addressing the potential for bioaccumulative effects on killer whales and Chinook salmon was prepared by the Corps in 2007. The white paper was appended to a revised BE and sent to NMFS with a request for reinitiation of Section 7 due to this new information, specifically for Puget Sound Chinook salmon, southern resident killer whale, and Steller sea lion. That analysis demonstrated that potential effects of bioaccumulation for polychlorinated biphenyls (PCB) and polychlorinated dioxins and furans (PCDD/F) for Chinook were discountable (Corps, 2007). This conclusion is still valid, and the PCB section is updated below.

Additional information Meador et al. (2000) derived a PCB Residue Effects Threshold (RET) of 2.4 ug/g-wet(lipid) for protection of juvenile salmonids. This threshold is intended to indicate a value at and below which no significant adverse effects would be expected. A Sediment Effects Threshold (SET) was also derived from the relationship shown below.

EQUATION 1: Relation between Sediment and Tissue Concentrations
$[C_{fish}]/f_{lip} = [C_{sed}]/f_{oc}$ * BSAF, where tissue $/f_{lip}$ = 2.4 ug/g-wet(lipid) = RET
Where:
C_{fish} = concentration in fish tissue (wet weight)
C_{sed} = concentration in sediment (dry weight)
f_{lip} = fraction of tissue that is lipid (dimensionless)
f_{oc} = fraction of sediment that is organic carbon (dimensionless)
BSAF = empirical relationship for accumulation of PCB: BSAF = $(\text{Tissue}/f_{lip}) \div (\text{Sediment}/f_{oc})$

Table 9. Sediment Effect Thresholds for PCB for Protection of Juvenile Salmonids. (From Meador et al. 2000).

Table 6. Sediment Effect Threshold (SET) concentration for total PCBs based on two BSAF values.

Tissue threshold (RET) µg/g lipid	Sediment TOC % dry wt.	Sediment threshold (SET) ng/g dry wt. (BSAF = 0.16)	Sediment threshold (SET) ng/g dry wt. (BSAF = 0.32)
2.4	1.0	150	75
2.4	1.5	225	113
2.4	2.0	300	150
2.4	2.5	375	188
2.4	3.0	450	225
2.4	3.5	525	263
2.4	4.0	600	300

Lipid-normalized residue effect threshold (RET) for PCBs from Table 1. SET determined with equation 1. Sediment PCB concentrations determined as ng/g OC but presented as ng/g dry wt. Values correspond to an organic-carbon normalized sediment concentration (sed_{oc}) of 15.0 µg/g OC for the mean BSAF (= 0.16) and 7.5 µg/g OC for the 95th percentile BSAF (= 0.32) (see text).

For PCB, all of the dispersive sites and all but one nondispersive sites, lack detected PCBs, with associated analytical reporting limits ranging from 3-86 ug/kg . (Detailed values are shown in Appendix C.) Elliott Bay is the nondispersive site exception, with the most recent on-site monitoring (2005) for 0-2 cm sediment result showing 130 ug/kg of total PCB, and an f_{oc} of 0.019. This is below the SET set by either the mean and upper-bound BSAFs shown in Table 9 above. Additionally, this dredged material site is not significantly elevated over its surroundings for PCB (see also Appendix B).

Fourth, adult and sub-adult Chinook salmon primarily feed on pelagic organisms and do not typically feed at depths where benthic habitats are altered by dredged material disposal. Thus, foraging habitat for this species would not be directly affected.

Fifth, adult and sub-adult Chinook salmon typically feed on pelagic organisms, where their primary foods are forage fish (herring and sandlance). Herring and sandlance are also pelagic, and their forage base would not be significantly affected by disposal activities. Sandlance can be demersal at times because they have no swim bladder, and sometimes rest in or on the bottom, but typically in less than 100 meters (328 feet) of water. Spawning areas for both species are in intertidal and shallow subtidal areas which are unaffected by disposal activities. Thus, continued disposal activities would not affect the prey base of adult and sub-adult Chinook salmon.

Sixth, juvenile Chinook salmon migrate from rivers to the Sound in the spring. Dredging activities and associated disposal activities are regulated to avoid outmigrating juveniles. During the early phases of estuarine/Puget Sound residence, juveniles reside in nearshore waters (typically no deeper than 30 to 70 meters [98 to 230 feet]) feeding on epibenthic and pelagic organisms, and would be unaffected by disposal activities. In addition, most juveniles would continue to occupy the nearshore environment during their migration to the Pacific Ocean, although they could (as noted with adult/sub-adult Chinook salmon) coincidentally occur in the dredged disposal areas. Effects of elevated water column suspended sediments would be short in duration and localized (as noted above), and are not expected to be lethal or significantly affect migrating juvenile salmon.

Finally, due to the wide distribution of this species within the action area; the relatively small area of pelagic habitat affected by disposal events; the low probability of the species coming in contact with the areas affected by a disposal activity; the infrequent and short-lived nature of disposal events; and the ability of these mobile species to quickly leave the affected area, the overall effects of disposal activities on Chinook salmon would be insignificant. The Corps has determined that the proposed action is **not likely to adversely affect** Puget Sound Chinook salmon.

8.1.5 Puget Sound Chinook Salmon Designated Critical Habitat

Critical habitat designation for Puget Sound Chinook salmon was originally designated in February 2000 but was later withdrawn. Critical habitat was re-designated in September 2005 (50 CFR Part 226, FR Vol. 70, No. 170, pages 52630-52858). This section covers the primary constituent elements determined essential to the conservation of Puget Sound Chinook salmon:

(1) Freshwater spawning sites with water quantity and quality conditions and substrate supporting spawning, incubation, and larval development.

The project is primarily in a marine area, as well as near the mouths of rivers (where dredging and barge-loading occur). There are no suitable freshwater spawning sites in the vicinity of these activity areas.

(2) Freshwater rearing sites with water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility; water quality and forage supporting juvenile development; natural cover such as shade, submerged and overhanging large wood, log jams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks.

The project is primarily in a marine area, as well as near the mouths of rivers (where dredging and barge-loading occur). There are no suitable freshwater spawning sites in the vicinity of these activity areas.

(3) Freshwater migration corridors free of obstruction with water quantity and quality conditions and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels, and undercut banks supporting juvenile and adult mobility and survival.

Other than loading of barges at dredging locations, project is in a marine area. Most dredging projects are conducted in tidally-influenced estuarine and riverine areas. Dredging effects are addressed in individual dredging Section 7 consultations. As described in Section 3.1 of this BE, loading of barges is done carefully to assure minimal dredged material is spilled into the water. Once loaded, the barges are hauled by tugs to the disposal sites. While being loaded, the barge creates a shadow and may cause migrating salmonids to veer away from the barge location—however, dredging activities are restricted by timing windows so that work is conducted during the period of time when salmon are not migrating—so this impact is discountable. The activity of tug and barge movement is transitory and does not constitute obstruction of migration.

(4) Estuarine areas free of obstruction with water quality, water quantity and salinity conditions supporting juvenile and adult physiological transitions between fresh and saltwater; natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels, and juvenile and adult forage, including aquatic invertebrates and fishes, supporting growth and maturation.

Other than loading of barges at dredging locations, project is in a marine area. A few dredging projects are conducted in estuarine areas. Dredging effects are addressed in individual dredging Section 7 consultations. As described in Section 3.1 of this BE, loading of barges is done carefully to assure minimal dredged material is spilled into the water. Once loaded, the barges are hauled by tugs to the

disposal sites. While being loaded, the barge creates a shadow and may cause migrating salmonids to veer away from the barge location—however, dredging activities are restricted by timing windows so that work is conducted during the period of time when salmon are not migrating—so this impact is discountable. The activity of tug and barge movement is transitory and does not constitute obstruction of migration.

(5) Nearshore marine areas free of obstruction with water quality and quantity conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation; and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulder and side channels.

Transport of dredged material from the dredging locations may have discountable and insignificant effects on the nearshore environment, in the unlikely event of sloughing of dredged material from the barge (see section 2.1 for more detailed information). The minimum distance from shore for all disposal sites is 762 meters. All disposal sites are greater than the 30-meter depth as defined by NOAA for critical habitat for Puget Sound Chinook salmon, except for Bellingham Bay, which is exempted from critical habitat designation (50 CFR Part 226, 2 September 2005). There are no other disposal areas in the vicinity of the nearshore, as defined in the Federal Register notice.

(6) Offshore marine areas with water quality conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation.

The designation of marine nearshore areas in Puget Sound is restricted to areas contiguous with the shoreline out to a depth no greater than 30 meters relative to the mean lower low water. This nearshore area generally coincides with the maximum depth of the photic zone in Puget Sound and contains physical or biological features essential to the conservation of salmonids (NMFS 2005). All sites except the Bellingham Bay site (29.0 meters) and the Rosario Strait sites (30-43 meters) are at depths of 30 meters or greater. Again, Bellingham Bay is exempted from critical habitat (NMFS 2005).

The following excerpt from the NMFS 2005 concurrence letter for PSDDA activities nicely summarizes the effects to Chinook critical habitat:

1. The project will not result in a barrier to migration to, or through, any marine habitat. The project proposes to dispose of clean dredge material in specified locations. This will have little, or no, impact to proposed critical habitat since the impact to affected areas will be transient. Effects to migratory habitat from the project are insignificant.

2. The project will not alter the food base within the action area. Macroinvertebrate and fish prey species will continue to be available. Prey species such as surf smelt (*Hypomesus pretiosus*), sand lance (*Ammodytes hexapterus*), and Pacific herring (*Clupea harengus pallasi*) are unlikely to be impacted by the project activities because these species do not spawn in PSSDA sites. Therefore, the project is not likely to reduce the abundance of prey.

3. The proposed project has the potential to alter water quality during dumping because of mobilization of sediment into the water column. However, the effects will be local and temporary and will not significantly impact water quality.

Due to the relatively small area of pelagic habitat affected by disposal events; the temporary and discountable impacts to turbidity, dissolved oxygen, and chemical contamination, the infrequent and short-lived nature of disposal events; the ability of forage fish species to quickly leave the affected area, and the ability of benthos to survive the deposition of sediment, the overall effects of disposal activities

on Chinook salmon critical habitat would be insignificant. The Corps has determined that the proposed action is **not likely to adversely affect** designated Puget Sound Chinook salmon Critical Habitat.

8.2 Hood Canal Summer-Run Chum Salmon

The Hood Canal Summer-Run evolutionarily significant unit of chum salmon (Oncorhynchus keta) was listed as a threatened species in March 1999.

8.2.1 Distribution and Timing

Emigration of chum fry/smolt from rivers to estuaries is relatively rapid after emergence, occurring in a matter of hours to a few weeks for small drainages (Groot and Margolis 1995, Johnson et al. 1997). Hood Canal summer-run chum salmon appear in the estuary between February and July, with peaks in estuarine residence in February and between mid-May to mid-July (Bax et al. 1978). Juvenile chum salmon occupy the estuary for a period of time prior to migration to the ocean. Observed residence times of individuals range from 4 to 32 days, with a common residence time of approximately 24 days (Simenstad et al. 1982, Johnson et al. 1997).

Tagging studies conducted by Jensen (1956) found that juvenile chum salmon tagged in Puget Sound moved rapidly northward to the Strait of Georgia and along the west coast of Vancouver Island and continued northward within a narrow band of about 20 miles from shore, apparently moving further offshore to the southwest after reaching the Alaskan coast. Jensen (1956) found some residualism of chum salmon within Puget Sound (for months to a year), however the extent of residualism is unclear (Johnson et al. 1997).

Most chum salmon mature between 3 to 5 years of age. The highest proportion of mature chum salmon returning to Washington streams is 3 years of age (Johnson et al. 1997). Maturing chum salmon begin to move coastward from offshore, north Pacific Ocean feeding grounds in May and June, and they enter coastal waters between June and November. Hood Canal summer-run chum salmon enter their natal rivers between September and mid-October, with the exception of the Union River stock, which typically returns a month earlier (mid-August to mid-September) (WDF 1992). Swimming speed on the return migration is relatively fast, with speeds between 9 and 50 miles per day reported by various authors (in Johnson et al. 1997). Once in the estuary, chum salmon may enter the river directly or may mill in the vicinity of the natal stream prior to migrating upstream to spawn. Various authors have measured estuarine residence by returning adult chum salmon as long as 20 to 50 days (in Johnson et al. 1997).

8.2.2 Migratory Pathways

Within the Hood Canal summer-run chum salmon ESU, river/creek drainages with current spawning populations include Quilcene, Dosewallips, Duckabush, Hamma Hamma, Dewatto, Tahuya, and Union Rivers, and three streams which drain to the Strait of Juan de Fuca, Snow and Salmon Creeks in Discovery Bay, and Jimmycomelately Creek in Sequim Bay. Some streams on the eastside of Hood Canal (Big Beef and Anderson creeks and the Dewatto River), have severely depleted runs of summer-run chum salmon, and have recently had no returning adults. (Johnson et al. 1997)

Hood Canal summer-run chum salmon that are ocean-migrating juveniles and returning adults could potentially pass through the dispersive disposal sites between Hood Canal and either the west coast of Vancouver Island or Georgia Strait. However, both juveniles and adults tend to travel close to shore and migrate directly and rapidly between the ocean and their natal stream. Therefore, chum salmon presence within areas influenced by dredged material disposal by would be very transitory.

8.2.3 Foraging and Food Web Relationships

During early estuarine residence, chum salmon feed on epibenthic and neritic organisms in shallow nearshore areas. During this period, chum salmon diets are dominated by harpacticoid copepods and gamarid amphipods (Groot and Margolis 1995, Bax et al. 1978, Simenstad et al. 1980). At about 45 to 55 mm, juvenile chum salmon move to deeper water and feed on pelagic organisms such as euphausiids, copepods, hyperiid amphipods, decapod larvae, and fish larvae (Groot and Margolis 1995, Groot et al. 1995, Beamish et al. 1998). Adult chum salmon continue to feed on pelagic organisms including hyperiid amphipods, fish, pteropods, euphausiids, and calanoid copepods.

8.2.4 Evaluation of Project Impacts

Potential project effects to chum salmon are very similar to those discussed for Chinook salmon in section 8.1.4. Due to the wide distribution of these species within the action area; the relatively small area of pelagic habitat affected by disposal events; the low probability of the species coming in contact with the areas affected by a disposal activity; the infrequent and short-lived nature of disposal events; and the ability of these mobile species to quickly leave the affected area, the overall effects of disposal activities on chum salmon would be insignificant. The Corps has determined that the proposed action is **not likely to adversely affect** Hood Canal summer-run chum salmon.

8.2.5 Hood Canal Chum Salmon Designated Critical Habitat

Critical habitat was re-designated on September 2, 2005 (50 CFR Part 226, FR Vol. 70, No. 170, pages 52630-52858). Primary constituent elements of critical habitat are the same as for Puget Sound Chinook salmon, and the effects analyses are the same as for Puget Sound Chinook designated critical habitat (see Section 8.1.5), though actually the potential for effects are primarily at the three dispersive sites (Port Townsend, Port Angeles, and Rosario). The Corps has determined that the proposed action is **not likely to adversely affect** designated Hood Canal summer run chum salmon **c**ritical habitat.

8.3 Steelhead

Puget Sound Steelhead (*Oncorhynchus mykiss*) was listed as threatened on May 11, 2007 (effective June 11, 2007).

8.3.1 Distribution and Timing

The present distribution of steelhead extends from Kamchatka in Asia, east to Alaska, and extending south along the Pacific Coast to the U.S. Mexico border (Busby et al., 1996). Steelhead that are anadromous can spend up to seven years in freshwater prior to smoltification and then three years in salt water prior to first spawning (though the majority of Puget Sound steelhead remain in the river for two years, and in the ocean for two years (Puget Sound Steelhead Biological Review Team, 2005)). Steelhead are iteroparous (spawn more than once) whereas the Pacific salmon is semelparous (spawn once and die).

Steelhead can be divided into two basic reproductive ecotypes, based on the state of sexual maturity at the time of river entry and duration of spawning migration (Burgner et al., 1992). The summer “stream maturing” type enters fresh water in a sexually immature state between May and October and requires several months to mature and spawn. The winter or “ocean maturing” type enters fresh water in a mature state and ready to spawn between November and April.

8.3.2 Migratory Pathways

The inshore migration pattern of steelhead in Puget Sound is not well understood; it is generally thought that steelhead smolts move quickly offshore (Hartt and Dell 1986—fide Puget Sound Steelhead Biological Review Team, 2005). Both Welch (2004) and Goetz (2007) confirm this rapid migration to the ocean once the smolts enter marine waters. Both Welch and Goetz found steelhead migration covering as much as 25 km/day. Welch found that wild steelhead enter the ocean in about 2.3 days, while Goetz's data indicate residence times of 7 to 26 days, with a rough average of about 15 days. However, as Welch points out, older kelts (3 yrs of age) may tend to linger (Ruggerone, et al, 1990, fide Welch, 2004), and demonstrate a "milling" pattern of movement. So far, data is lacking to demonstrate whether juvenile steelhead stay close to the nearshore or move offshore when moving through Puget Sound or Queen Charlotte Strait (Goetz, 2007; Welch, 2004), but studies that are underway suggest to Goetz that juvenile steelhead use both inshore and offshore areas (Goetz, 2007). John Stadler, NMFS (personal communication, 2007) stated "it is generally thought that smolts move quickly offshore after entering marine waters.".

8.3.3 Foraging and Food Web Relationships

Data on foraging habitats and prey base of steelhead while in Puget Sound could not be found by a search of the literature. Wydoski and Whitney (2003) report on stomach contents of juvenile steelhead in the Pacific Ocean:

> "Juvenile steelhead captured in purse seines in the Pacific Ocean off the Oregon/Washington coast consumed fishes as well as various invertebrates. Fishes were most important diets of juvenile steelhead while they were at sea, making up about 60 percent of the stomach contents by weight. Fishes that were dominant in juvenile steelhead diets included juvenile rockfish, sandlance, brown Irish lord (a native sculpin), and greenling. Invertebrates that were consumed were primarily euphausiids (planktonic marine crustaceans resembling shrimp) but also included barnacle larvae, copepods, amphipods, and squids."

LeBrasseur conducted a study of stomach contents of various salmonids, including steelhead, in the northeast Pacific Ocean in May and June, 1958:

> "Only 37 steelhead trout were available for examination. Among their stomach contents, fish and squid were predominant. Amphipods were generally present, whereas, copepods and euphausiids. were infrequently present, and never in more than trace amounts."

The "fish" in the stomach contents were not identified to species in LeBrasseur's study. In a parallel study to that of LeBrasseur, Manzer (1968) studied salmonid stomach contents in the northeast Pacific Ocean during the winter (January-February) of 1964. Four of the seven steelhead stomachs he examined contained food in their stomachs. It appeared to Manzer that the most important food organism was squid.

In a recent study, Myers, et al (2004) confirmed the earlier studies, in that the principal component of steelhead diet in the north Pacific is squid (GOA stands for Gulf of Alaska):

> "Analyses of steelhead diets in both the GOA and central North Pacific (CNP) showed that the dominant prey of all age groups were gonatid squid and fish. The percent composition of squid in steelhead diets was inversely related to Russian pink salmon abundance, although the relation was stronger in the CNP, where overlap in distribution of steelhead and Russian pink salmon is higher,

than in the GOA. Thus, climate change may affect ocean carrying capacity of steelhead through variation in ocean habitats and density-dependent trophic interactions."

Finally, Margaret Atcheson (2010) studied food habitats of steelhead in the Gulf of Alaska (GOA) and central north Pacific Ocean (CNP). She found that:

> "Steelhead caught in the GOA and CNP consumed a wide variety of prey. The dominant prey categories for steelhead were fish and squid. The primary species within these categories include Atka mackerel (*Pleurogrammus monopterygius)*, three-spined stickleback (*Gasterosteus aculeatus)*, lantern fish (*Myctophidea spp*.), and the minimal armhook squid (*Berryteuthis anonychus*)."

8.3.4 Evaluation of Project Impacts

The lack of data indicating juvenile steelhead behavior while in Puget Sound makes it somewhat problematic to assess impacts of transport and dredged material disposal activities. At the present time, it makes sense to use juvenile Chinook salmon behavior as a surrogate for juvenile steelhead. This seems to be a favorable comparison for at least two reasons: 1) juvenile Chinook salmon are smaller than juvenile steelhead when migrating through Puget Sound, making them more vulnerable to effects and 2) juvenile Chinook salmon demonstrate slightly longer residence times in Puget Sound than do juvenile steelhead, again making them more likely to encounter dredged material operations. The possible exception to this is that juvenile Chinook salmon are known to remain inshore during their outward migration, and we don't know if juvenile steelhead remain inshore. Given these similarities, the potential project effects to steelhead are considered to be very similar to those discussed for Chinook salmon in section 8.1.4.

The Corps prepared a white paper analyzing the potential effects of bioaccumulation of chemicals in Puget Sound Chinook salmon and Southern resident killer whales (USACE, 2007). A second white paper was prepared in 2010 to update the analyses based on more recent study results (see Appendix C). This analysis reaffirms our original determination that effects of bioaccumulation from disposal operations are discountable in steelhead.

In conclusion, due to the wide distribution of steelhead within the action area; the relatively small area of pelagic habitat affected by disposal events; the low probability of the species coming in contact with the areas affected by a disposal activity; the infrequent and short-lived nature of disposal events; and the ability of these mobile species to quickly leave the affected area, the overall effects of disposal activities on Puget Sound steelhead would be insignificant and discountable. The Corps has determined that the proposed action is **not likely to adversely affect** Puget Sound steelhead.

8.3.5 Steelhead Critical Habitat

NMFS has not designated critical habitat for Puget Sound steelhead. The following are habitat features in Puget Sound identified by NMFS as important for steelhead (FR Vol. 70, No. 64, pp. 17223-17227), April 5, 2005:

> "Nearshore marine areas free of obstruction with water quality and quantity conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation; and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels.

Offshore marine areas with water quality conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation."

The continued use of PSDDA disposal sites and transport of dredged material to these sites will have discountable effects on these habitat features.

8.4 Puget Sound Rockfish

The three species of rockfishes addressed in the following sections were added to the Federal list of endangered and threatened wildlife and plants by the National Marine Fisheries Service on April 28, 2010, to be effective on July 27, 2010 (NMFS, 2010). The Bocaccio is listed as endangered, while the other two species are listed as threatened.

8.4.1 Bocaccio (Sebastes paucispinis)

Bocaccio are an elongated rockfish, of the scorpion fish family, that ranges from northern British Columbia to central Baja California. These fish were once quite common on steep walls of Puget Sound, but are now quite rare. Adults generally occupy water 50- 250 meters in depth over rocky outcroppings, boulder fields, and sloping walls and will school with both conspecifics and other species of rock fish. Occasionally these adults will migrate onto mudflats adjacent to rocky substrates. Adults can also be found well off the substrata up in the water column. In a six-year (1983-1988) study conducted to help determine the best locations for open-water disposal sites under the PSDDA program, Donnelly and Burr (1995) caught very few rockfish. Four species were represented (quillback, copper, brown, and greenstripe), of which only quillback was abundant enough to rank in the top twenty-five species that were caught. This species showed greater relative abundance with greater depth, in most seasons. Parturition in British Columbia (dates for Washington are not available) occurs in February of each year (O'Connell, (1987; Wylie-Echeverria, 1987) . Larval bocaccio are pelagic, drifting at the mercy of the currents, usually occupying surface waters. By age 3.5 months the young will settle and recruit to inshore waters. Juveniles are found in much shallower waters over rocky substrate with various understory kelps and/or sandy bottoms with eelgrass. Approximately one month after settling juveniles will start to school. Adults and large juveniles feed on small fish and squid, whereas larvae and small juveniles feed on copepods, krill, diatoms, dinoflagellates and various larvae (Love et. al, 2002). Donnelly (2010) indicated that burrowing shrimp were the principal prey found in the stomachs of the rockfish caught in his 1983-1988 study.

8.4.1.1 Evaluation of Project Impacts

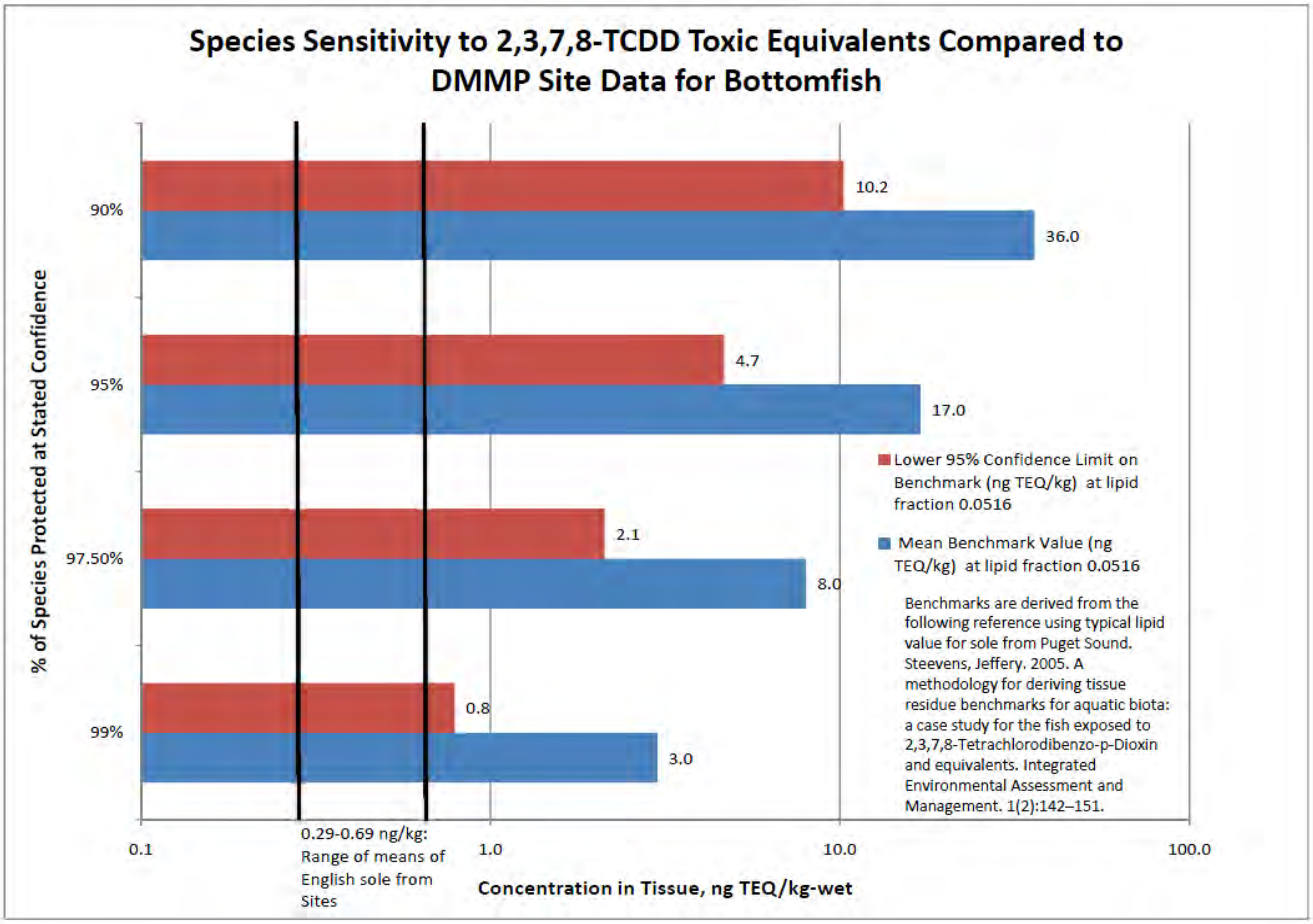
It is very unlikely that any adult bocaccio would occur in barge-loading areas or the disposal sites as they tend to inhabit deeper water with rocky substrate. Although juveniles are present in shallower water, they are also associated with rocky areas with kelp cover and sandy areas with eelgrass beds. None of these habitats are present within the barge-loading areas or the disposal sites. There is only a slight chance the larval stage of these species would be present at the barge-loading areas or the disposal sites because at this life stage they are pelagic drifters at the mercy of the currents (Tonnes, pers. comm., 2009). Even if they were to be present, the short-term and temporary nature of disposal operations, and insignificance of water and sediment chemistry effects relating to the potential of bioaccumulation of contaminants, are all considered to be discountable effects, for the reasons cited below. Lacking site-relevant PCB and PCDD/F monitoring data for rockfish tissue, we have used a theoretical approach based upon empirical relationships (similar to that used in Section 8.1.4 for defining SET for salmonids).

English sole represents a reasonable worst case for rockfish. Sole were considered in terms of PCDD/F in 2006

[http://www.nws.usace.army.mil/PublicMenu/documents/DMMO/060912_FINAL_AK_Dioxin_Evaluation.pdf]
as follows:

> The prospective ecological effects to English sole of PCDD/F exposure were evaluated quantitatively following EPA Ecological Risk Guidance (EPA 1997) using as a benchmark the geometric mean between the Lowest-effects Residue (LOER) and No-effects Residue (NOER) for whole body fish, using the methodology developed by Steevens et al. (2005). The fish species included several trout species, the northern pike, the white sucker, and the zebra fish, but no marine species. A range of population protection values (deemed "species protection values" in the paper) were described, so that the risk managers may decide which level of protection is desirable." Figure 13 (page following) shows PCDD/F TEQ in sole tissue from Table 6 compared against the mean and Lower Confidence Limit (LCL) on the mean benchmarks from Steevens' data. For the nondispersive sites, the site-wise range of means of sole PCDD/F is 0.29-0.69 ng TEQ/kg-wet. (No tissue monitoring data are available for the dispersive sites due to their rapidly losing dredged material.) To the extent that sole represent rockfish, the protection against effects from PCDD/F is greater than 99%.

Figure 13. Species Sensitivity to PCDD/F TEQ for Bottomfish



> For PCB, Stein et al. (1992) developed NOERs for English sole using a variety of physiological endpoints, and concluded that 3.7 mg PCB/kg (wet weight, whole body) is protective. A search of the USACE Biota-Sediment Accumulation Factors (BSAF) database

Table 10. Summer Flounder BSAF Calculation for Elliott Bay Site

				Resulting Fish PCB Conc at BSAF	
	Value	Units	Note	BSAF (mean) 2.89	BSAF (mean+ SE) 4.09
C_{sed}	130	ug/kg-dry	a		
flip	0.024	unitless	b		
foc	0.019	unitless	a		
C_{fish}	(estimated at right)	mg/kg-wet		0.47	0.67

Notes

a - Conditions are selected from Elliott Bay, 2005 survey, onsite conditions
b- Value is derived for Summer flounder from Sakurai et al. (2000), as filet-only (wet), adjusted by 2x for whole body

[http://el.erdc.usace.army.mil/bsafnew/] determined that the closest relative to sole in the database, summer flounder (*Paralichthys dentatus)*, had a mixed-PCB mean BSAF of 2.89 ± 1.2 standard error (Tracey and Hansen 1996). Table 10 shows an example calculation, using the relationships from the preceding EQUATION 1. Calculated fish tissue concentrations are well below the NOER cited above.

$$BSAF = (CFish/f_{lip})/(Csed/f_{oc})$$
$$Cfish = (f_{lip}*BSAF*C_{sed})/f_{oc}$$

Due to the lack of presence of Bocaccio in the project area and the analyses that indicates discountable bioaccumulative effects, the proposed action is **not likely to adversely affect** this species.

8.4.2 Canary Rockfish (S. pinniger)

Canary rockfish range from northern British Columbia to northern Baja California, potentially living to be 80+ years old. Adults occupy depths of 80-200 meters in areas with considerable current around pinnacles and high relief rock often schooling with both conspecifics and other species of rockfish. Parturition occurs in February each year (O'Connell, (1987; Wylie-Echeverria, 1987). Larval canary rockfish are pelagic, at the mercy of the currents, and tend to be present in the upper 100 meters of the water column. After 3-4 months the pelagic juveniles settle onto shallow benthic substrates such as tide pools and kelp beds. As juveniles grow they start to group and move into depths of 15-20 meters at the interface between rock and sand during the day and then disperse onto the sand flats at night. The juveniles gradually move from shallower to deeper area towards the end of summer. Adults and subadults feed on small fish and invertebrates while juveniles feed on copepods, krill eggs and various larvae (Love et. al., 2002).

8.4.2.1 Evaluation of Project Impacts

It is very unlikely that any adult canary rockfish will be present in the barge-loading areas or the disposal sites as they tend to inhabit deeper water with rocky and/or sandy substrate. Although juveniles tend to be present in shallower water, they are associated with rocky areas with kelp cover and/or areas with a rocky-sand interface. None of these habitats are present within the barge-loading areas or the disposal sites. There is only a slight chance the larval stage of these species would be present at the barge-loading areas or the disposal sites because at this life stage they are pelagic drifters at the mercy of the currents (Tonnes, pers. comm., 2009). Even if they were to be present, the short-term and temporary nature of

disposal operations, and insignificance of water and sediment chemistry effects relating to the potential of bioaccumulation of contaminants (see discussion under Bocaccio, Section 8.4.1.1), are all considered to be discountable effects.

Due to the lack of presence of canary rockfish in the project area and the analyses that indicates discountable bioaccumulative effects, the proposed action is **not likely to adversely affect** this species.

8.4.3 Yelloweye Rockfish (S. ruberrimus)

Yelloweye rockfish, a member of the scorpion fish family, range from the eastern portions of the Aleutian Islands to Northern California and can live up 118 years. Adults and subadults occupy areas rocky areas with refuge such as crevices, caves, and boulder piles. They are usually solitary but can co-occur with one to a few individuals of another species of rockfish. Occasionally, they will wander onto mudflats adjacent to rocky areas. Parturition appears to occur in May each year (O'Connell, (1987; Wylie-Echeverria, 1987). Very little is known about the larval stage of yelloweye rockfish (year 1), but young juveniles can be found on vertical walls with cloud sponges and anemones at depths greater than 15 meters. Yelloweye rockfish spend the majority of their time on the substrata where they feed on small fish, shrimp, crab, and lingcod eggs (Love et. al, 2002).

8.4.3.1 Evaluation of Project Impacts

It is very unlikely that any adult yelloweye rockfish will be present at barge-loading areas or the disposal sites as they inhabit water with rocky substrate that provides refuge space and/or invertebrate cover. This habitat is not present within barge-loading and disposal site areas. Although information is lacking for the larval portion of their life, like other species of rockfish it is rare that they would be present at the barge-loading and disposal sites because at this life stage they are pelagic drifters at the mercy of the currents (Tonnes, pers. comm., 2009). Even if they were to be present, the short-term and temporary nature of disposal operations, and insignificance of water and sediment chemistry effects relating to the potential of bioaccumulation of contaminants (see discussion under Bocaccio, Section 8.4.1.1), are all considered to be discountable effects.

Due to the lack of presence of yelloweye rockfish in the project area and the analyses that indicates discountable bioaccumulative effects, the proposed action is **not likely to adversely affect** this species.

8.5 Eulachon

Eulachon (*Thaleichthys pacificus*) was listed by NMFS on March 18, 2010. Eulachon spawn in major rivers such as the Columbia, and larger tributaries to the Columbia, such as the Cowlitz. The nearest know spawning river to the project area is the Fraser River (WDFW, 2008). Also see Section 7.7.3 on bull trout distribution for an anecdotal reference to eulachon in the Fraser River. Their movements in Puget Sound are unknown, other than some historic data. NOAA believes the species to be rare in Puget Sound, although data suggests they have been common in the past. The data suggests that eulachon may rarely come into Puget Sound in large schools, but this has seldom been documented (the last such documented large school of eulachon in Puget Sound was in 1938) (NOAA, 2010). Even if they were to be present, the short-term and temporary nature of disposal operations, and insignificance of water and sediment chemistry effects relating to the potential of bioaccumulation of contaminants Donnelly (personal communication, 2010) indicates that during fish seining to determine potential locations for open water disposal sites for the Puget Sound Dredged Disposal Analysis, eulachon were caught in the Straits of Juan de Fuca in April of 1987 and April of 1988, Port Angeles in April of 1987, and Port Townsend of April of 1988. No eulachon were caught in any other location below (south of) Admiralty Inlet.

8.5.1.1 Evaluation of Project Impacts

Based on the rarity of eulachon in Puget Sound, the potential for interaction with the open-water disposal operations is considered to be quite remote.

As there is a possibility that eulachon might be in the vicinity during disposal operations, even though remote, the operation could disrupt behavior of adults and juveniles. These potential effects are considered to be discountable. Therefore, the continued use of open water disposal sites in Puget Sound is **not likely to adversely affect** eulachon.

8.6 Steller Sea Lion

The Steller sea lion (*Eumetopias jubatus*) was listed as a threatened species in November 1990. In 1997, the North Pacific's population of Steller sea lions was separated into two distinct stocks, one of which was reclassified as endangered. The status of the eastern stock, which includes the population inhabiting the waters of the Washington coast, remains unchanged. Critical habitat has been designated for this species, but none occurs in Washington.

During the past 30 years, Steller sea lion (SSL) populations have suffered a dramatic decline. Numbers in the rookeries of central/southern California, the central Bering Sea, and in the core Alaskan ranges have all decreased substantially. A number of natural and anthropogenic factors have been hypothesized as contributing to these declines, but it is generally thought that a nutritional deficiency resulting from a lack of abundance or availability of suitable prey is involved (Steller Sea Lion Recovery Team 1992). Major shifts in the abundance of fish in the Bering Sea over the past several decades are well documented. The Alaska pollock and Atka mackerel fisheries have specifically been implicated in decreasing the availability of prey.

8.6.1 Distribution

The number of SSLs found in Washington varies significantly throughout the year, and perhaps between years. Although Puget Sound falls within the distribution of SSL, their numbers in the region are generally small and mostly concentrated in the northern portion of Puget Sound and the Strait of Juan de Fuca. However, following the large El Nino of 1985-1986, several hundred animals were reported to have appeared in south Puget Sound. There are no known annual counts and, as with offshore areas, their movements into Puget Sound seem sporadic. Steller sea lions have been seen in many inland waters, including the San Juan Islands, rock outcroppings along the Strait of Juan de Fuca, near Everett, in Shilshole Bay, off the Ballard Locks, and occasionally in south Puget Sound. Peak monthly counts indicate that SSL are most abundant off the Washington coast during March-April and August-November (Gearin and Jeffries 1996). Steller sea lions may be observed along the Washington coast year around, but they are least abundant in May-July, which corresponds to the breeding time off Oregon and British Columbia.

No breeding rookeries or major haul-out sites have been identified in Washington waters. When not on land Steller sea lions are generally seen inshore, less than 5 miles from the coast. Steller sea lion foraging patterns vary depending upon age, season, and reproductive status, as well as the distribution and availability of prey. Foraging patterns of females during the winter months vary considerably; individuals travel an average of 133 km and dive an average of 5.3 hours per day. The vast majority of feeding dives occur to a depth of 100 m (328 feet), although feeding to depths over 250 meters (820 feet) has been reported (Merrick 1995, Swain and Calkins 1997).

8.6.2 Foraging and Food Web Relationships

Early investigators in Alaska reported that, prior to the mid-1970s, stomachs examined from SSL showed a high percentage of forage species (e.g., herring, capelin, sandlances etc.) in the diet (Alverson 1992). Following a major oceanographic regime shift in the mid-1970s, diets of SSL in the Alaska region have been dominated by pollock and Atka mackerel, with smaller amounts of a variety of other species including salmon, squid, flounders, and cods. In an investigation into the decline of the SSL population during the period following the regime shift, Merrick et al. (1997) noted that the SSL diet appeared to be determined not only by the individual components or species, but by the mix or diversity of prey in the diet. The importance of prey diversity, as well as abundance, may be vital to the success of populations in a region.

Brown and Riemer (1992) investigated the feeding patterns of SSL based on fecal material collected from the haul-out and rookery sites off Oregon. They found that Pacific whiting and Pacific lamprey were the two most frequently identified prey species. Various species of salmon were also quite common.

The diet of Steller sea lions occurring in Puget Sound, the Strait of Juan de Fuca and off the coast of Washington is not well known, although they appear to be largely opportunistic feeders (Gearin and Jeffries 1996). Examination of scat and stomach contents indicate Pacific whiting (hake), rockfish, cod, pollock, herring, and smelt are frequent prey items (Beach et al. 1985, Gearin and Jeffries 1996). For the most part, SSL are not known to prey significantly on bottom-dwelling invertebrates, although in Alaska, crabs and shrimp have been noted to compose a small portion of the food items consumed.

As noted in Appendix B, SSLs in Alaska have been determined to be near adverse-effects levels for PCDD/F. No comparable data have been seen for Puget Sound, but the Alaskan population is part of the eastern Pacific stock, so may represent Puget Sound individuals.

8.6.3 Evaluation of Project Impacts

Given the lack of rookery and major haul-out areas in Puget Sound or in waters adjacent to Washington's coast, when in the action area Steller sea lions are likely on foraging expeditions. Disposal activities will have no effect on breeding habitat or behavior. Noise associated with disposal operations may have an effect on foraging behavior. However, impacts of any sound disturbance would likely result in temporary displacement of animals from the immediate disposal area rather than injury. The tugs and barges travel slowly, and thus potential take from collisions is extremely unlikely. No haul-out sites will be physically disturbed by disposal operations.

As discussed in Section 4.4, disposal operations are not expected to result in a widespread or long-term reduction in the abundance and distribution of common prey items in the action area. However, Steller sea lions forage on a wider variety of prey items than other species addressed in that analysis of effects on trophic structure, including some groundfishes (e.g., rockfish, cod, hake, flounder) whose habitats could potentially be affected by dredged material disposal. Only the Rosario Strait, Bellingham Bay, and Port Townsend sites occur at depths where both young and adult SSL might occasionally forage on benthic organisms.

The likelihood of significant impacts to the SSL prey base seems extremely remote if we take into account the very small fraction of the action area where disposal actually occurs, the wide variety of prey species taken by SSLs, and the fact that only three of the eight disposal sites are at depths generally foraged by SSLs. (Data on PCB and PCDD/F for these sites are incorporated into Appendix C; in general, the chemical inventories for these sites are non-detected, or are within the plausible concentration range for sediments not including urbanized areas in Puget Sound.) Indirect effects caused by toxins in

prey items are also unlikely since the dredged material is tested for bioaccumulative chemicals prior to the determination of its suitability for open-water disposal; also see Section 8.10.3 and appendix B for additional discussion on the potential for bioaccumulation of contaminants. Increases in turbidity associated with disposal activities have the potential to reduce visibility in the immediate vicinity of the disposal sites, thereby reducing foraging success for any animals that happen to be in the area. This effect would be insignificant given its temporary and highly localized nature, particularly with respect to this species' foraging range.

The Corps has determined that the proposed action is **not likely to adversely affect** the Steller sea lion since the potential for exposure to significant quantities of contaminants or significant sound disturbance or impacts to prey abundance will be minimal. The proposed action will have **no effect** on designated critical habitat for this species, as none occurs within the action area.

8.7 Coastal/Puget Sound Bull Trout

The Coastal/Puget Sound population segment of bull trout (*Salvelinus confluentus*) was listed as a threatened species in October 1999. Bull trout populations have declined through much of the species' range; some local populations are extinct, and many other stocks are isolated and may be at risk (Rieman and McIntyre 1993). A combination of factors including habitat degradation, expansion of exotic species, and exploitation has contributed to the decline and fragmentation of indigenous bull trout populations.

8.7.1 Distribution and Timing

The scope of this BA includes three analysis areas (as defined in 64FR 58909): Strait of Juan de Fuca; Hood Canal; and Puget Sound. Within these analysis areas are included the following rivers in which bull trout occur: Elwha River, Angeles Basin, Dungeness River, Skokomish River, Nisqually River, Puyallup River, Green River, Lake Washington Basin, Snohomish River-Skykomish River, Stillaguamish River, Skagit River, and Nooksack River.

Bull trout in Puget Sound drainages exhibit four types of life history strategies. The three freshwater forms include ad fluvial forms, which migrate between lakes and streams; fluvial forms, which migrate within river systems; and resident forms, which are non-migratory. The fourth strategy, anadromy, occurs when the fish spawn in fresh water after rearing for some portion of their life in the ocean. The anadromous form of bull trout has been little studied; however, larger juvenile and adult bull trout are known to migrate through the marine waters of Puget Sound (Goetz 1989). The anadromous form may spend as many as 200 days annually in marine waters (Kraemer, 1994). Recent studies conducted by the Corps in Northern Puget Sound systems provide information on the migration patterns of anadromous native char. In the Skagit and Snohomish rivers, native char sub-adults migrate downstream between April and May at two or three years of age. By early autumn sub-adult native char are approximately 250-300 mm long when they move back to the lower portions of their natal streams where they are thought to overwinter. Native char migrate back to the marine environment as early as February where they spend several months in preparation for the spawning migration. Mature native char (age=4, >400 mm in length) leave the tidal waters in May through July and begin their upstream spawning migration. The FWS assumes bull trout could be found anywhere in Puget Sound (Spaulding, 1999).

8.7.2 Migratory Pathways

The Corps has been conducting acoustic tag studies on bull trout for several years primarily to determine presence and absence of native char in various locations in the Puget Sound along with determining migration timing and migration/movement routes. Over 50 fixed monitoring stations have been installed

from Shilshole Bay in the south, northern ward to north Swinomish channel. In addition, fixed monitoring stations have been installed in the Snohomish, Stillaguamish, and the Skagit Rivers. The Corps has also conducted over one hundred hours of mobile tracking throughout the Puget Sound and the above-mentioned rivers. The results of the study indicate that native char are strongly associated with the near shore environment, the vast majority of which are detected along shorelines at a water depth of less than 18.0 meters. The few native char detected in water depths greater than 18.0 meters were still located in area less than 100.0 meters from the shoreline (Goetz, et al, 2004).

8.7.3 Foraging and Food Web Relationships

Bull trout primarily feed on surf smelt (*Hypomesus pretiosus*), Pacific herring, Pacific sand lance, pink salmon smolts, and chum salmon smolts (Kraemer, 1994). Jordan (1884; 1887) first qualitatively described bull trout and its food habits as "From Puget Sound northward it is generally abundant. It feeds voraciously in the salt water on smelt of various sorts, young trout, sand lances, shrimps, anchovies, herrings, and even sticklebacks. In fresh waters it probably eats whatever living thing it can get." Combining two references from Jordan (1884; 1887) for eulachon and bull trout in the Fraser River estuary – Jordan (1884) "They are taken in Fraser River at the time of the eulachon run, but they probably then ascend the river to feed upon the eulachon, and not for spawning purpose. As a food-fish this beautiful species ranks high." And Jordan (1887) -- "Victoria--…A large part of the Victoria market comes from Fraser's River. In their season (May) the eulachon (*Thaleichthys pacificus*) is the best panfish in this region. They run up the lower Fraser in enormous numbers, and every fish feeds on them. Even the sturgeons gorge themselves upon them." The distribution of bull trout in nearshore marine waters has been hypothesized to be highly correlated to the nearshore distribution of baitfish in Puget Sound (WDFW 1999). At that time, no formal dietary analysis of anadromous bull trout residing in wider Puget Sound had been conducted. However, field observations indicated that surf smelt (*Hypomesus pretiosus*), Pacific herring (*Clupea harengus pallasi*), Pacific sand lance (*Ammodytes hexapterus*), pink (*Oncorhynchus gorbuscha*) and chum (*O. keta*) salmon, and numerous invertebrate species composed the majority of the prey species for bull trout residing in northern Puget Sound (Kraemer 1994). Miller et al. (1977) captured a single bull trout in 1976 during town net surveys conducted in Padilla Bay (North Puget Sound), which had consumed 61 Dungeness crab (*Cancer magister*) megalops, twelve macroinvertebrates, six gammarid shrimp, and four ostracods. Footen (2000) captured seven (7) bull trout (mean FL = 360 mm) in Shilshole Bay during the late spring of 2000. Stomach contents were composed of: Pacific sand lance (61%); juvenile Chinook salmon (27%); and juvenile chum salmon (12%). Pentilla (2003) captured five bull trout during forage fish beach seine surveys conducted in northern Puget Sound in 1974- 1975. Informal observations of the stomach contents of these fish captured in Utsalady Bay (northwest Camano Island) were primarily composed of surf smelt and juvenile herring.

In Puget Sound, nearshore residency periods of forage fish (Pacific sand lance, Pacific herring, and surf smelt) overlap with bull trout (Bargmann 1998; Emmett et al. 1991). Further, anadromous bull trout opportunistically utilize forage fish species (surf smelt, Pacific herring, and Pacific sand lance) almost exclusively when they are present in the nearshore marine habitats. Due to the importance of forage fish species to bull trout and many other Puget Sound species, changes in abundance of forage fish can impact a substantial number of fish, mammals, and birds (West 1997). Forage fish in Puget Sound play an important role as a midlevel food web species. Typically the populations of mid-level populations vary greatly in size and have dramatic influences on the higher trophic levels (as prey items) and the lower trophic levels (as predators) and act as both up and down control rather than in the typical bottom up or top down control mechanisms (Bakun 1996).

8.7.4 Evaluation of Project Impacts

In general, potential effects on native char are similar to those experienced by Chinook salmon (see Section 7.1.4), however the potential for native char to be present in the disposal areas is much more unlikely than Chinook salmon due to their strong affinity to the nearshore environment (Goetz, et al, 2004). Also, Section 8.1.4 describes the low likelihood of toxicity due to PCB, and Section 8.4.1.1 describes the low likelihood of effects from PCDD/F, using a highly conservative bottomfish surrogate.

Bioaccumulative effects are expected to be less likely than in Chinook salmon, again due to the propensity of bull trout to remain in relatively shallow nearshore environments. In addition, and perhaps more importantly, the bull trout preference for fishes such as sandlance and herring, which also tend to remain in nearshore environments, means that their exposures to contaminants through the DMMP open-water disposal program are discountable, since the forage fish themselves have little chance to encounter contaminants through bioaccumulation as a result of open-water disposal in Puget Sound.

Therefore, due to the relatively small area of pelagic habitat affected by disposal events; the low probability of the species coming in contact with the areas affected by a disposal activity; the infrequent and short-lived nature of disposal events; the low likelihood of bioaccumulative effects; and the ability of these mobile species to quickly leave the affected area, the overall effects of disposal activities on bull trout would be insignificant. The Corps has determined that the proposed action is **not likely to adversely affect** Coastal-Puget Sound bull trout.

8.7.5 Coastal/Puget Sound Bull Trout Proposed Critical Habitat

The USFWS designated critical habitat for the Coastal/Puget Sound population segment of bull trout (USFWS 2005). In February 2010, the USFWS proposed revisions to designated critical habitat for the entire range of listed bull trout. This section covers the primary constituent elements determined essential to the conservation of Coastal/Puget Sound bull trout (50 CFR Part 17, FR Vol. 69, No. 122, page 35776):

(1) Water temperatures ranging from 36 to 59 ^{o}F (2 to 15 ^{o}C), with adequate thermal Refugia available for temperatures at the upper end of this range.

Project is in a marine area. There are no fresh water habitats in the project vicinity.

(2) Complex stream channels with features such as woody debris, side channels, pools, and undercut banks to provide a variety of depths, velocities, and instream structures.

Project is in a marine area. There are no complex steam channels in the project vicinity.

(3) Substrates of sufficient amount, size, and composition to ensure success of egg and embryo overwinter survival, fry emergence, and young-of-the-year and juvenile survival.

Project is in a marine area. There are no spawning areas in the project vicinity.

(4) A natural hydrograph, including peak, high, low, and base flows within historic ranges or, if regulated, a hydrograph that demonstrates the ability to support bull trout populations by minimizing daily and day-to-day fluctuations and minimizing departures from the natural cycle of flow levels corresponding with seasonal variation.

Project is in a marine area. There are no fresh water habitats in the project vicinity.

(5) Springs, seeps, groundwater sources, and subsurface water connectivity to contribute to water quality and quantity.

Project is in a marine area. There are no freshwater habitats in the project vicinity.

(6) Migratory corridors with minimal physical, biological, or water quality impediments between spawning, rearing, overwintering, and foraging habitats, including intermittent or seasonal barriers induced by high water temperatures or low flows.

Designated critical habitat extends offshore to the depth of 33 feet (ft) (10 meters (m)) relative to mean lower low water (MLLW; average of all the lower low-water heights of the two daily tidal levels). This equates to the average depth of the photic zone, and is consistent with the offshore extent of the nearshore habitat identified under the Puget Sound Nearshore Ecosystem Restoration Project (Corps and WDFW 2001). This area between MHHW and minus 10 MLLW is considered the habitat most consistently used by bull trout in marine waters based on known use, forage fish availability, and ongoing migration studies (Kramer 1994; Goetz, et al, 2004), and captures geological and ecological processes important to maintaining these habitats.

Most dredging projects are conducted in freshwater riverine areas. Dredging effects are addressed in individual dredging Section 7 consultations. As described in Section 3.1 of this BE, loading of barges is done carefully to assure minimal dredged material is spilled into the water. Once loaded, the barges are hauled by tugs to the disposal sites. While being loaded, the barge creates a shadow and may cause migrating salmonids to veer away from the barge location—however, dredging activities are restricted by timing windows so that work is conducted during the period of time when salmon are not migrating (juvenile salmon provide a source of prey to bull trout)—so this impact is discountable. The activity of tug and barge movement is transitory and does not constitute obstruction of migration. As a result the Corps has determined that the proposed action has discountable effects on Coastal/Puget Sound bull trout migratory corridors.

(7) An abundant food base including terrestrial organisms of riparian origin, aquatic macroinvertebrates, and forage fish

See discussion in Section 8.7.4 and (6) above. The continued transport and open-water disposal of dredged material would have discountable effects on forage fish and other prey species of coastal/Puget Sound bull trout.

(8) Few or no nonnative predatory, interbreeding, or competitive species present.

The continued transport and open-water disposal of dredged material would have no effect on predatory or competitive species of coastal/Puget Sound bull trout.

(9) Permanent water of sufficient quantity and quality such that normal reproduction, growth and survival are not inhibited.

The continued transport and open-water disposal of dredged material would have no effect on the permanence of water, and would have discountable and temporary effects on water quality with discountable effects to coastal/Puget Sound bull trout growth and survival.

Based on the foregoing analysis, the Corps has determined that the proposed action is **not likely to adversely affect** coastal/Puget Sound bull trout designated critical habitat.

8.8 Marbled Murrelet

The marbled murrelet (*Brachyramphus marmoratus*) was listed as a threatened species in October 1992. Primary causes of population decline include the loss of nesting habitat, and direct mortality from gillnet fisheries and oil spills. Critical habitat has been designated for this species in Washington, but it occurs in terrestrial nesting habitat and not in the marine waters of the action area, and is not discussed further in this BA.

8.8.1 Distribution

Marbled murrelets are permanent residents of Puget Sound, but the species is not abundant anywhere in Puget Sound (Speich and Wahl 1995). The majority of birds are found as singles or in pairs in a band about 300 to 2000 meters from shore (Strachan et al. 1995). The murrelet forages by pursuit diving in relatively shallow waters, usually between 20 and 80 meters in depth, but there have been observations of diving in waters more than 100 meters deep (Strachan et al. 1995).

Regional patterns of marbled murrelet activity in marine waters tend to be seasonal, and are tied to exposure to winter storm activity. There is a general shift of birds from the Strait of Juan de Fuca and British Columbia during spring and summer to areas in the San Juan areas and eastern bays during the fall and winter (Speich and Wahl 1995). Murrelets commonly aggregate near localized food sources, resulting in a clumped distribution. They are regularly found in specific areas (e.g., Hood Canal, Rosario Strait/San Juans), as foraging distribution is closely linked to areas of tidal mixing where prey congregate. However, occurrences are highly variable as they move from one area to another often in short periods of time.

8.8.2 Foraging and Food Web Relationships

The primary prey items for marbled murrelets in Puget Sound include Pacific sand lance (*Ammodytes hexapterus*), Pacific herring (*Clupea harengus*), and krill (euphausiids) (Burkett, 1995). The preference for forage fish, which tend to remain in nearshore environments, means that their exposures to contaminants through the DMMP open-water disposal program are discountable, since the forage fish themselves have little chance to encounter contaminants through bioaccumulation as a result of open-water disposal in Puget Sound. Also, Section 8.1.4 describes the low likelihood of toxicity due to PCB, and Section 8.4.1.1 describes the low likelihood of effects from PCDD/F, using a highly conservative bottomfish surrogate. Euphausiids are at a lower trophic level, and, even if exposed to disposal of dredged material, the likelihood of bioaccumulative effects in marbled murrelets as a result of preying on krill near an open-water disposal site is considered to be discountable.

8.8.3 Evaluation of Project Impacts

Potential effects from continued operations of the PSDDA non-dispersive and dispersive, open-water disposal sites to the marbled murrelet, are insignificant and discountable. This determination is supported by numerous factors.

First, marbled murrelets tend to be closely associated with the shoreline, generally feeding in waters less than 30 meters in depth and less than 500 meters from shore (Sealy, 1975) thus marbled murrelets would rarely be present at any of the disposal sites.

Second, should a marbled murrelet coincidentally be present in the disposal area during a discharge event, potential take from collisions is extremely unlikely as tugs and barges travel slowly, allowing marbled murrelets to quickly migrate away from the approaching barge and move to an undisturbed area.

Third, marbled murrelets would be expected to avoid the sediment plume while feeding, especially since their forage species would likely avoid the sediment plume as well. The period during which sediments in the water column are elevated is relatively short (approximately 12 minutes in midwater areas studied by Truitt [1986a, 1986b]) and localized. Both forage fish and marbled murrelets would migrate from the area affected by the discharge and recover relatively quickly from the stress caused by the falling sediment.

Fourth, the potential for toxic effects of contaminants released from discharged sediments is minimal. See discussion in Section 8.8.2 above.

Fifth, marbled murrelets primarily feed on pelagic organisms and do not typically feed at depths where benthic habitats are altered by dredged material disposal. Thus, foraging habitat for these species would not be directly affected.

Finally, as noted above, marbled murrelets typically feed on pelagic organisms, where their primary foods are forage fish (herring and sand lance). Herring, and sand lance are also pelagic, and their forage base would not be significantly affected by disposal activities. Sand lance can be demersal at times because they have no swim bladder, and sometimes rest in or on the bottom, but typically in less than 100 meters of water. Spawning areas for both of these species are in intertidal and shallow subtidal areas which are unaffected by disposal activities. Thus, continued disposal activities would not affect the prey base of marbled murrelets.

Based on the above analysis the continued operations of the PSDDA dispersive and non-dispersive, unconfined, open-water disposal sites are **not likely to adversely affect** the marbled murrelet, and will have **no effect** on designated critical habitat.

8.9 Bald Eagle

The bald eagle (*Haliaeetus leucocephalus*) was listed as threatened on 11 March 1967 and delisted in 2007. The bald eagle remains protected under the Bald Eagle and Golden Eagle Protection Act (BEGEPA). The following discussion is included to assure compliance with the BEGEPA.

8.9.1 Distribution

Bald eagles are present throughout the year in the Puget Sound basin, and nest along the coastline of the sound. Nest sites are throughout the basin where large, open, and accessible trees (usually Douglas fir, western red cedar, western hemlock, and black cottonwood) are present. Bald eagles also winter throughout the basin but are most common along streams that support salmon runs, where the eagles feed on spawned-out salmon.

8.9.2 Foraging and Food Web Relationships

Bald eagles are opportunistic feeders that prefer fish but have been known to eat a variety of mammals, amphibians, crustaceans, and birds. Bald eagles will also pursue and capture live birds and fish swimming close to the water's surface. Bird species taken are usually waterfowl, but may also include gulls (Hayward, et al., 1977; Richter, 1984; Leschner, 1984.)

8.9.3 Evaluation of Project Impacts

Potential effects to bald eagles from continued operations of the PSDDA non-dispersive and dispersive, open-water disposal sites are insignificant and discountable. This determination is supported by numerous factors.

First, the disposal sites are located in deep water, away from the nearshore, in low-productivity areas. Bald eagles tend to forage in nearshore areas that are shallow and therefore should rarely be present at any of the disposal sites.

Second, the prey base of the bald eagle are unlikely to be in the area of the disposal sites during disposal due to the temporary increase in turbidity. The period in which sediments in the water column are elevated is relatively short (approximately 12 minutes in midwater areas studied by Truitt [1986a, 1986b]) and localized. Forage fish and bald eagles would migrate from the area affected by the discharge and recover relatively quickly from the stress caused by the falling sediment.

Third, the large trees in which the bald eagle nest and roost will not be impacted by the transportation or disposal of dredged material. Therefore these actions will have no impact on the nesting ability of the bald eagle.

Fourth, the potential for toxic effects of the contaminants released from discharged sediments is minimal. Sediments are determined to be suitable for discharge through a series of physical, chemical and biological testing procedures which have been subject to thorough review by the regulating agencies and the public.

Finally, bald eagles are accustomed to vessels of all sizes on Puget Sound. The introduction of barges to unload dredged material is not expected to disturb them.

Because bald eagles are present in the action area there is a potential for effect. However, for the reasons cited above, the transport of dredged material and subsequent disposal at approved PSDDA sites are **not likely to adversely affect** bald eagles.

8.10 Southern Resident Killer Whales

The Southern Resident killer whale (SRKW) was listed as endangered on November 18, 2005 (70 FR 69903). Primary causes of population decline include habitat loss, decline in availability of prey items, pollution (PCBs, dioxins, furans), and noise disturbance from vessel traffic and whale watching. Critical habitat was designated November 29, 2006, consisting of the marine waters of Puget Sound, San Juan Islands and Straight of Juan De Fuca greater than 20 feet. Rivers and streams flowing into the Puget Sound are not designated as critical habitat.

The following analysis evaluates the potential risks from Dredged Material Management Program activities to the population of Southern resident killer whales (*Orcinus orca*). The risks evaluated are dredging operations, including the act of dredging itself, transport and openwater disposal of dredged material. The information provided is based on a review of literature and current on-going studies of bioaccumulation in killer whales and their prey; see a supplementary white paper, 2010, Appendix B.

8.10.1 Listing and Potential Threat from Biomagnification

When SRKW was listed, the Corps included analysis of the species in its Biological Evaluation for transport and disposal of dredged material at open water PSDDA sites in March 2005. NMFS concurred

with that assessment (NMFS, 2005a), but then expressed verbal concerns that effects to the endangered SRKW are not specifically addressed. These concerns precipitated preparation of the aforementioned white paper, which affirmed that operation of the DMMP program (i.e., transport and open-water disposal of dredged material) is not likely to adversely affect SRKW. NMFS concurred with this finding in 2007. In response to slightly different concerns, a new supplementary white paper was prepared (Appendix B). The new white paper covers new ground as compared to the 2007 version, but the conclusions drawn in the 2007 white paper are still valid. Since that white paper was already provided to NMFS, it is not appended to this document.

SRKW are known to consume over 95% of their diet as Chinook salmon from Puget Sound and adjacent waters in the Straits of Georgia, resulting in high levels of biomagnifying organic compounds. Recent research developments in the Pacific Northwest focusing on contaminants in sediments and their biomagnification potential in marine mammals have led to a review of the existing information as of 2010, and additional analysis (Appendix B). The conclusions of this review are described below (also see the discussion of project impacts to Chinook salmon in Section 8.1.4.).

Several factors may affect SRKW survival and well-being, but chiefly physical disturbance of behavior patterns by boat noise or intrusive boating activities, reduction of food source (chiefly adult resident Chinook salmon), and bioaccumulation of PBTs.

Under the DMMP, disposal site-related effects, including toxicity and bioaccumulation, are limited to "minor adverse" effects, as determined through testing for chemistry, toxicity, and bedded bioaccumulation tests (for persistent, bioaccumulative toxins, PBTs), and at times site-specific evaluations such as risk assessment are used as tools for making this determination. Sediments with higher than minor levels of adverse effect must be disposed of at an approved upland confined disposal site, or in an approved confined aquatic site.

8.10.2 Distribution

Although killer whales have been observed in tropical waters and the open sea, they are most abundant in coastal habitats and high latitudes. In the northeastern Pacific Ocean, killer whales occur in the eastern Bering Sea (Braham and Dahlheim, 1982) and are frequently observed near the Aleutian Islands (Scammon, 1874; Murie, 1959; Waite et al., 2001). They reportedly occur year round in the waters of southeastern Alaska (Scheffer, 1967) and the intercoastal waterways of British Columbia and Washington State (Balcomb and Goebel, 1976; Bigg et al., 1987; Osborne et al., 1988). There are occasional reports of killer whales along the coasts of Washington, Oregon, and California (Norris and Prescott, 1961; Fiscus and Niggol, 1965; Rice, 1968; Gilmore, 1976; Black et al., 1997; NMFS, 2004), both coasts of Baja California (Dahlheim et al., 1982), the offshore tropical Pacific (Dahlheim et al., 1982), the Gulf of Panama, and the Galapagos Islands. In the western North Pacific, killer whales occur frequently along the Soviet coast in the Bering Sea, the Sea of Okhotsk, the Sea of Japan, and along the eastern side of Sakhalin and the Kuril Islands (Tomilin, 1957). There are numerous accounts of their occurrence off the coasts of China (Wang, 1985) and Japan (Nishiwaki and Handa, 1958; Kasuya, 1971; Ohsumi, 1975). Data from the central Pacific are scarce. They have been reported off Hawaii, but do not appear to be abundant in these waters (Tomich, 1986; Caretta et al., 2001). Northwest marine waters are frequented by three ecotypes of killer whales: resident, transient, and offshore (Ford et al. 1998). Resident killer whales are further distinguished as northern residents (NRKW) that are often found in the waters off northeast Vancouver Island, BC, and southern residents (SRKW) that are often found in the waters off southeast Vancouver Island and into Puget Sound.

8.10.2.1 Southern Residents

The Southern Resident killer whale assemblage contains three pods-- J pod, K pod, and L pod--and is considered a stock under the MMPA (NOAA 2004). Their range during the spring, summer, and fall includes the inland waterways of Puget Sound, Strait of Juan de Fuca, and Southern Georgia Strait. Their occurrence in the coastal waters off Oregon, Washington, Vancouver Island, and more recently off the coast of central California in the south and off the Queen Charlotte Islands to the north has been documented. Little is known about the winter movements and range of the Southern Resident stock. Southern Residents have not been seen to associate with other resident whales, and mitochondrial and nuclear genetic data suggest that Southern Residents interbreed with other killer whale populations rarely if at all (Hoelzel et al., 1998; Barrett-Lennard, 2000; Barrett-Lennard and Ellis, 2001).

8.10.3 Foraging and Food Web Relationships

Killer whales are classified as top predators in the food chain and Southern Resident killer whales are fish eaters. Resident killer whale populations preferentially feed on Chinook, which comprise about 96% of their total diet (Ross et al. 2000, Hayteas and Duffield 2000, and Jarman et al. 1996). Hanson et al. (2010) estimate from fecal analysis that 80-90% of the Chinook consumed by SRKW originate from the Fraser River (including the South Thompson River), and only 6 to 14% originate from natal streams in the Puget Sound region. However, these latter Chinook have fed in PCB-rich Puget Sound. So, despite contributing a small fraction of the Chinook and representing much less than 50% of the range of SRKW, approximately half of the PCB burden in SRKW is believed to come from Puget Sound (Ross 2010, personal communication).

Appendix B addresses what is known of biomagnification and the relative contribution of the DMMP open-water disposal sites on this process. It is clear that SRKW as well as harbor seals have accumulated high levels of contaminants (in particular, PCB, PCDD/F, and PBDE) in their tissues, and that a significant amount of their body burden arises from exposure to prey derived from Puget Sound and the Strait of Juan de Fuca. Numerous studies (e.g., Ylitalo et al. 2005, West et al. 2008) confirm presence of relatively high levels of PCB in herring, Chinook salmon and SRKWs. SRKW appear to assimilate 4-6.6 times as much PCB as the northern resident populations, partly because of higher PCB concentrations in prey, and partly because SRKW prey have lower lipid content, requiring more prey consumption (Cullon et al. 2009).

8.10.4 Evaluation of Project Impacts

Potential effects to killer whales due to continued operations of the PSDDA dispersive and non-dispersive, unconfined, open-water disposal sites are insignificant. This determination is supported by the following discussion.

<u>Short term impacts to SRKW from barge transport/release of chemicals</u>. Should a killer whale coincidentally be present *en route* to or in the disposal area during a discharge event, it would experience a short period of non-lethal discomfort due to high suspended sediments in the water column. The water column elevation is localized and of short duration (approximately 12 minutes in mid-water areas studied by Truitt [1986a, 1986b]). Killer whales would migrate from the area affected by the discharge and recover relatively quickly from the discomfort. Effects of elevated water column suspended sediments would be short in duration and localized (as noted above), and are not expected to be lethal or significantly affect killer whales.

<u>Low potential impacts to SRKW's pelagic prey base from biomagnifying chemicals</u>. SRKW feed primarily on adult Chinook salmon. As the presence of salmon in the disposal areas would be rare, it is

unlikely that there would be significant increase in transfer of contaminants to the whales. Adult Chinook salmon typically feed on pelagic organisms to include principally forage fish (herring and sandlance) and gonatid squid. This forage base would not be significantly affected by disposal activities: herring are generally plankton feeders, while sandlance can sometimes rest in or on the bottom at times because they have no swim bladder, they typically do so in water less than 100 meters (328 feet). Spawning areas for both species are in intertidal and shallow subtidal areas unaffected by disposal activities.

Trophic models and uncertainties. To assess the effects of a sediment management program on a top predator that feeds on pelagic prey is difficult. Quantitative trophic models (Gobas 1993, Arnot and Gobas 2002, Windward 2008, and Gobas and Arnot 2010, in press) for predicting transfer of PCB from sediment to biota and subsequently through the food-web to higher predators have been applied in the Great Lakes, San Francisco Bay, the Lower Duwamish Waterway Superfund Site in Seattle, and Lake Washington in Seattle. Canada is currently using modeling to address intakes of PCBs by SRKW, northern residents, and transient populations, and will include Puget Sound as one of the exposure areas. This report is not yet available. These models use mechanistic relationships of release of PCB from sediment into water and benthos, and calculate biomagnification via food-web transfers. None of the models (including the Canadian model) are constructed at a suitable scale to support decision-making with regard to sediment management on the scale of dredged material sites. For instance, the Great Lakes, San Francisco Bay, and Lake Washington models are at the system level, and utilize measures of central tendency for sediment over wide areas as inputs. One model, the Lower Duwamish Food Web Model, is constructed on a series of 2- mile (on average) reaches, extending for a total length of five miles of that waterway, and was mainly applied to bottomfish and invertebrates.

The primary input of PCB to these models is via sediment, due to the affinity of PCB for that medium. However, in Puget Sound, with several highly contaminated riverine and near-shore environments, the distribution of PCBs in sediment is extremely skewed, i.e., has a few observations that are very high, and many that are low to moderate, which makes it difficult to select a reasonable input parameter for parameterizing a model. Orders of magnitude exist between the PCB concentrations found in such highly contaminated areas and the near-urban or non-urban areas of the Sound. In Puget Sound monitoring data sets, there are also variable PCB analytical methodologies (209 congeners, or a subset of congeners, or Aroclors) resulting in a wide range of analytical sensitivities, which contribute to the difficulty of calculating representative input parameters for PCB.

Another issue of scale involves the size of the dredged material sites relative to Puget Sound at large, which constitutes some 2,600 km^2 in comparison to c. 13 km^2 for sum of the 5 nondispersive sites, several of which are infrequently used.

As noted above, SRKW prey species “sample” their prey from specific areas of Puget Sound, and the prey also “sample” their environment consisting of water, sediment, and plankton. Pelagic fish are much less clearly linked to the sediment than are demersal fish. The existing models either ignore or greatly simplify behavior that affects exposure of fish to their environment. However, once concentrations are known from Chinook, there are well-calibrated models for predicting or explaining dietary inputs to SRKW (e.g., Hickie et al. 2007). To build and calibrate a model that relates sediment concentrations by location and depth (to accommodate fish behavior) is beyond the scope and resources of the DMMP. As no calibrated model is available that is able to assess effects of dredged material disposal at unconfined, open-water sites in Puget Sound, DMMP has relied upon site monitoring and inventories from testing of dredged material for suitability which is the best information available to assess bioaccumulation in Puget Sound. This is summarized in Appendix C. In summary, for PCB and PCDD/F on-site concentration are not generally elevated relative to the surrounding sediment at any of the dredged material sites, and are in the range of concentrations that typify Puget Sound predominantly

nonurban data sets. The DMMP's data for PBDE are not definitive, because the analytical technique used had lower resolution than that used in the Puget Sound Ambient Monitoring program.
The DMMP will continue to stay abreast of the best available information through regular meetings and other discussion with the DMMP agencies.

Low likely potential increase in availability of biomagnifying compounds to SRKW through disposal. While the current conditions of contamination in Puget Sound have the potential to affect SRKW, the programmatic actions of transport, placement, and disposal of dredged materials containing biomagnifying substances result in discountable effects to SRKW. First, the potential for toxic effects of contaminants released from discharged sediments is managed through a carefully designed program that examines impacts from sediment to benthos, epibenthos, and fish through a series of physical, chemical and biological testing procedures which have been subject to thorough review by the regulating agencies and the public. Second, because the DMMP program has resulted in sediment levels at open-water disposal sites that are at or below the mean of concentrations for PCBs and other chemicals observed in Puget Sound, or in the case of the Elliott and Commencement Bay sites, the bays in which they reside, the dredged material program has not exacerbated sediment contamination in Puget Sound, and thus would not cause additional adverse effects to SRKW. (See Appendix B for further discussion.) Furthermore, for dioxins, the proposed revision to the DMMP interim guidelines includes a site management objective of 4 pptr (or less), which was derived from a survey of non-urban background concentrations in Puget Sound.

Noise. Noise pollution from marine vessel traffic and how it may affect orca vocalizations and hearing is one of the main concerns with decline in the southern resident killer whale population. Killer whales rely on their highly developed acoustic sensory system for navigating, locating prey, and communicating with other individuals. Excessive noise levels may mask echolocation and other signals used by the species, as well as temporarily or permanently damage hearing sensitivity (NMFS 2005b).

Three studies that measured the killer whale audiogram show the range is approximately 500Hz up to 105kHz with varying sensitivities; the range of highest sensitivity is 18-42kHz, which includes their most common clicking noise at 20kHz (Hall and Johnson 1971, Bain et al. 1993, Szymanski et al. 1999). Very little data is available for the important parameter of received noise levels for killer whale tolerances and reactions. Erbe (2002) measured boat noise source levels at 145 to 169 dB re 1 μPA at 1m, and found this noise level elicited a behavioral response at 200m, and masked killer whale vocalizations at 14km distance. This study also found orca vocalizations to fall in the range of 105 to 124 dB re 1 μPA. The operation of most large marine vessels, including tugs that would have the barges for open-water sediment disposal, produce up to 180 dB, but mostly within the range of 80-1000 Hz, which is mostly below the hearing threshold of killer whales (generally above 6kHz) (Kipple and Gabriele, 2007). While the operation of the tug and barge would increase ambient noise levels along the immediate travel route, impacts of any sound disturbance would likely result in temporary, short-range displacement of animals rather than injury.

Noise generated by operation of the tug and barge will not significantly add to the typical noise spectrum that is already present in Puget Sound and marine waters around the San Juan Islands. Notably, tug Captains are instructed to stay clear of any killer whales that are sighted within the vicinity of the vessel. For these reasons, the effect of noise on killer whales produced by the tug and barge operations would be insignificant and would not lead to harassment of southern resident killer whales.

In summary, due to the wide distribution of these species within the action area; the relatively small area of pelagic habitat affected by disposal events; the low probability of the species coming in contact with the areas affected by a disposal activity; the infrequent and short-lived nature of disposal events; and the ability of these mobile species to quickly leave the affected area, the overall effects of disposal activities

on killer whales would be insignificant. The Corps has determined that the proposed action is **not likely to affect** Southern Resident Killer Whales.

8.10.5 Designated Critical Habitat

The action area falls within the Puget Sound marine area designated as critical habitat for the southern resident killer whale population. The 3 primary constituent elements (PCEs) of the designated CH are:

(1) Water quality to support growth and development;
(2) Prey species of sufficient quantity, quality, and availability to support individual growth, reproduction, and development as well as overall population growth;
(3) Passage conditions to allow for migration, resting, and foraging.

The continued use of open-water disposal sites in Puget Sound will have insignificant effects on the three key primary constituent elements. Specifically, minor and temporary turbidity caused by the dumping of dredged material will not cause a significant decline in water quality such that growth and development would decrease. While bioaccumulation of contaminants in tissues is an issue, as shown in the white papers (appendix B), the contribution of the disposal activities and the disposal sites themselves is negligible and discountable and has insignificant effects on the food web upon which the southern resident killer whales depend. Lastly, as discussed above, the operation of the tug and barge would not cause a blockage to passage of the killer whales through the area, especially as encounters with killer whales are extremely rare. For these reasons, continued use of the DMMP open-water disposal sites in Puget Sound is **not likely to adversely affect** designated critical habitat for southern resident killer whales.

8.11 Humpback Whale

The humpback whale (Megaptera novaeangliae) was listed as endangered on 2 June 1970. The primary cause for decline in the population of the humpback whale was due to whaling the early part of the 20th century. (ARKive [Internet]) Today the primary cause for population decline is the whales' vulnerability to changes in the marine environment. Other possible causes in population decline are pollution and potential alteration of fish stocks resulting from climate change. No critical habitat has been designated for the humpback whale.

8.11.1 Distribution

Humpback whales are found in tropical and polar seas in shallow, coastal areas (ARKive [Internet]). They occur seasonally off the coast of Washington along the continental shelf and shelf-edge waters (NMFS, 2004.) About every other year humpback whales will stray into Puget Sound but tend not to stay for extended periods of time. Although, in late spring 2004 a small humpback whale spent about two weeks in the Puget Sound near Tacoma.

8.11.2 Foraging and Food Web Relations

There are known humpback whale feeding grounds off the coast of California, Oregon, and Washington. These whales feed primarily on krill, herring, and capelin. Humpback whales utilize a wide range of feeding techniques, at times involving more than one individual and resembling a form of cooperative participation. (NMFS, 2004)

8.11.3 Evaluation of Project Impacts

Potential effects to humpback whales due to continued operations of the PSDDA dispersive and non-dispersive, unconfined, open-water disposal sites are insignificant. This determination is supported by numerous factors.

First, the likelihood of a humpback whale being present in the Puget Sound and in the disposal area during a discharge is improbable at best.
Second, the potential for toxic effects of contaminants released from discharged sediments is minimal. Sediments are determined to be suitable for discharge through a series of physical, chemical and biological testing procedures, which have been subject to thorough review by the regulating agencies and the public, and, since humpbacks seldom, if ever, feed in Puget Sound, the exposure to contaminants will be insignificant and discountable.

Third, effects of elevated water column suspended sediments would be short in duration and localized , and are not expected to be lethal or significantly affect humpback whales. If a humpback whale was in the disposal area during a discharge event, it could experience a short period of non-lethal discomfort due to the high suspended sediment concentration in the water column. The period during which sediments in the water column are elevated is relatively short (approximately 10 minutes in midwater areas studied by Truitt [1986a, 1986b]) and localized. Humpback whales would migrate from the area affected by the discharge and recover relatively quickly from the discomfort.

Fourth, although humpback whales are sensitive to vessel movements and noise it is expected that if the whales are present they would move out of the way of the vessels and related noise. Because of the low occurrence of humpback whales in the Puget Sound it is unlikely that there will be contact between the whales and the vessels.

Finally, due to the low occurrence of these whales within the action area; the low probability of the species coming in contact with the areas affected by a disposal activity; the infrequent and short-lived nature of disposal events; and the ability of these mobile species to quickly leave the affected area, the overall effects of disposal activities on humpback whales would be insignificant. The Corps determined that the proposed action is **not likely to adversely affect** humpback whales.

8.12 Leatherback Sea Turtle

The leatherback sea turtle (Dermochelys coriacea) was listed as endangered on 2 June 1970. The primary cause for decline of the leatherback turtle is due to accidental capture in fisheries and the over harvest of eggs. Other causes for decline in this species is habitat loss, boat strikes, and ingestion of discarded plastics. (ARKive [Internet]) Although critical habitat has been identified for this species, it does not occur within the project area, and is not addressed further in this BA.

8.12.1 Distribution

Leatherback sea turtles inhabit the shelf and offshore waters of the Pacific Ocean, including Washington, during the summer months. Their use of the inland waters of Washington is accidental at best. (NMFS, 2004.)

8.12.2 Foraging and Food Web Relationships

Adult leatherback sea turtles primarily feed on jellyfish and other soft-bodied species and feeds in temperate waters. (ARKive [Internet])

8.12.3 Evaluation of Project Impacts

Because leatherback sea turtles only use the inland waters of Washington accidentally and mechanisms of potential impact would be insignificant even if a sea turtle was present during disposal operations, the Corps has determined that the proposed action would have **no effect** on leatherback sea turtles nor their critical habitat.

8.13 Green Sturgeon

The green sturgeon, (*Acipenser medirostris*), is a widely distributed, marine-oriented sturgeon found in nearshore waters from Baja California to Canada (NOAA 2007). Their estuarine/marine distribution and the seasonality of estuarine use are largely unknown.

Green sturgeon are anadromous, spawning in the Sacramento, Klamath and Rogue rivers in the spring (NOAA 2007). Spawning occurs in deep pools or holes in large, turbulent river mainstreams. Specific characteristics of spawning habitat are unknown but are likely large cobbles, but can range from clean sand to bedrock (NOAA 2007).

Two distinct population segments (DPS) have been defined for green sturgeon - a northern DPS with spawning populations in the Klamath and Rogue rivers and a southern DPS that spawns in the Sacramento River (NOM 2007). The southern DPS was listed as threatened in 2006. According to the Final Rule, the southern DPS includes all spawning populations of green sturgeon south of the Eel River in California. The northern DPS remains a species of concern.

8.13.1 Distribution

Green sturgeon congregate in coastal waters and estuaries, including non-natal estuaries, where they are vulnerable to capture in salmon gillnet and white sturgeon sport fisheries. Green sturgeon are known to enter Washington estuaries during summer when water temperatures are more than 2 degrees Celsius warmer than adjacent coastal waters (Moser and Lindley 2007). Information from fisheries-dependent sampling suggests that green sturgeon only occupy large estuaries during the summer and early fall in the northwestern United States. Commercial catches of green sturgeon peak in October in the Columbia River estuary, and records from other estuarine fisheries (Willapa Bay and Grays Harbor, Washington) support the idea that sturgeon are only present in these estuaries from June until October (0. Langness, Washington Department of Fish and Wildlife, pers. comm. in Moser and Lindley (2007)). That they are known to occur in Puget Sound was learned largely through radio tag detections (Goetz, 2010).

8.13.2 Foraging and Food Web Relationships

Sturgeon migrations are thought to be related to feeding and spawning (Bemis and Kynard 1997). They suggested that green sturgeon move into estuaries of non-natal rivers to feed. However, the empty gut contents of green sturgeon captured in the Columbia River gillnet fishery suggests that these green sturgeon were not actively foraging in the estuary (T. Rien, Oregon Department of Fish and Wildlife, pers. comm.. in Moser and Lindley (2007)). The fact that they are caught on baited hooks incidentally during the sport season for white sturgeon in the Columbia River suggests they are feeding in the estuaries. Feeding behavior while in Puget Sound is unknown; however, in California sturgeon generally feed on benthic invertebrates, such as shrimp, crabs, worms, mollusks, and epibenthic crustaceans. Adult green sturgeon caught in Washington had preyed on sand lance and callianassid shrimp (P. Foley, University of California, Davis, unpublished data, as cited in Moyle *et al*. 1992).

8.13.3 Evaluation of Project Impacts

Green sturgeon are rare in Puget Sound, and are unlikely to be found at the depths of the open-water DMMP disposal sites. Even if they were to be present, the short-term and temporary nature of disposal operations, and the lack of significant elevation of PCB and PCDD/F in sediment at the sites relative to the without-dredging condition, lead to a determination of **not likely to adversely affect** for continued use of open-water disposal sites in Puget Sound.

8.13.4 Designated Critical Habitat

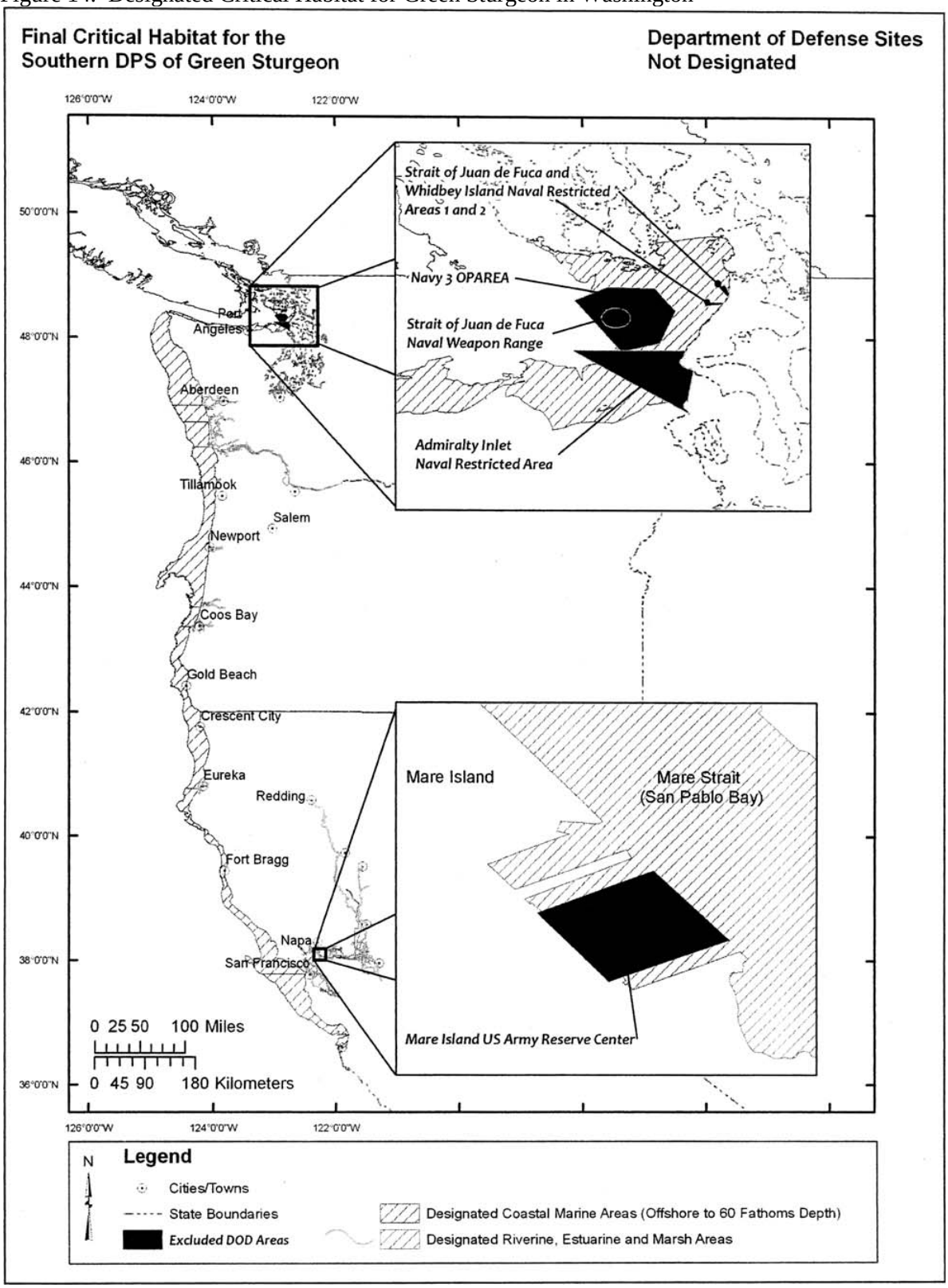
Critical habitat for green sturgeon was designated October 2009, and includes waters in the Strait of Juan de Fuca east to the northwestern shoreline of Whidbey Island, and then across Puget Sound from Partridge Point to Point Wilson at Port Townsend, and north up to the southern edge of the San Juan Islands (see map from FR Vol. 74, No. 195 / Friday, October 9, 2009, p. 52351; Figure 14). Designated critical habitat includes two of the DMMP disposal sites: Port Angeles and Port Townsend. The Rosario Strait disposal site is just north of the northern extent of designated critical habitat.

Effects to designated green sturgeon critical habitat are covered under the seven Primary Constituent Elements (PCE) essential for the conservation of the green sturgeon as outlined below:

PCEs – For freshwater riverine systems and estuarine habitats
1. Food resources- Dredged material disposal operations would have insignificant effects on infaunal and bottom-dwelling organisms, as no significant populations of these organisms occur at the Port Angeles or Port Townsend disposal sites.
2. Substrate type or size – Both Port Angeles and Port Townsend disposal sites are dispersive; dredged materials that are disposed at these sites drift away and do not accumulate on the bottom. Therefore, the existing substrate would not change as a result of disposal operations.
3. Water flow – Open-water disposal operations do not affect the flow of water.
4. Water quality – As addressed in the BE (Section 8.4.1.1) and appendix B, water and sediment chemistry may be insignificantly altered as a result of open-water disposal of dredged materials. The potential for bioaccumulation of contaminants in green sturgeon tissues is considered to be insignificant.
5. Migratory corridors – Continued use of open-water disposal sites in the Strait of Juan de Fuca will not affect migratory corridors for green sturgeon.
6. Depth – Both Port Angeles and Port Townsend disposal sites are dispersive; dredged materials that are disposed at these sites drift away and do not accumulate on the bottom. Depth of water is therefore not affected by disposal operations.
7. Sediment quality – As addressed in the BE and appendix B, water and sediment chemistry may be insignificantly altered as a result of open-water disposal of dredged materials. The potential for bioaccumulation of contaminants in green sturgeon tissues is considered to be discountable.

In conclusion, continued open-water disposal at the Port Angeles and Port Townsend disposal sites is **not likely to adversely affect** designated critical habitat for green sturgeon.

Figure 14. Designated Critical Habitat for Green Sturgeon in Washington



8.14 Conclusion

Table 11 summarizes the effect determinations made for each of the species potentially occurring in the project vicinity.

Table 11. Determination Summary Table

Species	Effect Determination	Designated Critical Habitat/Proposed Critical Habitat
Puget Sound Chinook *Oncorhynchus tshawytscha*	Not likely to adversely affect	Not likely to adversely affect
Hood Canal Summer-Run Chum *Oncorhynchus keta*	Not likely to adversely affect	Not likely to adversely affect
Steller Sea Lion *Eumetopias jubatus*	Not likely to adversely affect	No effect
Bocaccio *Sebastes paucispinis*	Not likely to adversely affect	NA
Canary Rockfish *S. pinniger*	Not likely to adversely affect	NA
Yelloweye Rockfish *S. ruberrimus*	Not likely to adversely affect	NA
Eulachon *Thaleichthys pacificus*	Not likely to adversely affect	NA
Coastal/Puget Sound Bull Trout *Salvelinus confluentus*	Not likely to adversely affect	Not likely to adversely affect
Marbled Murrelet *Brachyramphus marmoratus*	Not likely to adversely affect	No effect
Bald Eagle *Haliaeetus leucocephalus*	Not likely to adversely affect	NA
Southern Resident Killer Whale *Orcinus orca*	Not likely to adversely affect	Not likely to adversely affect
Humpback Whale *Megaptera novaeangliae*	Not likely to adversely affect	NA
Leatherback Sea Turtle *Dermochelys coriacea*	No effect	No effect
Green Sturgeon *Acipenser medirostris*	Not likely to adversely affect	Not likely to adversely affect

9 ESSENTIAL FISH HABITAT EVALUATION

9.1 Essential Fish Habitat Designations

Pursuant to the MSFCMA and the 1996 Sustainable Fisheries Act (SFA), an EFH evaluation of impacts is necessary for federal actions, including activities that are associated with dredge material disposal. The EFH evaluation applies to all species managed under a federal Fishery Management Plan (FMP). For the Pacific West Coast (excluding Alaska), there are three FMPs, covering groundfish, coastal pelagic species, and Pacific salmon.

Estuaries of Washington State, including Puget Sound and the Pacific coast, are designated as EFH for various groundfish, coastal pelagic, and salmonid species (PFMC 1998a, 1998b). A detailed discussion of EFH for groundfish is provided in the Final Environmental Assessment/Regulatory Impact Review for Amendment 11 to the Pacific Coast Groundfish Fishery Management Plan (PFMC 1998b) and the NMFS Essential Fish Habitat for West Coast Groundfish Appendix (NMFS 1998). A detailed discussion of EFH for coastal pelagic species is provided in Amendment 8 to the Coastal Pelagic Species Fishery Management Plan (PFMC 1998a). Salmonid EFH is discussed in Appendix A of Amendment 14 to the Pacific Coast Salmon Plan (PFMC 1999). A summary of EFH for each FMP follows:

Groundfish: EFH for Pacific coast groundfish is defined as the aquatic habitat necessary to allow for groundfish production to support long-term sustainable fisheries for groundfish and for groundfish contributions to a healthy ecosystem. Descriptions of groundfish EFH for each of the 83 species and their life stages result in more than 400 EFH identifications. When these EFHs are taken together, the groundfish EFH includes all waters from the mean higher high water line, and the upriver extent of saltwater intrusion in river mouths, along the coasts of Washington, Oregon, and California seaward to the boundary of the U.S. EEZ.

Coastal pelagic species: Amendment 8 to the Coastal Pelagic Species Fishery Management Plan describes the habitat requirements of five pelagic species: Northern anchovy, Pacific sardine, Pacific (chub) mackerel, jack mackerel, and market squid. These four finfish and market squid are treated as a single species complex because of similarities in their life histories and habitat requirements. EFH for coastal pelagic species is defined as the east-west geographic boundary of EFH for CPS as defined by all marine and estuarine waters from the shoreline along the coasts of California, Oregon, and Washington offshore to the limits of the EEZ and above the thermocline where sea surface temperatures range between 10° – 26° C. The southern boundary is the U.S.-Mexico maritime boundary. The northern boundary is more dynamic, and is defined as the position of the 10° C isotherm, which varies seasonally and annually.

Pacific salmon - Chinook, coho, and Puget Sound pink salmon: EFH for the Pacific coast salmon fishery means those waters and substrate necessary for salmon production needed to support a long-term sustainable salmon fishery and salmon contributions to a healthy ecosystem. To achieve that level of production, EFH must include all those streams, lakes, ponds, wetlands, and other currently viable water bodies and most of the habitat historically accessible to salmon in Washington, Oregon, Idaho, and California. Exceptions include areas upstream of certain impassable manmade barriers (as identified by the PFMC), and longstanding, naturally impassable barriers (i.e., natural waterfalls in existence for several hundred years). In the estuarine and marine areas, salmon EFH extends from the nearshore and tidal submerged environments within state territorial waters out to the full extent of the exclusive economic zone (370.4 km/230.2 miles) offshore of Washington, Oregon, and California north of Point Conception.

Furthermore, the Groundfish FMP categorizes EFH into seven units called "composite" EFHs. EFH and life history stages for groundfish, pelagic, and salmonid species commonly found in Puget Sound that could potentially be affected by continued open dredged material disposal are listed in appendix C (NMFS 1998; WDF 1992). The seven composite EFH identifications are listed below.

- Estuarine - Those waters, substrates and associated biological communities within bays and estuaries of the EEZ, from mean higher high water level (MHHW, which is the high tide line) or extent of upriver saltwater intrusion to the respective outer boundaries for each bay or estuary as defined in 33 CFR 80.1 (Coast Guard lines of demarcation).
- Rocky Shelf - Those waters, substrates, and associated biological communities living on or within 10 meters (5.5 fathoms) overlying rocky areas, including reefs, pinnacles, boulders, and cobble, along the continental shelf, excluding canyons, from the high tide line MHHW to the shelf break (~200 meters or 109 fathoms).
- Nonrocky Shelf - Those waters, substrates, and associated biological communities living on or within 10 meters (5.5 fathoms) overlying the substrates of the continental shelf, excluding the rocky shelf and canyon composites, from the high tide line MHHW to the shelf break (~200 meters or 109 fathoms).
- Canyon - Those waters, substrates, and associated biological communities living within submarine canyons, including the walls, beds, seafloor, and any outcrops or landslide morphology, such as slump scarps and debris fields.
- Continental Slope/Basin - Those waters, substrates, and biological communities living on or within 20 meters (11 fathoms) overlying the substrates of the continental slope and basin below the shelf break (~200 meters or 109 fathoms) and extending to the westward boundary of the EEZ.
- Neritic Zone - Those waters and biological communities living in the water column more than 10 meters (5.5 fathoms) above the continental shelf.
- Oceanic Zone - Those waters and biological communities living in the water column more than 20 meters (11 fathoms) above the continental slope and abyssal plain, extending to the westward boundary of the EEZ.

9.2 Potential effects of PSDDA deep-water disposal on EFH

The PSDDA program was developed to minimize potential effects on the physical, chemical, and biological characteristics of disposal sites while providing an economically feasible alternative to upland disposal. The selection of both dispersive and nondispersive sites was based on an evaluation of benthic resources at candidate sites. Analytical procedures, collectively called the Benthic Resources Assessment Technique (BRAT) (Lunz and Kendall 1982, Clarke and Lunz 1985), were used to estimate the relative amount of trophic support that a given benthic habitat provides to fishes. Results of the BRAT analyses were used to help determine final site selections.

The discharge of dredged material subsequent to dredging operations may result in a variety of potential effects on EFH. This section discusses the transport of dredged material and the dredged material disposal. Potential effects of dredged material disposal are further analyzed under the following categories: contaminants, biological oxygen demand, entrainment, turbidity, and smothering.

9.2.1 Transport of Dredged Materials

Transport of dredged material is addressed in Section 3.1 of this BE. As described in that section, transport of dredged material is very unlikely to have any effect on EFH.

9.2.2 Disposal of Dredged Materials

A number of potential effects to biota are generally considered in the evaluation of dredged material disposal. The discharge of dredged material consists of the material traveling through the water column and impacting and dispersing on the bottom (see Disposal Activities section for a more detailed discussion of dredged material disposal).

9.2.2.1 Contaminants

Exposure of salmon, coastal pelagic, and groundfish species to significant levels of contaminants is not expected. As noted throughout this analysis, and in appendix B, sediment is rigorously tested for chemicals of concern and potential for biological effects before it is determined to be suitable for disposal at PSDDA sites. Material that contains higher levels of contaminants is disposed at approved confined disposal site in upland or nearshore areas.

9.2.2.2 Biological Oxygen Demand

The potential for biological impacts associated with oxygen demand of dredged materials is sometimes cited as a concern. Water quality monitoring of experimental disposal sites in Elliott Bay, a nondispersive site, during and after disposal showed no significant long-term impacts to water quality for up to 9 months (PSDDA/FEIS 1988). Although there was a small, short-term decrease in dissolved oxygen, concentrations never decreased below the 5-mg/l minimum set by regulatory agencies as harmful to migratory fish. Because of the high degree of mixing at the dispersive sites, oxygen-demanding materials would be rapidly diluted and any decrease in dissolved oxygen content in the water would be unmeasurable.

9.2.2.3 Entrainment

Entrainment of adult or juvenile fish by released dredged material as it falls through the water column could occur but is unlikely to affect significant numbers of individuals. Adults of most species are highly mobile and could actively avoid or escape the descending plume of dredged material. For example, Chinook salmon have a maximum burst speed of about 15 body lengths per second for a fish measuring 30 cm in length, and about 8 body lengths per second for a fish measuring 100 cm in length (Webb 1995). Yearling and older fish would require from 1 to 3 seconds to escape even from the center of the release zone. Smaller species, such as sardines or mackerel, have slower swimming speeds (3 to 10 body lengths per second) and therefore entrainment is possible when individuals are located in the immediate path of the descending plume of material. Most fish would be expected to disperse during dredge material disposal operations and avoid the affected area.

Dredging (and therefore disposal) is not currently allowed between March 15 and June 15 to protect outmigrating juvenile salmon. Dredged material disposal is not allowed at the Port Townsend or Port Angeles sites between September 1 and November 30 to protect shrimp. NMFS has indicated that additional PSDDA site closures are not required to protect juvenile or adult salmon (Donnelly pers. comm.). Since juvenile salmon migrate rather rapidly to the ocean environment, these closures minimize the potential occurrence of outmigrating juvenile salmon in the disposal site areas. These timing restrictions would also protect other fish species.

Additionally, the disposal sites are located in deep pelagic offshore habitat lacking physical or biological components that would attract or concentrate salmon or coastal pelagic species. Physical structures (e.g., pilings, rock outcroppings, etc.) are not present,. Potential effects to groundfish are discussed separately under "smothering" below.

9.2.2.4 Turbidity (Water Column)

In the course of its descent through the water column, some amount of sediment disperses into the water column.

Increases in turbidity associated with the disposal of dredged material could result in a temporary, localized reduction in the feeding success of visual predators. High levels of suspended sediment can clog gills and cause sublethal physiological effects or mortality of juvenile and adult fish. Sediment suspended at the surface or midwater would be more likely to affect salmon and coastal pelagic species than sediments dispersed on or near the bottom. As to non-dispersive sites, salmon are pelagic species and should not occur near the substrate at the disposal sites because of the depth of the sites.

Although dredged sediments could occur in the water column for a period of hours, turbidity would reach ambient levels rather quickly. PSDDA/DSSTA 1989 evaluated the transport and duration of suspended sediment in the water column following a generic disposal event at the dispersive sites. At the end of 1 hour, calculation indicated that suspended sediment traveled 1,097 meters (3,600 feet) and concentrations associated with loss of sediment from the jet would be approximately 0.25 mg/l, a level that is approximately one-quarter of the ambient concentration. Research by Truitt (1986a) indicates that very little suspended sediment is released near the surface or midwater during dredged material disposal (figure 7). Most sediment is released as the jet of dredged material impacts the bottom. An increase in turbidity at all locations is estimated to be short-lived (i.e., 12 minutes).

In a study published in 1983, Pequegnat reported maximum concentrations of suspended solids observed in the field in the range of 1,000 mg/l. The same researcher found that lethal concentrations of suspended sediments for adult marine organisms were an order of magnitude or higher than maximal suspended sediment concentrations observed in the field during dredging operations. Field bioassays on the tolerances of juvenile salmonids to suspended solids indicated the LC50 for wild chum salmon exposed to suspended sediments was 1,047 mg/l (Martin et al. 1977). The study also concluded that healthy juvenile chum salmon could withstand very high concentrations of suspended sediments (up to 3,056 mg/l) without apparent effects. Studies by Redding et al. (1987) found that exposure to relatively high suspended sediment loads (2,000 to 2,500 mg/l) did not seem to severely stress yearling coho salmon and steelhead.

Increased turbidity and suspended sediment in the vicinity of the disposal sites could cause a temporary and localized decrease in phytoplankton productivity or cause mortality of pelagic fish eggs, larvae, and zooplankton. However, the disposal sites lack components that would attract or concentrate plankton or fish. This factor could reduce effects, especially on mackerel, anchovy, and sardines. These species often feed in areas of high plankton abundance (e.g. upwelling fronts). Entrainment of copepods or krill could occur because of their small size and limited ability to move, as could entrainment of their food organisms (e.g., phytoplankton, rotifers, etc.). However, the localized effects and low frequency of disposal probably will not significantly impact planktonic or pelagic invertebrate populations. These organisms are widely distributed throughout the Sound, and the localized, short-term, and infrequent disposal of materials would not substantively affect Sound-wide populations of these organisms.

9.2.2.5 Smothering

For dispersive sites, only a limited amount of dredged material descends to or remains on the benthos. The high velocity of the currents at the sites leads to the rapid erosion of any remaining material. Species that persist in high current environments are adapted to the dynamic nature of these sites. Sediment transport, accumulation, and erosion are common during ebbing, flooding, and slack tides.

As the main jet of material hits bottom at nondispersive sites, the material spreads across an area usually less than 610 meters (2,000 feet) down current and 305 meters (1,000 feet) on either side of the discharge point. The impact itself can affect epibenthic and benthic organisms within the direct impact area. As the jet impacts the bottom, there is a density/momentum-driven surge of material away from the impact point. As the material settles, a gradient in the thickness of the newly deposited material tends to emerge, with thicker deposits near the impact site and thinner deposits at greater distances from the center of the site. If the disposed material settling on the bottom is thick enough, it can smother benthic fauna, including flatfish that are unable to rapidly leave the area. Monitoring studies at PSDDA sites indicate that the benthic communities were able to recover when dredged material cover was less than 10 cm thick (Corps 1992).

Longer-term impacts can occur if sediments are sufficiently contaminated to result in toxicity or bioaccumulation. As noted throughout this analysis, only sediments that pass rigorous chemical (and sometimes biological) testing are discharged at PSDDA sites. The DMMP does not allow for the disposal of dredged material that would result in unacceptable impacts to the environment. Monitoring studies at the nondispersive disposal sites have verified that sediment conditions are within acceptable ranges. Therefore, potential toxicity and bioaccumulation associated with dredged material disposal are not likely.

Changes in sediment character (e.g. percent silt, clay, sand, gravel) have occurred at the PSDDA sites. Changes in sediment character can affect benthic community structure and productivity. Temporary and localized impacts to benthic fauna inside the disposal site are expected from burial. Monitoring of benthic fauna just outside the Elliott Bay site in 1992 verified that no adverse environmental effects occurred beyond the boundary of the disposal site (PSDDA 1994). The abundance of major benthic taxa at the transect stations was similar to the abundances measured during baseline studies. Significantly, monitoring at the Elliott Bay site also revealed lower concentrations of chemical contaminants within the disposal site than in the surrounding sediments. The disposal of clean sediments through the PSDDA program is in effect creating a cap over existing contaminated sediments within the Elliott Bay disposal site.

The 1990 monitoring results at Port Gardner after the disposal of 990,000 cubic yards of dredged material indicated that all the site management objectives were met (i.e., all three monitoring questions as described in Table 8 relative to site management objectives were not exceeded). An evaluation of the benthic infaunal transect data indicated there was a 50% reduction in major taxa relative to baseline conditions, but the reductions were attributable to regional effects and not caused by dredged material. The same benthic major taxa reductions were observed at benchmark stations outside the direct influences of dredged material disposal. The monitoring results also confirmed that there were no unacceptable adverse effects on biological resources immediately offsite caused by dredged material.

9.3 Conclusions

The PSDDA program was developed to minimize the potential effects of dredged material disposal on the environment and included a rigorous site selection process and development of toxicological screening criteria to achieve this goal. The disposal of dredged material has the potential to affect habitat, including

EFH, as discussed above. The repeated accumulation of disposed material is the primary mechanism by which EFH may be affected.

Although disposed material may descend to the benthic habitats at the dispersive sites, accumulation is not likely to occur because of the high currents at these sites. Any material that reaches the bottom is rapidly exported from the site. For nondispersive sites, disposed material may accumulate on benthic habitats and may affect sessile or slow moving organisms within the disposal zone. Repeated disturbance is likely to affect the productivity of these sites and may reduce the abundance of organisms that cannot rapidly recolonize the disturbed area.

Several factors have been found to be important in determining the rate at which a disturbed site is recolonized by soft-bottom benthic invertebrate species. Soft bottom sediments are frequently disturbed because wave actions and currents can move soft sediments about. Resident organisms are adapted to such natural perturbations and tend to recover quickly. Recovery of the motile organisms on disturbed soft-bottom habitats can occur by adult migration, as well as by larval sediment and growth; both phenomena are more rapid on soft-bottom habitats than hard substrate.

The PSDDA program limits the area of potential effect by concentrating disposal activities at defined sites, chosen based on their relatively low habitat value. The limited area of the disposal sites (650 to 884 acres for dispersive sites and 260 to 415 acres for nondispersive sites) ensures that the disposal sites remain surrounded by unaltered habitat, facilitating recruitment and utilization of the areas by neighboring species. Although 2001 monitoring at the Commencement Bay site indicated that some dredged material had extended beyond the site boundary, no discernable effects on the benthic community have been identified. Analyses using the ST-FATE model will be used to formulate future Commencement Bay site recommendations. Physical surveys at other nondispersive disposal sites have confirmed that the QA/QC for dump barge positioning is effective and material is remaining in the targeted areas.

9.4 Conservation Measures

A number of measures and procedures inherent in the DMMP act in combination to minimize the potential for impacts to biota and habitat (including EFH) in Puget Sound. These include

- consideration of beneficial-use disposal sites for appropriate dredged material;
- consolidation of dredged material disposal sites to minimize the area and locations affected by dredged material disposal;
- siting of dredged material disposal sites in areas of relatively low habitat value or low use by biota (distance offshore, depth, areas with low known resource value);
- timing of dredging and disposal events to avoid overlap with sensitive migration or life history periods of salmon;
- using dredged material testing protocols to ensure the suitability of materials for unconfined, open-water discharge;
- sequencing of disposal when possible with the cleanest material disposed last, thereby improving the quality of the surface sediment at the disposal site;conducting site monitoring activities (physical, chemical and biological) to determine if unacceptable impacts are occurring at disposal sites;
- performing annual review of monitoring results; and
- using adaptive management of the DMMP by multiagency task force.

The PSDDA program addresses all recommended conservation measures put forth by the Pacific Fisheries Management Council in their management plans for Pacific salmon, coastal pelagic species, and Pacific coast groundfish species (PFMC 1999, 1998a and b).

9.5 Determination of Effect

9.5.1 Pacific Salmon EFH

Based on the analysis provided in this document the transport and disposal of dredged material under the PSSDA program is **not likely to adversely affect** EFH for pacific salmon species. The disposal sites, because of their location and depth, do not substantially contribute as habitat for salmon or their prey base. Although indirect food web linkages between deeper benthic environments and salmon species exist, the short-term and localized disturbances associated with dredged material disposal would be minimal and discountable.

9.5.2 Coastal Pelagic EFH

Based on the analysis provided in this document the transport and disposal of dredged material under the PSSDA program is **not likely to adversely affect** EFH for coastal pelagic species. The disposal sites, because of their location and depth, do not substantially contribute as habitat for coastal pelagic species and their prey base. Potential effects on water column habitat are limited and short-term, primarily restricted to several minutes after disposal events. The intermittent use of the disposal sites ensures that temporary effects do not rise to significant levels that may result in harm to coastal pelagic EFH.

9.5.3 Groundfish EFH

Based on the analysis provided in this document the transport and disposal of dredged material under the PSDDA program **may adversely affect** the EFH for groundfish species, but the adverse effect on EFH would not be substantial because of the conservation measures listed above. The PSDDA program has, by design, included site selection criteria to minimize the potential for deleterious effects caused by impacts to the trophic structure that supports groundfish species.

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Appendix A

Screening Level (SL), Bioaccumulation Trigger (BT), and Maximum Level (ML) Guideline Chemistry Values (Dry Weight Normalized)

2010 SCREENING LEVEL (SL), BIOACCUMULATION TRIGGER (BT), AND MAXIMUM LEVEL (ML) GUIDELINE CHEMISTRY VALUES

CHEMICAL	CAS(1) NUMBER	SCREENING LEVEL	BIOACCUM TRIGGER	MAXIMUM LEVEL
METALS (mg/kg)				
Antimony	7440-36-0	150	---	200
Arsenic	7440-38-2	57	507.1	700
Cadmium	7440-43-9	5.1	11.3	14
Chromium	7440-47-3	---(2)	267	---(2)
Copper	7440-50-8	390	1027	1,300
Lead	7439-92-1	450	975	1,200
Mercury	7439-97-6	0.41	1.5	2.3
Nickel	7440-02-0	140	370 (3)	370
Selenium	7782-49-2	---(2)	3	---(2)
Silver	7440-22-4	6.1	6.1 (4)	8.4
Zinc	7440-66-6	410	2783	3,800
ORGANOMETALLIC COMPOUNDS (ug/L)				
Tributyltin (5) (interstitial water)	56573-85-4	0.15	0.15	---
ORGANICS (ug/kg)				
Total LPAH	---	5,200	---	29,000
Naphthalene	91-20-3	2,100	---	2,400
Acenaphthylene	208-96-8	560	---	1,300
Acenaphthene	83-32-9	500	---	2,000
Fluorene	86-73-7	540	---	3,600
Phenanthrene	85-01-8	1,500	---	21,000
Anthracene	120-12-7	960	---	13,000
2-Methylnaphthalene	91-57-6	670	---	1,900
Total HPAH	---	12,000	---	69,000
Fluoranthene	206-44-0	1,700	4,600	30,000
Pyrene	129-00-0	2,600	11,980	16,000
Benz(a)anthracene	56-55-3	1,300	---	5,100
Chrysene	218-01-9	1,400	---	21,000
Benzofluoranthenes (b+k)	205-99-2 207-08-9	3,200	---	9,900
Benzo(a)pyrene	50-32-8	1,600	---	3,600
Indeno(1,2,3-c,d)pyrene	193-39-5	600	---	4,400
Dibenz(a,h)anthracene	53-70-3	230	---	1,900
Benzo(g,h,i)perylene	191-24-2	670	---	3,200
CHLORINATED HYDROCARBONS				
1,3-Dichlorobenzene	541-73-1	170	---	---
1,4-Dichlorobenzene	106-46-7	110	---	120
1,2-Dichlorobenzene	95-50-1	35	---	110
1,2,4-Trichlorobenzene	120-82-1	31	---	64
Hexachlorobenzene (HCB)	118-74-1	22	168	230

CHEMICAL	CAS(1) NUMBER	SCREENING LEVEL	BIOACCUM TRIGGER	MAXIMUM LEVEL
PHTHALATES				
Dimethyl phthalate	131-11-3	71 (7)	---	1,400 (7)
Diethyl phthalate	84-66-2	200 (7)	---	1,200 (7)
Di-n-butyl phthalate	84-74-2	1,400 (7)	---	5,100 (7)
Butyl benzyl phthalate	85-68-7	63 (7)	---	970 (7)
Bis(2-ethylhexyl) phthalate	117-81-7	1,300 (7)	---	8,300 (7)
Di-n-octyl phthalate	117-84-0	6,200	---	6,200 (7)
PHENOLS				
Phenol	108-95-2	420	---	1,200
2-Methylphenol	95-48-7	63	---	77
4-Methylphenol	106-44-5	670	---	3,600
2,4-Dimethylphenol	105-67-9	29	---	210
Pentachlorophenol	87-86-5	400	504	690
MISCELLANEOUS EXTRACTABLES				
Benzyl alcohol	100-51-6	57	---	870
Benzoic acid	65-85-0	650	---	760
Dibenzofuran	132-64-9	540	---	1,700
Hexachloroethane	67-72-1	1,400	---	14,000
Hexachlorobutadiene	87-68-3	29	---	270
N-Nitrosodiphenylamine	86-30-6	28	---	130
VOLATILE ORGANICS				
Trichloroethene	79-01-6	160	---	1,600
Tetrachloroethene	127-18-4	57	---	210
Ethylbenzene	100-41-4	10	---	50
Total Xylene (sum of o-, m-, p-)	95-47-6 108-38-3 106-42-3	40	---	160
PESTICIDES				
Total DDT (sum of 4,4'-DDD, 4,4'-DDE and 4,4'-DDT)	72-54-8 72-55-9 50-29-3	6.9	50	69
Aldrin	309-00-2	10	---	---
Chlordane	54-74-9	10	37	---
Dieldrin	60-57-1	10	---	---
Heptachlor	76-44-8	10	---	---
Alpha-BHC	319-84-6	---	10 (6)	---
Gamma-BHC (Lindane)	58-89-9	10	---	---
Total PCBs	---	130	38 (6)	3,100

(1) Chemical Abstract Service Registry Number

(2) As no SL value exists to trigger toxicity testing, this chemical will only be evaluated for its bioaccumulative potential.

(3) BT adjusted to new ML for nickel.

(4) BT adjusted to new SL for silver.

(5) See Testing, Reporting, and Evaluation of Tributyltin Data in PSDDA and SMS Programs at URL http://www.nws.usace.army.mil/dmmo/8th_arm/tbt_96.htm

(6) This value is normalized to total organic carbon, and is expressed in mg/kg (TOC normalized).
(7) 2004 SL's based on 1998 AETs.

APPENDIX B.

Consideration of DMMP Effects on Marine Mammals

APPENDIX B.

Consideration of Puget Sound Dredged Material Management Program (DMMP) Actions in Terms of Effects on Biomagnification of Persistent Organic Pollutants in Southern Resident Killer Whales, and Steller Sea Lions

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Executive Summary

A number of lines of evidence suggest that biomagnifying compounds such as polychlorinated biphenyls (PCBs), polychlorinated dioxins/furans (PCDD/F), and polybrominated diphenyl ethers (PBDEs) are entering the food web in Puget Sound at levels that may have toxic effects on organisms protected under the Endangered Species Act or the Marine Mammals Protection Act. This supplement describes a) the evidence for endangerment and food-web relationships from sediment to Southern Resident Killer Whale, Steller Sea Lion, and Harbor Seal, and b) how the Dredged Material Management Program (DMMP) evaluates its actions in terms of impacts to these organisms during decision-making related to transport and disposal of dredged materials at unconfined, open-water sites in Puget Sound.

Southern Resident Killer Whale (SRKW), Steller Sea Lion, and Harbor Seals consume prey species that frequent Puget Sound (the purview of the DMMP). NOAA has designated SRKW Critical Habitat (CH) that includes seven of the eight DMMP open-water disposal sites (only Port Townsend is not in CH). SRKW appear to assimilate 4-6.6 times as much PCB as the northern resident populations, partly because of higher PCB concentrations in prey and partly because SRKW prey have lower lipid content, requiring more prey consumption (Cullon et al. 2009). SRKW consume Chinook as a major part of their diet; in turn, adult Chinook consume herring, which feed on zooplankton and smaller pelagic fish. Steller Sea Lions and seals consume pelagic and demersal fish and shellfish. Numerous studies (e.g., Ylitalo et al. 2005, , West et al. 2008) confirm presence of relatively high levels of PCB in herring, Chinook salmon and SRKWs. PCB levels in Puget Sound biota are higher than in San Francisco Bay, although comparably high levels of sediment PCB occur in both. Puget Sound is a largely "closed" system regarding sediment, due to 2 sills near the outlet into the Strait of Juan de Fuca; San Francisco Bay is an open system which loses sediment to offshore currents.

Quantitative food-web models for predicting transfer of PCB from sediment to biota and subsequently through the food-web to higher consumers have been developed for the Great Lakes, San Francisco Bay, the Lower Duwamish Waterway Superfund Site in Seattle, and Lake Washington in Seattle (Gobas 1993, Arnot and Gobas 2002, Windward 2008, and Gobas and Arnot 2010, in press). While no model has yet been constructed and calibrated for Puget Sound, efforts by Condon and Gobas (2005) and Shaw et al. (2005) are currently underway to explain and predict system loadings of PCB to SRKW in the Strait of Georgia, and this model may be extended to Puget Sound (Peter Ross, Canadian Division of Fisheries and Oceans, personal communication). These models use estimates (based upon equilibrium calculations from one environmental compartment to another. For example, PCB migration from sediment into into surface water, into benthos, into plankton, into fish, and into higher predators. The models are not constructed at a suitable scale to support decision-making with regard to sediment management. The Great Lakes, San Francisco Bay, Georgia Strait and Lake Washington models are at the ecosystem level, and utilize measures of central tendency for sediment; the Strait of Georgia or Puget Sound models are not available for review at

this time of writing. The Lower Duwamish Food Web Model is constructed on the scale of 5 miles of the waterway.

Despite convincing evidence of biomagnifying compounds in dredged materials, no currently available model is able to assess the contribution of bioavailable, biomagnifying contaminants from sediment placement at dredged material disposal at unconfined, open-water sites in Puget Sound. Some reasons for this follow.

a) Because of variable PCB analytical methodologies used in Puget Sound (measuring all 209 congeners, or a subset of 19 congeners multiplied by 2 to equal the 209 [the NOAA method], or mixtures of Aroclors), the associated wide range of analytical sensitivities, and the several method of summation of compound suites with large percentages of non-detected data, it is difficult to confidently calculate a central tendency measure for the Sound.

b) From the existing analytical information, is apparent that the Puget Sound sediment distribution of PCB is highly skewed, with extreme values in the Lower Duwamish Waterway and the associated Elliott Bay in Seattle, and in Everett Harbor. Orders of magnitude exist between such areas and the near-urban or non-urban areas of the Sound.

c) Non-dispersive dredged material disposal sites are monitored to determine whether there is a significant increase of PCBs and exceedance of sediment screening or maximum levels. The same is true of PCDD/F, for which a site-background-based site management goal is currently being implemented in the program, and a regional background management goal is proposed. Site monitoring has demonstrated that the dredged material evaluation procedures are generally keeping sediment chemical concentrations on-site below management thresholds for PCB, PCDD/F and other persistent bioaccumulative compounds such as Hg and DDT. A review of PCB and PCDD/F o- and off-site concentrations presented in this paper shows that these compounds are not generally elevated relative to their surroundings in the post-disposal site environment, and are in the range of concentrations that typify Puget Sound urban plus nonurban data sets. In one case, Elliott Bay, the urban surroundings are significantly elevated relative to the rest of Puget Sound; but there is no significant difference between the on-site and off-site concentrations of PCBs. PCDD/F are also very similar on- and off-site.

d) Both spatial resolution of a model at the level of DMMP dredged material sites and knowledge of fish behavior related to DMMP sites are necessary to determine the prospective exposure of SRKW from dredged material placement. The primary SRKW diet is Chinook, which are not usually present at open-water dredged material sites. Adult Chinook are sight-feeders on herring and squid, and feed preferentially in waters of shallower depth than most sites, and along shorelines. In general, Puget Sound open-water dredged material disposal sites are located in deeper water than Chinook feed (with the single exception, Bellingham Bay, not likely to be used again in future), and have been intentionally sited in areas of low faunal abundance.

However, sole (or similar species such as halibut) is a minor part of SRKW diet.

e) Current models assume that all sediment (not just dredged material placed at open water sites) are emitting soluble contaminants that are taken up by benthos, demersal fish, phytoplankton, zooplankton, herring and Chinook. Materials deemed suitable for placement at Puget Sound open-water sites are sediments in Puget Sound or adjacent fresh water lakes (e.g., Lake Washington) that have been tested to assure that they do not exceed contaminant thresholds, although these thresholds are not currently based upon biomagnification potential. Movement from one part of the Sound to another (e.g., from Elliott Bay to north Sound) would not affect the statistical distribution of the chemical suites at the system level.

f) The flux of PCB and PBDE in dissolved and particulate form in the open waters of Puget Sound and the Strait of Georgia are currently being evaluated (Shaw et al. 2007; Dangerfield et al. 2007; Gries [Washington Department of Ecology, personal communication] 2010), and are a critical step in understanding bioavailability of these compound suites for the trophic web. This information, when available, may be used to validate and refine models should address the relative importance of such sediments and surface water as sources. As models are developed, the DMMP will follow their progress and consider program implications.

Current biomagnifying compound conditions in Puget Sound (with or without DMMP activities) appear to adversely affect SRKW, Steller Sea Lions, and Harbor Seals. Based upon information in hand, the programmatic actions of transport, placement, and disposal of dredged materials include biomagnifying substances that are at or below the mean of concentrations for PCBs observed in Puget Sound and have discountable effects to ESA-listed species. The DMMP the program is in the process of adopting a regional nonurban background approach to limit contributions to the dredged material sites and their surroundings from PCDD/F, which will reduce the allowable concentrations; this adoption is in process at this time of writing. Existing tools are inadequate for assessing the programmatic activities' incremental effects to marine mammals. PCBs will be measured by the more sensitive congener method in future during site monitoring. PBDEs are not currently on the primary list of Compounds of Concern for Bioaccumulation, although they have been measured in past monitoring events for nondispersive sites using low-resolution methodologies; in the future, high-resolution chromatography/spectrometry will be used to monitor sites. PBDEs are on a secondary (optional) list of substances, and may need to be considered more frequently, especially for Central Puget Sound, where there are indications that highest values occur in Puget Sound sediment.

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1. Objectives of Supplemental White Paper

This document is an addendum to the 2010 Dredged Material Management Program (DMMP) Biological Evaluation under the Endangered Species Act, and discusses biomagnifying compound suites present in dredged material in Puget Sound as they relate to the programmatic actions of determination of suitability of dredged materials for disposal at unconfined, open water disposal sites, and the physical transport and disposal of dredged materials at unconfined, open-water sites in Puget Sound.

As context to this addendum, several lines of evidence suggest that biomagnifying compounds such as polychlorinated biphenyls (PCBs), polychlorinated dioxins/furans (PCDD/F), and polybrominated diphenyl ethers (PBDEs) are entering the food web in Puget Sound at concentrations that may have toxic effects on organisms protected under the Endangered Species Act or the Marine Mammals Protection Act.

This document describes a) the evidence for endangerment and food-web relationships from sediment to Southern Resident Killer Whale (SRKW, *Orcinus orca*), and the Steller Seal Lion (*Eumetopias jubatus*), and the Harbor Sea (*Phoca vitulina*); and b) how the Dredged Material Management Program (DMMP) evaluates its programmatic actions in terms of impacts to mammalian species regulated by the Endangered Species Act and Marine Mammals Protection Act in Puget Sound.

The DMMP is the joint responsibility of the US Army Corps of Engineers (Seattle District USACE), US EPA Region 10, and the State of Washington Departments of Ecology and Natural Resources. Activities addressed under this program include dredged material transport and placement at approved disposal sites, and nondispersive disposal site management. Sediment dredging occurs under individual or nationwide permits granted by USACE, and are scrutinized Biological Evaluations/Assessments and consultations as needed; the consultation associated with permitting is not addressed in this document.

Threatened and endangered populations discussed in this paper are the SRKW and the Steller Seal Lion. The Harbor Seal is protected under the Marine Mammals Protection Act.

2. Issue Formulation

a. Programmatic Consideration of Effects from Dredged Material Disposal on Marine Mammals.

The DMMP is committed to updating its programmatic guidelines with the most relevant scientific information related to consequences of its activities. Scientific literature has increasingly indicated that members of top marine mammal species are adversely affected by persistent and toxic organic compounds that biomagnify (i.e., increase in concentration in tissue towards higher trophic levels). The compound suites discussed in this paper – PCB, PCDD/F, and PBDE – are believed to be the chief biomagnifying compounds affecting marine mammals in Puget Sound. Biomagnification to upper trophic levels may occur at hundreds or thousands of times greater than environmental concentrations. Section 2b below describes the rationale for concern for biomagnification of these compounds, which may occur at low levels in dredged materials handled in the program.

The following paragraphs summarize programmatic considerations regarding To date, the DMMP has generally only evaluated ecological effects to lower trophic levels, including site benthos and bottom-foraging fish, and also prospective effects to human health. This is because the quantitative linkage between open-water dredged material disposal and prey species for marine mammals is highly uncertain. Open water dredged material disposal sites are generally in deep Puget Sound waters (Bellingham Bay site is an exception). Dredged material sites were selected for low levels of benthic organisms relative to surroundings and are or low quality habitat compared to most of Puget Sound. Site management has focused on effects arising from anticipated close contact of sediment and site biota.

Chinook salmon are a pelagic species that constitute about 96 % of the food source for SRKW-- Ross et al. (2000). Programmatic evaluations of potential effects due to dredged material placement on Chinook have cited the r the low likelihood of exposure to site chemicals. To illustrate, the following text is abridged from the Biological Evaluation, which has citations to support the statements.

- Although adult and subadult Chinook salmon may coincidentally occur near areas of disposal activities, there are no site features that would encourage Chinook salmon to congregate.
- During disposal, Chinooks' exposure to dredged material related substances would be very short-term (less than 10 minutes as measured by elevated suspended solids in the water column).
- The potential for toxic effects of contaminants released from discharged sediments is minimal, since sediments have been subjected to a series of physical,

chemical and biological testing procedures and thorough review by the regulating agencies and the public.

- Foraging habitat for Chinook would not be adversely affected by transport, placement, and management of the sites, as adult and sub-adult Chinook primarily feed on pelagic organisms that also do not typically feed at depths of dredged material disposal sites.
- Chinooks' forage base would not be significantly affected by disposal activities. Herring and sandlance spawn in intertidal and shallow subtidal areas. Although sandlance can sometimes rest on the bottom, this typically occurs in less than 100 meters of water, shallower than most DMMP sites.
- Dredging activities and associated disposal activities are regulated to avoid out-migrating juvenile Chinook as they migrate from rivers to the Sound in the spring. During the early phases of estuarine/Puget Sound residence, juveniles reside in near-shore waters (typically no deeper than 30 to 70 meters) feeding on epibenthic and pelagic organisms, which would be unaffected by disposal activities. Most juveniles continue to occupy the nearshore environment during their migration to the Pacific Ocean, although they could coincidentally occur in surface waters near dredged disposal areas. Effects of elevated water column suspended sediments would be short in duration and localized (as noted above), and are not expected to adversely affect migrating juvenile salmon.

Accurate prediction of effects from disposal events and sites via trophic links to pelagic organisms and to SRKW is difficult. Other fish, such as halibut, English sole, and sablefish are eaten by SRKW, as well as Steller sea lions and harbor seals, and these fish may forage at both nondispersive and dispersive dredged material sites. The DMMP monitoring program periodically checks benthos in the vicinity of the nondispersive sites. In some instances, fish trawls have been made as well. However, the program has not attempted to evaluate a mechanistic multi-level trophic model to marine mammals, because there are many uncertainties and there is lack of a tool to do so. These include the following.

- Trophic relationships/pathways are documented in the literature, but fish behavior, including feeding ranges, the time a forage fish could potentially exposed to site related chemicals, and feeding ranges for marine mammals in relation to their prey base are not sufficiently known at this writing.
- Variable measurement precisions of PCBs in sediments/dredged material dominate the Puget Sound data sets, and make "background" comparisons difficult. At present, the DMMP requires characterization of dredged material by the higher-detection-limit Aroclor method, but the more precise congener method may be required in future. Thus, it is difficult to determine what changes – if any – the DMMP activities are making on available inventory of biomagnifying compounds in Puget Sound. (This paper compiles available information to that end, however.)
- PBDEs are not currently on the list of potentially bioaccumulative substances requiring testing. Site monitoring data exist for PBDEs at several nondispersive sites; no detected values have been seen. However, it elevated detection limits may be responsible for this observation. Information from this paper will be

utilized by the program to make a determination of the need for addition of PBDEs to the programmatic requirements.

- As described below, there exist trophic models to predict biomagnification to whales and seals for PCBs; however, these are not currently calibrated for Puget Sound conditions, nor are they likely to be at a scale to be usable to predict changes in exposure due to DMMP activities.

b. Evidence of Effects on Marine Mammals

SRKW are a top predator with both migrant and resident populations in Puget Sound (Calambokidis et al. 1984 and Ross et al. 2000). Critical Habitat has been established for SRKW in Washington waters (Figure 1, page following.) For the location of DMMP disposal sites, compare Figures 7 and 9; all but the Port Townsend site in Northern Puget Sound are in SRKW Critical Habitat.

SRKWs have demonstrated significant decreases in population in the last 30 years, likely associated with pollution. Ross et al. (2005) stated:

> "Marine mammals are often exposed to high concentrations of persistent organic pollutants as a result of their long lives, relative inability to breakdown such contaminants, and their high position in marine food chains. We previously demonstrated that southern resident killer whales are heavily contaminated with polychlorinated biphenyls (PCBs). Our harbour seal monitoring work has supported evidence that Puget Sound is a regional PCB hotspot. In a further attempt to characterize local killer whale habitat quality, we measured new generation flame retardants, polybrominated diphenyl ethers (PBDEs), in non-migrating harbour seals from four sites in Washington State and British Columbia. Our results suggest that the largely unregulated PBDEs represent a significant and emerging concern at the top of the coastal food chain. In a study of harbour seal "food baskets", PCBs and DDT represented the major contaminant classes in the diet of Strait of Georgia seals, but PBDEs have taken second place in the diet of Puget Sound seals. Increasing concentrations over time, and higher concentrations in Puget Sound seals and their prey, highlight the emergence of this new concern in this transboundary region. This information should be relevant to Conservation Planning for the southern resident killer whale community."

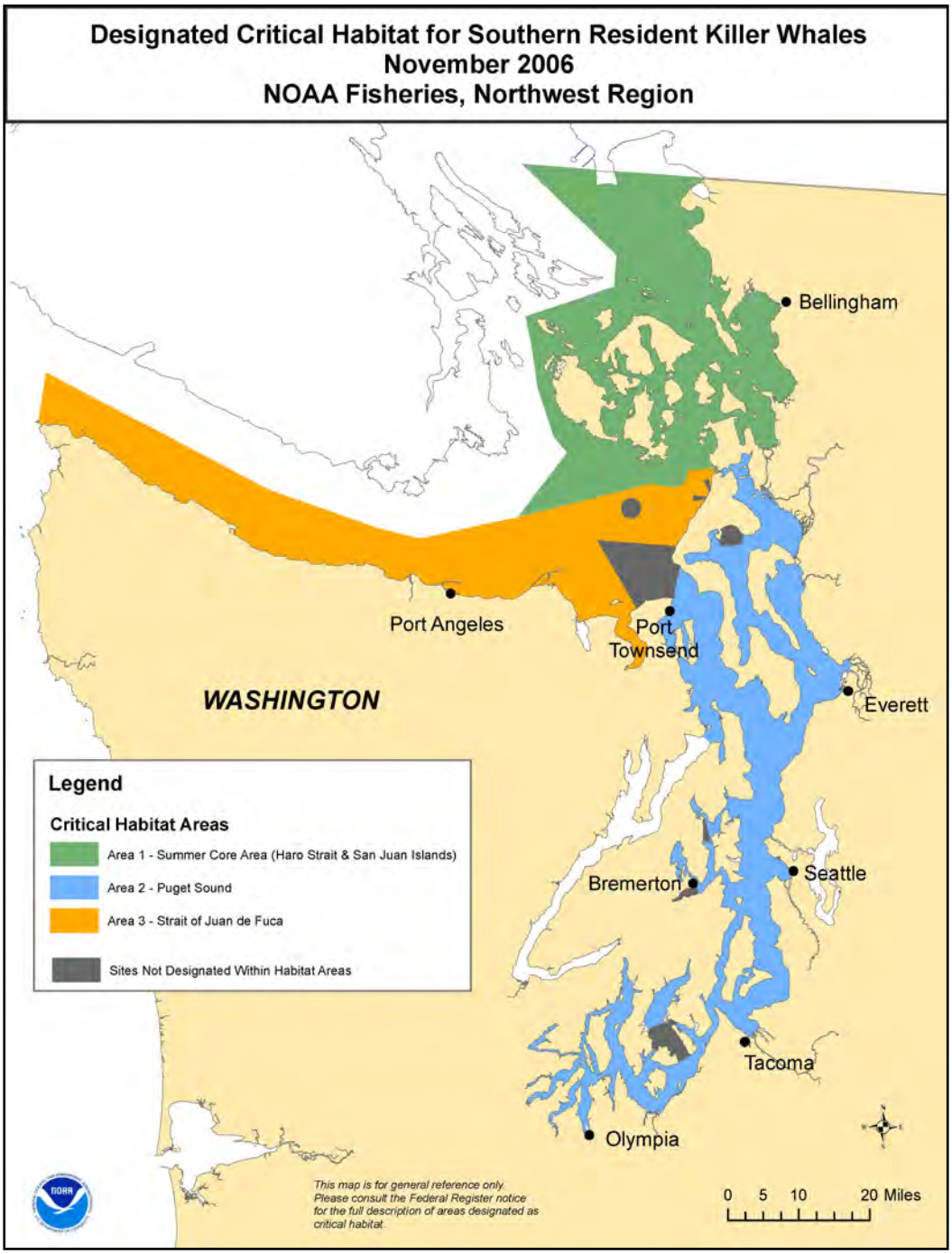


Figure 1. Designated SRKW Critical Habitat in Washington
[http://www.fakr.noaa.gov/protectedresources/whales/killerwhales/attachmentb.pdf]

Tissue Levels of PCB in Marine Mammals

Ross et al. (2000) stated, "Southern Resident and transient killer whales of British Columbia can now be considered among the most contaminated cetaceans in the world." The current number of SRKW is 89, including 2 calves.
[http://daily.sightline.org/daily_score/archive/2010/04/14/orca-update]

Biomagnification of PCBs into transient killer whale populations is significantly higher than in SRKW or northern resident killer whales, probably related to transient's preferred diet of marine mammals (Hayteas and Duffield 2000, and Ross et al. 2000). Migrant pods may be exposed to more contaminated prey items during migration than resident populations (Hayteas and Duffield 2000).

Regarding *Harbor Seals*, Puget Sound populations are more contaminated than the more northerly populations. (Figure 2).

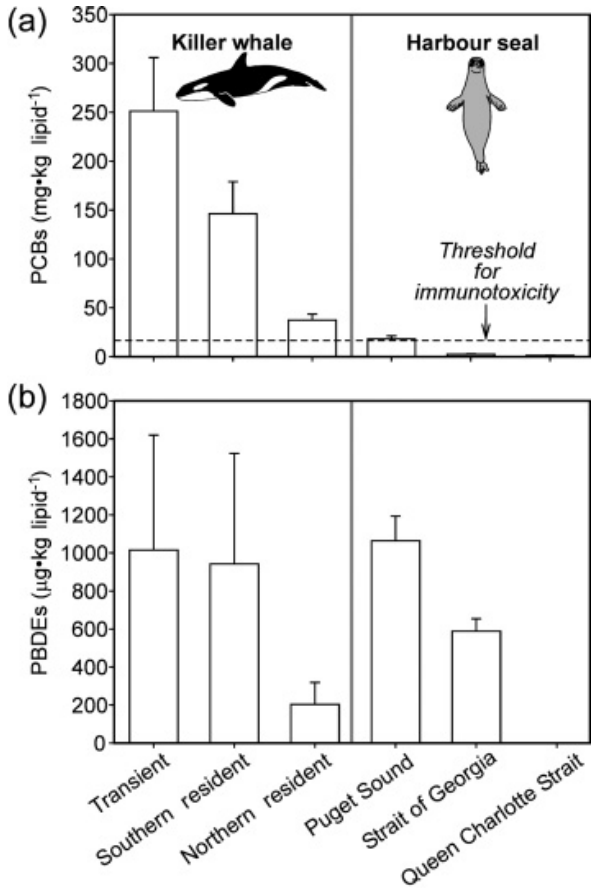


Figure 2. Comparison of Killer Whale and Harbor Seal Body Burdens of ΣPCB[1] and ΣPBDE in US and Canada, from Ross et al. (2000).

[1] In this document, when total PCBs are referenced as a quantity (e.g., sum of congeners or Aroclors), ΣPCB is used. A similar convention is used for PBDE and PCDD/F.

Ross et al. (2000) and Krahn et al. (2007) reported SRKW ΣPCB concentrations for the periods 1993-6 and 2004-6, respectively (Figure 3). There is a suggestion of reduction in ΣPCB in male SRKW.

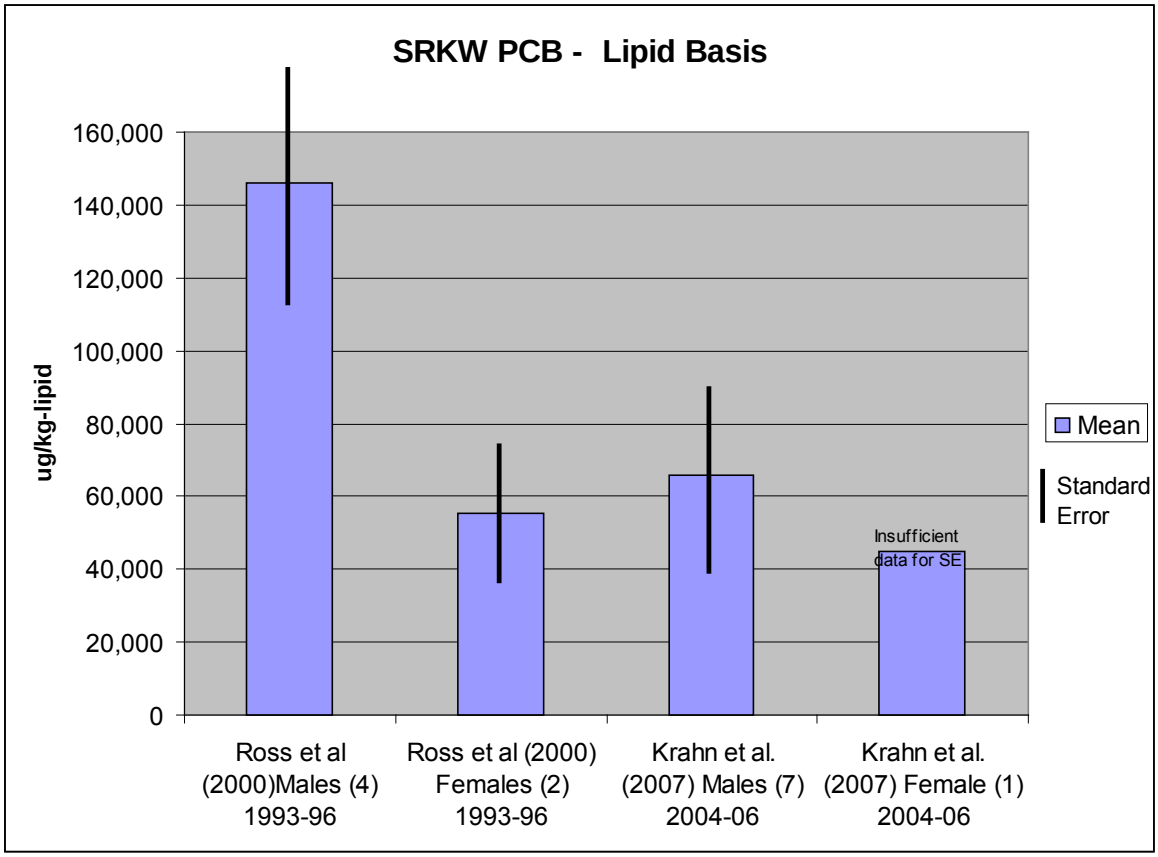


Figure 3. Southern Resident Killer Whale Blubber ΣPCB (regraphed from cited sources)

ΣPBDEs in SRKW blubber were also measured by Krahn et al. (2007): males (n=8) averaged 62,125 (± standard error 17,727) µg/kg (lipid); the single female had 7,500 µg/kg (lipid).

Resident killer whale populations preferentially feed on Chinook, which comprise about 96% of their total diet (Ross et al. 2000, Hayteas and Duffield 2000, and Jarman et al. 1996). Hanson et al. (2010) estimate from fecal analysis that 80-90% of the Chinook consumed by SRKW originate from the Fraser River (including the South Thompson River), and only 6 to 14% originate from natal streams in the Puget Sound region. However, these latter Chinook have fed in relatively PCB-rich Puget Sound. So, despite a much larger range than Puget Sound and the Straits of Juan de Fuca, a significant portion of the PCB burden in SRKW is believed to come from Puget Sound.

Prey fish concentrations of ΣPCBs from the Puget Sound Ambient Monitoring Program (PSAMP) were summarized in Washington Department of Health (2006). For English sole, all of Puget Sound had a range of 2-462 µg/kg-wet, and a mean of 38.6 µg/kg-wet. In the same units, the following are area-wise means: urban (73.6), near-urban (17.2), and non-urban (9.3). Since English sole are demersal, their body burdens are better correlated with their location.

O'Neill et al. (2006) noted that Chinook salmon from Puget Sound are approximately three times more contaminated with PCBs than other northeastern Pacific Chinook populations because of their increased residence time of some stocks or individuals in Puget Sound. Wild Coho salmon from Puget Sound also have higher PCB levels than Coho from the southern Georgia Basin, likely associated with their longer residence in Puget Sound.

The Puget Sound Chinook-muscle-ΣPCB range was 11-223 µg/kg-wet, with a mean of 73.2 µg/kg-wet for fish caught in the salt water. The means for saltwater Chinook in central and south Puget Sound were very similar (70.6 and 75.6 µg/kg-wet, respectively). Correlation of concentration with location was much less notable with these pelagic fish. DOH (2006) noted that PSAMP data indicated higher PCB concentrations are found in resident Chinook salmon (blackmouth) caught in winter in south Puget Sound than non-resident fish captured in Puget Sound during the spring or fall fishery. The authors used a Washington Department of Fisheries regression model of PCB to body length to estimate PCB concentration in blackmouth muscle tissue could range from 65 µg/kg -wet at the minimum legal length to a large fish with 100 µg/kg -wet.

Herring is a food source for many animals that are higher in the food web. Juvenile and adult herring inhabit the water column and are eaten by seals, diving birds, and many marine fish species including Chinook and Coho salmon which are both prey eaten by SRKW. Between 1999 and 2003, PSAMP results from 1,055 three-year old male herring in 6 of 14 major Puget Sound and Georgia Basin stocks were reported by O'Neill et al. (2006). Results are shown in Figure 5 below. ΣPCB in whole bodies of herring from Port Orchard and Squaxin (central and southern Puget Sound, respectively) were four to nine times higher than those from the Georgia Basin. Levels of ΣPCB in Puget Sound herring are similar to levels measured in herring from the Baltic Sea in Northern Europe, one of the more highly contaminated marine ecosystems in the world (O'Neill, et al. 2006)

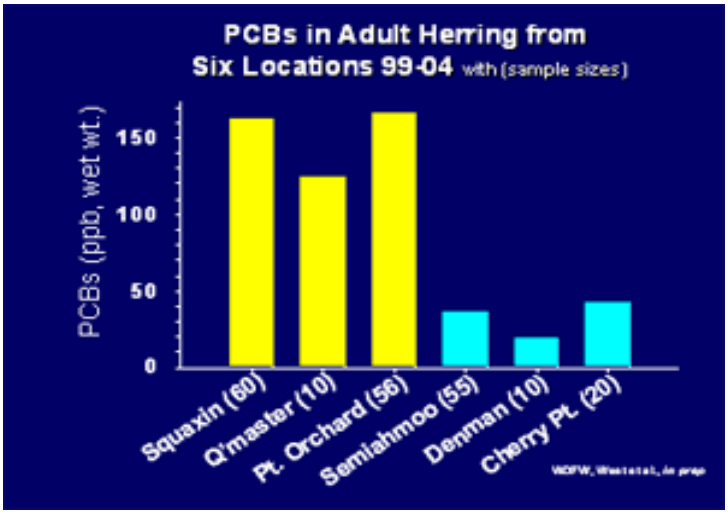


Figure 4. ΣPCB in Adult Herring from Six Puget Sound Locations, 1999-2004.

Steller sea lions have declined precipitously over the last three decades, and the western stock is listed as endangered. Information on west coast stocks (the Eastern Pacific population) is mainly available from Alaskan waters. Critical habitat has been designated, but does not include Washington State waters. Steller sea lions' habitation of Puget Sound is sporadic and seasonal. They are more likely to inhabit north Puget Sound waters than others, but have been recorded for all areas. No breeding rookeries or major haul-out areas have been identified in Washington waters. Their prey species consist of benthic and pelgic fish, including herring, capelin, sand-lance, Pollock, mackerel, flounder, cod, salmon and squid.

Concentrations of ΣPCB in some Steller Sea Lions from Alaska approach or exceed levels that cause physiological problems in other marine mammals. Myers and Atkinson (2005) measured 239 Steller sea lions from the Gulf of Alaska, pups from southwest Alaska and three captive animals. Myers and Shannon (2005, 2006) noted the following in a conference proceedings (slightly rearranged here):

> "Kannan et al. (2000) recommended a PCB threshold concentration of 11,000 ng/g lipid weight for marine mammal blood.
>
> - Western Alaskan sea lion pups' mean ΣPCBs was 5,155 ± 610 µg/kg - lipid weight (below threshold levels). However, 9 out of 76 pups (or 12%) exceeded the threshold concentration.
> - [PCB related] TEQs measured in the blood of immune-compromised harbor seals (DeSwart et al., 1994, 1996; Ross et al., 1995) was 72 pg/g (ng/kg) lipid. Western Alaskan pups' TEQ averaged 71 pg/g (ng/kg) lipid, which is near the threshold."

<u>Toxic Effects of PCB and PCDD/F on Marine Mammals</u>

These two compound suites' toxicity are treated together, as they are believed to be related. In the population analysis associated with National Marine Fisheries Service (NMFS 2007) proposal to list SRKW, the following statements appear (but the word in square brackets is an added clarification).
[http://www.fakr.noaa.gov/protectedresources/whales/killerwhales/attachmentb.pdf]

> "On the basis of studies in other mammals, additional adverse health effects of DDT and metabolites, PCBs, dioxins, and furans are possible in killer whales, and even likely in individuals with high exposure. Exposure to mono-*ortho* and di-*ortho* PCB (non dioxin-like) congeners and metabolites may result in effects not mediated by the same biochemical pathways as 2,3,7,8-TCDD, and therefore not predicted by TEQs. Such effects include neurobehavioral, neurochemical, carcinogenic, and endocrinological changes (Ahlborg et al., 1992). Because these types of effects are difficult to observe in wild populations, there is no way to account for such effects in Southern Resident killer whales with available information. Direct assessments of DDT, PCB, dioxin, and furan effects in many species of mammals (as well as fish and birds) have proven these organochlorines to be potent agents of numerous adverse health effects (Eisler and Belisle, 1996; Eisler, 1986; Smith, 1991). For example, Beland et al. (1993) and DeGuise et al. (1995) documented high incidences of tumors, including malignant neoplasms, in St. Lawrence beluga whales contaminated with…PCBs, (8.3 – 412 mg/kg lipid weight in blubber) and lower levels of dioxins and furans (Muir et al. 1996).
>
> From a[n Atlantic beluga whale] population estimated at 500 animals, 18 collected post-mortem had tumors, a rate of 3.6 percent. The possibility that such effects occur in Southern Resident killer whales is relevant to its risk of extinction: an animal fighting an infection or the development of a tumor, one that has neurobehavioral abnormalities, liver disease or an altered endocrine system, or some combination of these effects, will be less fit for survival in the wild."

Ross et al. (2000) states the following.

> "…low to moderate concentrations of both the `dioxin-like' and the non-`dioxin-like' PCBs, PCDDs and PCDFs are known to cause immunotoxicity, neurotoxicity, reproductive impairment and endocrine disruption in laboratory animals (Brouwer et al., 1998; Vos and Luster, 1989) and wildlife species (Colborn et al., 1993; Fry, 1995; Guillette et al., 1995; Luebke et al., 1997).

Additionally, PCBs have been linked to cancer in both humans (Bertazzi et al. 2001) and California sea lions (Ylitalo et al. 2005), and are listed as probable human carcinogens by the US EPA and International Agency for Research on Cancer (ATSDR 2000)."

Vitamin A is important in many mammalian developmental, reproductive, and immunological processes. Mos et al. (2007) noted that vitamin A physiology is under strict physiological regulation in all mammals. PCBs and structurally related

compounds including PCDD/F can interfere with vitamin A transport, storage and metabolism, thereby promoting more rapid excretion. Observed vitamin A disruption in harbor seals suggests that PCBs are adversely affecting free-ranging marine mammals. Vitamin A may represent a sensitive biomarker in toxicological studies of marine mammals.

Adverse tissue-residue effects concentrations for these compounds for marine mammals are summarized in Table 1. The affected organism is listed in the left column; the basis column shows the tissue residue source. For instance, the first data row indicates that wildlife are affected when their tissue residue exceeds the value shown in the third column. The fourth data row discloses data based upon observed effects to dolphin as they apply to SRKW tissue residue. Note that all SRKW measured by Ross (2000) and Krahn et al. (2007) (Figure 3) exceeded all of the lipid-based whale-tissue toxicity thresholds. Also, the entire range of the Puget Sound Chinook PCB values cited in DOH (2006) are above the Chinook-based dietary threshold, and the mean is nearly an order of magnitude higher than that threshold.

Table 1. Residue-based PCB and PCDD/F TEQ Toxicity Values for Marine Mammals

Compound: Organism (study)	Basis	Residue Effects Concentration
ΣPCB: Toxicity to Fish-eating Wildlife (Hickie et al. 2007)	Marine Mammal Tissue	50,000 µg/kg -wet
ΣPCB: Harbor Seal (Ross et al. 1996)	SRKW Tissue	17,000 µg/kg-lipid
ΣPCB: Revised Harbor Seal (Mos et al. 2010)	SRKW Tissue	1,300 µg/kg-lipid
ΣPCB: Bottlenose dolphin (Hall et al. 2007)	SRKW Tissue	10,000 µg/kg-lipid
ΣPCB: Chinook (Hickie et al. 2007) to protect 95% of SRKW below the toxicity threshold at the top of the table	Chinook Tissue in SRKW Diet	8 µg/kg -wet
ΣPCB: Harbor seal pups (Johnson et al. 2007) [A]	Fish Tissue in Seal Diet	0.8 µg/kg-wet
ΣPCDD/F TEQ (includes ΣPCB): toxicity to Harbor seals (Ross et al. 2005)	Marine Mammal Tissue	255 ng TEQ/kg (lipid)
ΣPCDD/F TEQ: Harbor seals exhibiting immune suppression (DeSwart et al., 1994, 1996; Ross et al., 1995)	Marine Mammal Tissue	72 ng TEQ/kg (lipid)

[A] Johnson et al. (2007) state, "The No Adverse Effects Level (NOAEL) for mink (*Mustela vison* - $NOAEL_{mink}$) was converted to effects levels for harbor seal pups ($NOAEL_{SealPup}$) by scaling the dose to the ratio of mink body weight to body weight (bw) of harbor seal pups: $NOAEL_{SealPup} = NOAEL_{Mink}(bw_{Mink}/bw_{SealPup})^{1/4}$ according to the method of Sample et al. (1996)."

Tissue Levels of PCDD/F

Ross (2000) measured ΣPCDD/F dioxin-like Toxicity Equivalents (TEQ) from SRKW Northern Resident, and Transient populations. Unlike ΣPCB, there were no significant differences amongst these populations. Figure 4 illustrates the results, using 1998 Toxicity Equivalence Factors. [2] The authors concluded that, although ΣPCDD/F TEQ is less than PCB dioxin-like congeners, it still exceeds body burdens that are known to represent harm to Harbor Seals based upon mammalian toxicity equivalence factors. Ross et al. (2004) conclude that it appears that ΣPCB contamination in Puget Sound indicates localized sources, but that Σ PCDD/F are much more widespread (possibly suggesting atmospheric deposition), although there are some source-related signals for PCDD/F for the Strait of Georgia.

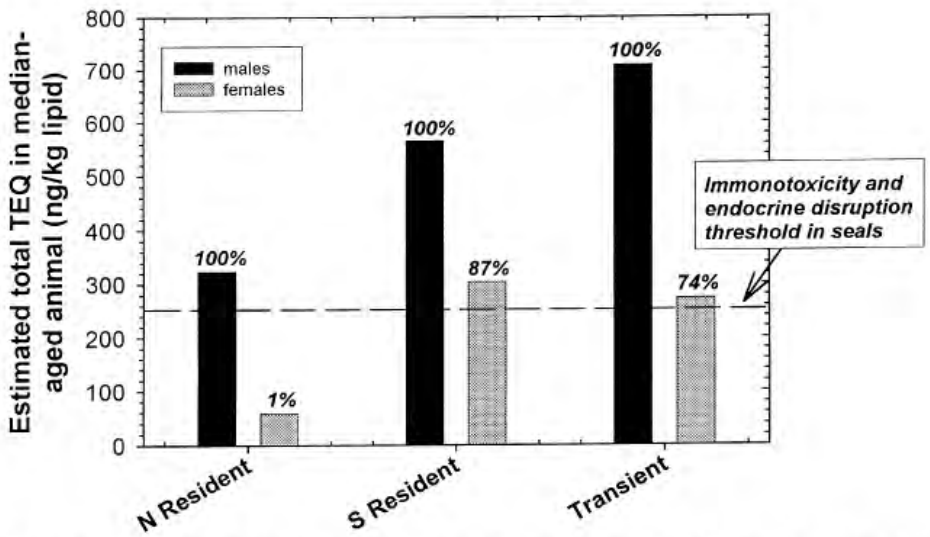


Fig. 5 Estimated total dioxin Toxic Equivalents (TEQ_{98}; ng kg^{-1} lw) in 12-year-old male and 25-year-old female killer whales from each of the three communities studied. These represent the median ages for the southern resident community, with the age-adjusted estimates allowing for a more direct comparative evaluation of risk among the three communities. Numbers above each bar represent the estimated percentage of males and females from the three free-ranging killer whale communities ($N = 212$, 89 and at least 219 individuals, respectively) in British Columbia that exceed the toxicity threshold established previously for harbour seals (De Swart et al., 1995; Ross et al., 1995).

Figure 5. PCDD/F TEQ from Ross (2000)

<u>Tissue Levels of PBDE</u>

[2] These have since been changed (WHO 2005), but the changes were not likely to substantially modify these results.

Harbor seals provide a picture of tissue ΣPBDE that is also relevant for SRKW. Ross et al. (2005) compared PBDE Concentrations from Harbor Seals in British Columbia and Washington (Figure 2). It is clear that Harbor Seals are significantly more contaminated in Puget Sound. The pattern holds for herring as well (Figure 6), and herring are a food source for seals.

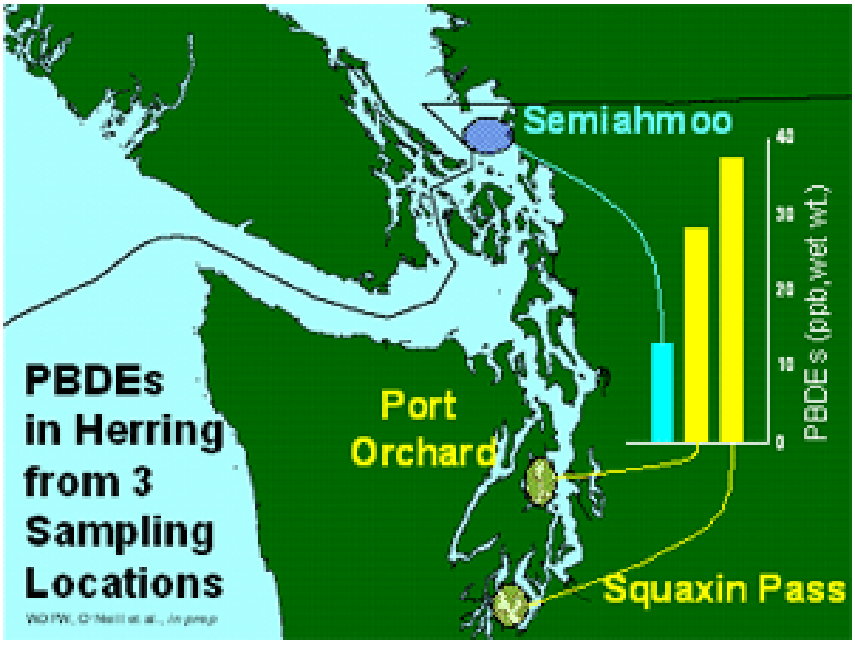


Figure 6. PBDEs in Herring from Puget Sound and Strait of Georgia (Dutch and Aasen 2007)

Ross et al. (2005) state: "An analysis of harbor seal samples collected between 1984 and 2003 revealed that PBDE concentrations in harbor seals from Gertrude Island, South Puget Sound, increased from 15 to 1,064 micrograms of pollutant per kilogram of fat – a meteoric increase of 1500 percent." (Figure 7).

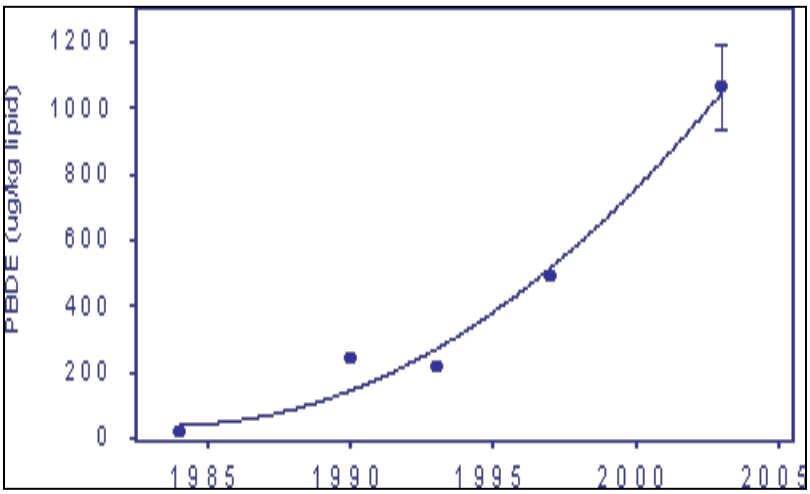


Figure 7. Increase in Flame Retardants in Harbor Seal Fat, South Puget Sound, 1984-2003.

Regarding PBDE in prey fish, Puget Sound Resident salmon sampled in 2003 and 2004 had PBDE at 40 µg/g, about 28 times higher than those levels reported for Chinook salmon returning to northern British Columbia (O'Neill et al. 2006).

Dutch and Aasen (2007) report the following.

> "Eleven of the 12 congeners measured in the sediments were also measured in tissue from 5 species of fish collected from Puget Sound by O'Neill and West, Washington Department of Fish and Wildlife. Of these, seven were detected in the fish tissue, while four (BDE-71, -138/166, -183, and -209) were usually below method detection limits. … All species accumulated BDE-47 in the highest concentrations, while BDE-49 was relatively high in the herring and Chinook samples. Congeners BDE-99 and -100 were relatively high in all species except the Quillback Rockfish. Congeners BDE-66, -153, and - 154 were present, but relatively low in all five species. Levels of PBDEs in English Sole muscle tissue were highest in and near urban/industrial bays and decreased in more rural areas …. Levels of PBDEs in herring tissue were highest in southern [Puget Sound] stocks and lowest in the most northern stocks. Whether high or low, proportions of the various BDE congeners appeared to remain consistent within species between locations."

<u>Toxic Effects of PBDE</u>

PBDEs are a class of endocrine disrupting compounds that have been found to affect neurological development, thyroid hormone levels and immune function in animals (Rayne et al. 2004). Studies in laboratory animals link PBDEs with effects on hormone (thyroid) function, which are critical to normal brain function. PBDEs are very similar in structure to PCBs, are extremely persistent, and bind to sediments and fat. US EPA (2008) issued an Oral Reference Dose for deca-BDE (BDE-209) of 7 µg/kg body weight per day based on rat studies, with an Uncertainty Factor of 300. Deca-BDE is also a *possible human carcinogen* according to the citation. The Oral Reference Dose is not lipid-normalized; the range of average US male and female 30-50 year old body fat is 13-25%, so the lipid-normalized value would be 6.75-54 µg/kg /d [lipid].

c. Summary of Hazards

There is sufficient information on biomagnification and toxic effects of PCB, PCDD/F, and PBDEs to SRKW, Steller sea lions, and Harbor seals in Puget Sound.

3. PCBs, PCDD/Fs and PBDEs in Puget Sound Sediments

This section is intended to provide context for later discussion of the relationship between DMMP actions and the subject species.

a. PCB

Estimates of ΣPCB by mass in sediments.

Because of variable PCB analytical methodologies used in Puget Sound (measuring all 209 congeners, or a subset of 19 congeners multiplied by 2 to equal the 209 [the NOAA method], or Aroclor mixtures), the associated wide range of analytical sensitivities, and a variety of methods to express results from datasets with a large number of nondetects, data sets are difficult to compare, and it is difficult to confidently calculate a central tendency measure for the Sound. From a brief survey of analytical information presented below, is apparent that the Puget Sound sediment distribution of PCB is skewed, with extreme values in the Lower Duwamish Waterway, and Elliott Bay, and in Everett Harbor. Based on the following paragraphs, the mean or median ΣPCB concentration in Puget Sound surface (0-10 cm) sediments likely falls between about 3 µg/kg (for nonurban areas) and approximately 54 µg/kg (for a representative mixture of urban and nonurban locations). However, estimates of central tendency of ΣPCB from Puget Sound are highly variable, as are the underlying data. It matters greatly whether urban sites are included in the evaluation.

A query on Washington State's Environmental Information Management (EIM) System conducted for this white paper selected ΣPCB results from the 0-10 cm depth for the years 1998-2009. There were a total of 513 marine subtidal and intertidal samples selected, and the EIM query did not exclude information on clean-up sites, and was not balanced with regard to urban versus nonurban area sampled; both of these facts likely bias the results, and the query is shown only to demonstrate all of the available data from the period. Slightly more than 90% of these data were detected values. The dataset did not conform to any parametric distribution, and a nonparametric (Kaplan-Meier) statistical analysis was conducted using EPA's software, ProUCL version 4.00.04. The range of minimum to maximum was 5 orders of magnitude.

Table 2. EIM Query and Dutch et al. (2003) Estimates of Puget Sound ΣPCB by Mass.

Compound(Measure)	n	Minimum	Mean	Maximum
EIM: ΣPCB (µg/kg , congener+Aroclor)	513	0.105	261.2 ± 43.4 (by KM ± Standard Error)	11,000
Dutch et al. (2003) (µg/kg , 19 congeners x 2)	300	8.37	80.23	4,892
Dutch et al. (2003) (ug/kg, detected congeners only)	300	ND	50.11	4,658

Table 2 also includes the analysis of Long et al. (2003), which evaluated 300 Puget Sound Ambient Monitoring Program (PSAMP) sediment sampling results for ΣPCBs taken from 1997 to 1999. This report appears to be more balanced than the EIM query shown, but does include urban bays. Regional means varied significantly (detected congeners only, in µg/kg): Strait of Georgia (0.1), Whidbey Basin (131.16), Admiralty Inlet (2.42), Central Puget Sound (76.06), and South Puget Sound (3.34).

PCB congener 153 was generally the highest concentration, followed by concentrations of congeners 101, 118, 138. The range of ΣPCBs was 2 orders of magnitude. The distribution of ΣPCB results was highly skewed towards the lower concentrations or non-detected values. Dutch et al. (2003) stated that 21 of the 300 samples exceeded the State of Washington PCB Sediment Quality Standard of 12 mg/kg organic-carbon normalized for ΣPCBs; and that these represented an area of only about 7.2 km^2, or about 0.3%, of the surveyed area of 2,363 km^2.

A recent DMMP (2009) survey using the US EPA vessel OSV Bold showed considerably lower values, as it targeted *only* nonurban areas of Puget Sound and sought to exclude locations near outfalls or known cleanup sites. Seventy samples were taken. Only Aroclor 1268 was detected, and that only in 9% of samples, from Carr Inlet, Holmes Harbor, and South Sound. Detected ΣPCBs (Aroclors) ranged from 2.1 µg/kg to 31 µg/kg. A total of 166 PCB individual and co-eluting congeners (shown in brackets) were reported. The pentachlorobiphenyls [90+101+113], [110+115], 118, and the hexachlorobiphenyls [153+168] were detected in 94% of samples. The hexachlorobiphenyls [129+138+163] were detected in 96% of samples. Summaries for both Aroclor-based and congener-based sediments in this nonurban study are shown in Table 3.

Table 3. OSV Bold (DMMP 2009) Statistical Summary of Puget Sound Non-Urban Sedimentary ΣPCB and ΣPCDD/F by Mass.

Compound(Measure)	Minimum	50th Percentile	90th Percentile	Maximum
ΣPCB (µg/kg , all congeners; KMSum[A])	0.0385	0.765	2.79	10.6
ΣPCDD/F (µg/kg , all congeners; KM Sum)	0.00582	0.112	0.282	0.485

[A] Kaplan-Meier Summation is a nonparametric technique for summation without using surrogate values for nondetected congeners

Information compiled for the Lower Duwamish Waterway Superfund Site Feasibility Study (AECOM 2010) includes PCB data from Washington Department of Ecology and King County in the Green River above the Lower Duwamish Superfund Site. These data are being used to ascertain inputs to that urbanized water- and air-shed to support the ongoing bed-load estimates Feasibility Study. The data include sediments and suspended solids quantified by the congener method for PCBs. These data suggest a baseline input to the river and Sound from the Seattle area near the high end of the mean values for the foreseeable future. The data in Table 4 are and King County 2004-2007 data (cited in AECOM 2010).

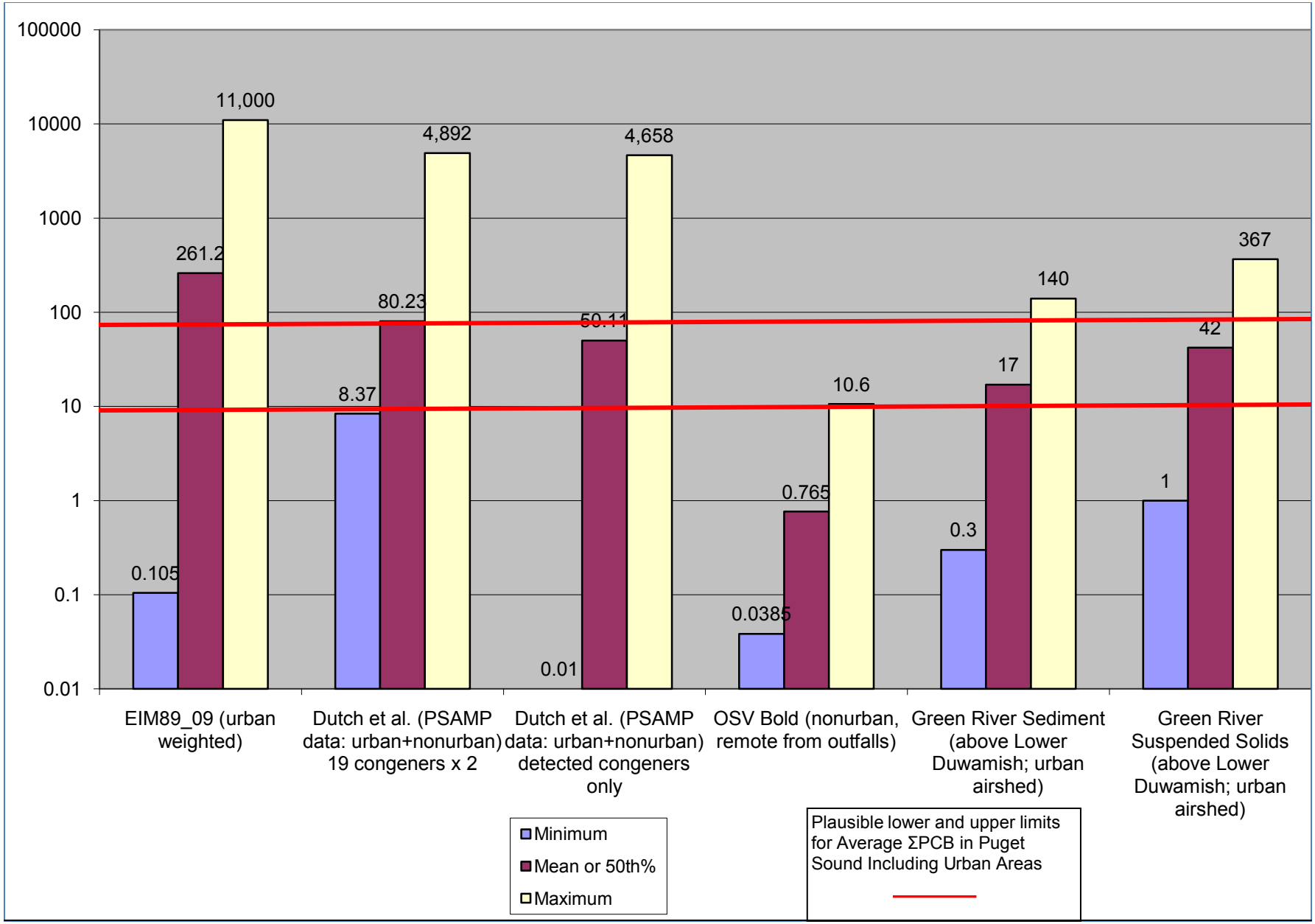
Table 4. Statistical Summary of ΣPCB by Mass in Urbanized Freshwater Bodies Draining into Puget Sound

Compound(Measure)	n	Minimum Detected	Median	Mean	Maximum
Sediment in Green River; ΣPCB (µg/kg , congener; 0.5*DL method)	73	0.3	10	17	140
Suspended Solids in Green River; ΣPCB (µg/kg , congener; 0.5*DL method)	29	1	11	42	367
0-2 cm in Lake Washington; ΣPCB (µg/kg, congener; 1*DL method; recalculated from gamma distribution)	52	1.8	11	14.3	57

Also in Table 4, Ecology (2010) surveyed the top 2 cm of sediments in Lake Washington for ΣPCBs by the congener method. The study included modeling of biomagnification into northern pikeminnow. The model was determined to be sensitive to freely-dissolved water concentrations (which, however, were not measured in the study).

Figure 8 displays the marine data described above, and suggests a plausible range for average Puget Sound ΣPCBs (µg/kg) for the datasets that include some urban samples.

Figure 8. Summary of Several Puget Sound ΣPCB Datasets (µg/kg). (Page following.)


100000
10000
1000
100
10
1
0.1
0.01
11,000
261.2
0.105
4,892
80.23
8.37
4,658
50.11
0.01
10.6
0.765
0.0385
140
17
0.3
367
42
1
EIM89_09 (urban weighted)
Dutch et al. (PSAMP data: urban+nonurban) 19 congeners x 2
Dutch et al. (PSAMP data: urban+nonurban) detected congeners only
OSV Bold (nonurban, remote from outfalls)
Green River Sediment (above Lower Duwamish; urban airshed)
Green River Suspended Solids (above Lower Duwamish; urban airshed)
Minimum
Mean or 50th%
Maximum
Plausible lower and upper limits for Average ΣPCB in Puget Sound Including Urban Areas

Estimates of PCB by sediment toxicity equivalents (TEQ) to 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD).

Inouye (2009) presented a paper at a June, 2009 DMMP Dioxin Workshop which described a query on the EIM database for Puget Sound marine sediment ΣPCB, and estimation of PCB TEQs from congeners.
[http://www.nws.usace.army.mil/PublicMenu/documents/DMMO/DMMP_Draft_PCB_presentation_062409.pdf]

Table 5. PCB TEQ from Washington Department of Ecology EIM Database With and Without Cleanup Sites.

Summation Method	n	Minimum, ng/kg	50th Percentile ng/kg	90th Percentile, ng/kg	Maximum, ng/kg
All EIM Stations					
SUM TEQ (ND=0)	1,649	0	0.06	0.06	1,359
SUM TEQ (ND=0.5*DL)		6E-05	0.18	0.36	1,384
EIM Minus Cleanup Sites					
SUM TEQ (ND=0)	803	0	0	0.18	140
SUM TEQ (ND=0.5*DL)		6E-05	0.05	0.25	140

In the DMMP (2009) Bold study, PCB congener TEQs were calculated using the World Health Organization (2005) toxic equivalency factors for mammals, and the Kaplan-Meier nonparametric method for summation of non-detected values. The non-urban sites in this study (Table 6) were significantly lower than those reported by Inouye (2009), which included urban areas (Table 5). Figure 9 compares the values from EIM and Bold. Figure 10 shows a map of the Bold TEQ results.

Table 6. OSV Bold (DMMP 2009) Statistical Summary of Puget Sound Non-Urban Sedimentary PCB and PCDD/F by Toxicity Equivalents.

Compound(Measure)	Minimum	50th Percentile	90th Percentile	Maximum
Bold PCB TEQ (ng/kg, dioxin-like congeners, KMSum)	0	0.0035	0.0071	0.168
PCDD/F TEQ (ng/kg, 2,3,7,8-chlorine-substituted congeners, KMSum)	0.047	0.774	2.69	11.6

As illustrated in Figure 9, the plausible range for the 50th-percentiles of PCB-related TEQs with cleanup sites included is 0.06 to 0.18 ng PCB TEQ/kg; the plausible 50th percentile range for urban and nonurban settings after removing known cleanup sites is < 0.0035 to 0.05 ng PCB TEQ/kg. For comparison, the DMMP (2009) PCDD/F TEQs are shown above in Table 6: the 50th percentile, 0.774 ng PCDD/F TEQ/kg, is 1-2 orders of magnitude higher than that of PCB TEQs from Bold or EIM minus cleanup data .

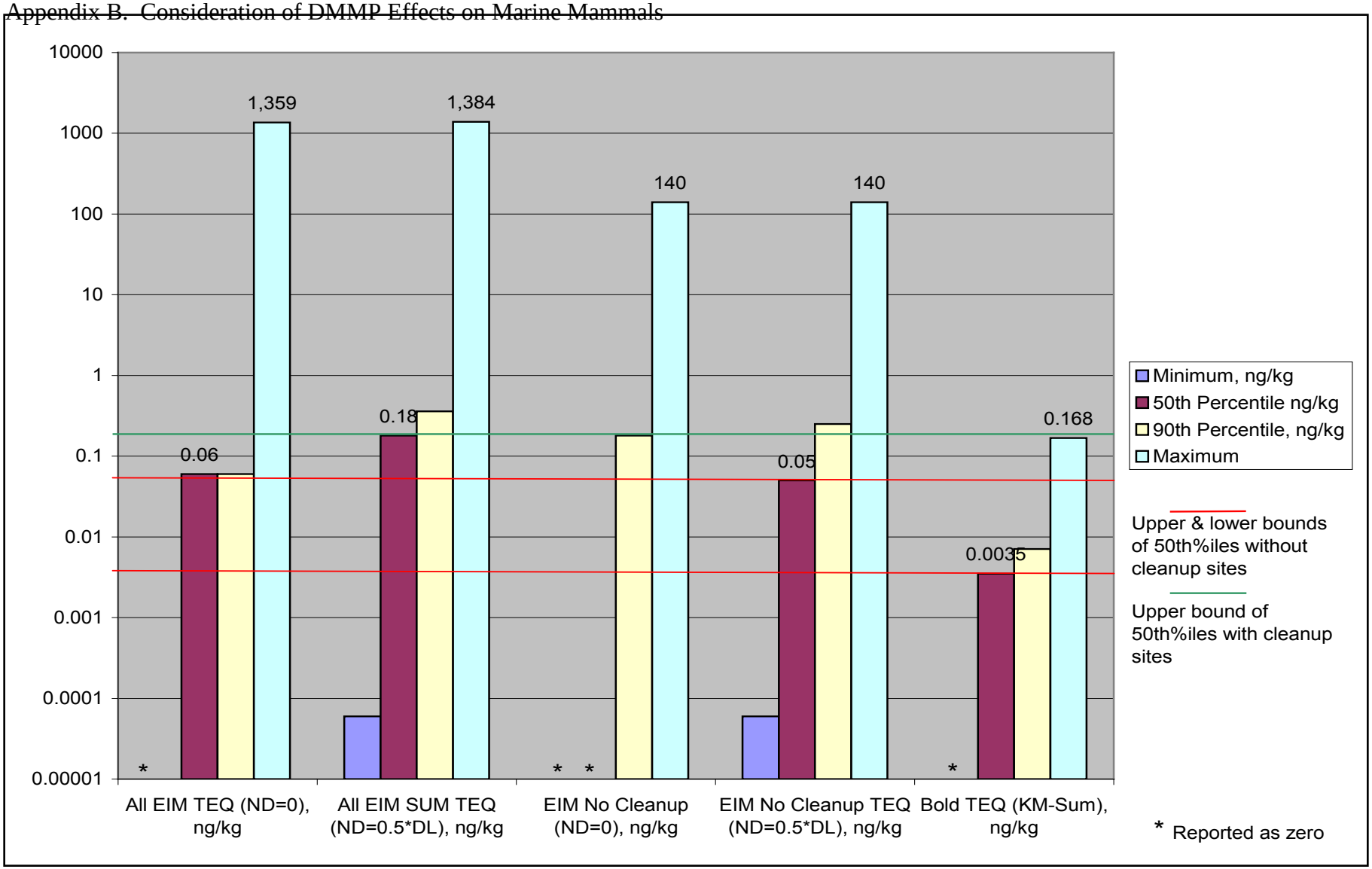


Figure 9. Compilation of PCB-related Sediment TEQ (ng/kg) from Puget Sound Data Sets (see Tables 5 and 6 for sources)

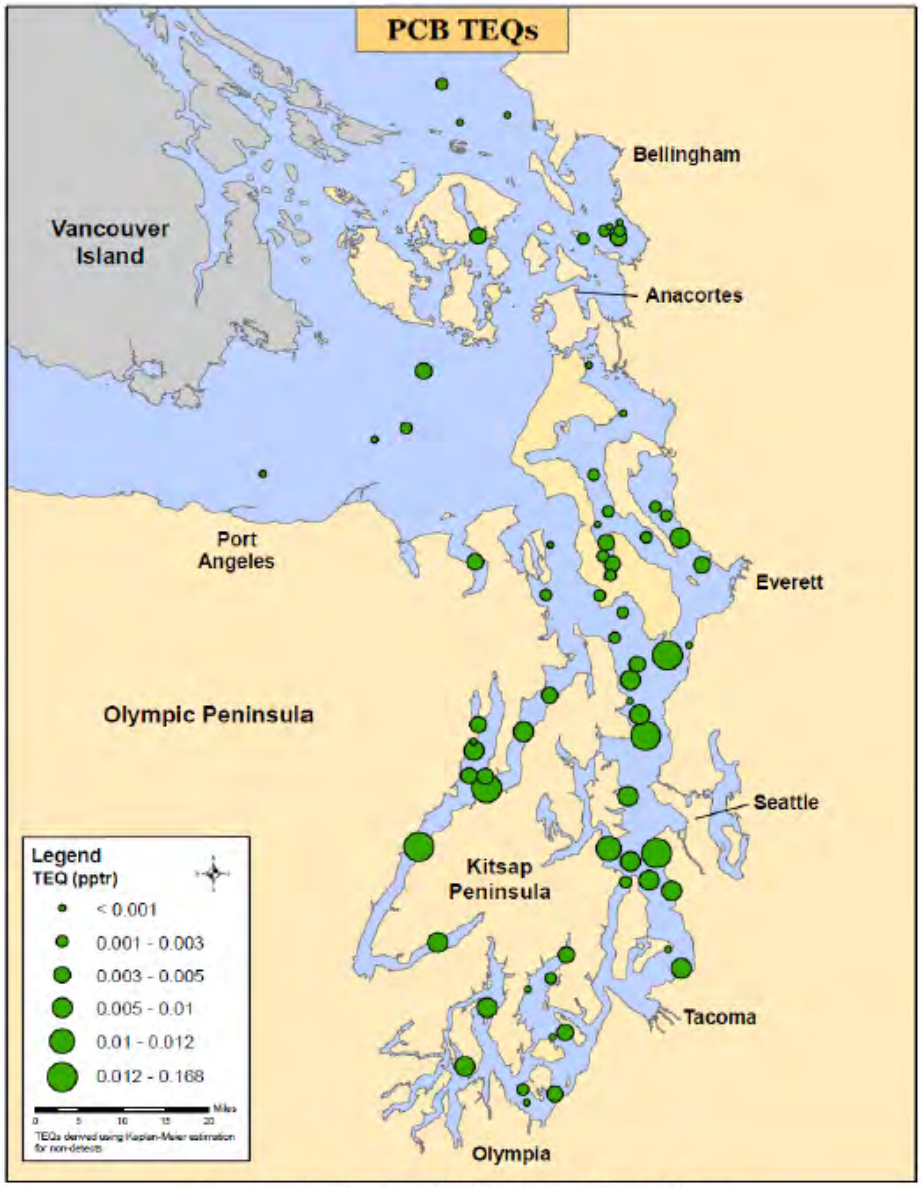


Figure 8. Distribution of PCB TEQs (weighted KM sum)

Figure 10. PCB TEQs from DMMP (2009)

b. PCDD/F

The following URL summarizes all ΣPCDD/F TEQs for Puget Sound, Grays Harbor, and adjacent freshwater bodies. .
[http://www.nws.usace.army.mil/PublicMenu/Doc_list.cfm?sitename=DMMO&pagename=Dioxin_TEQ_maps]. Puget Sound is shown in Figure 11.

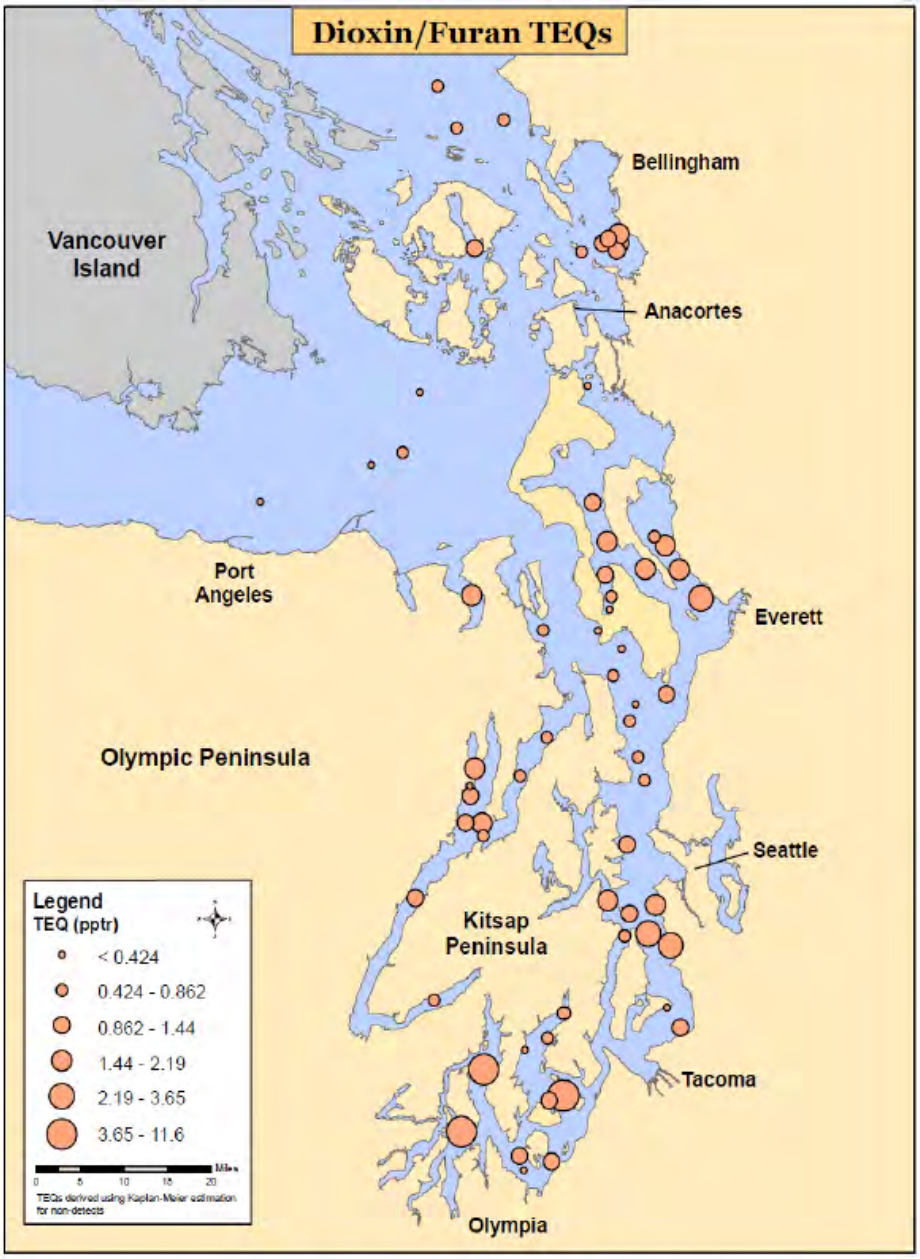


Figure 7. Distribution of Dioxin/Furan TEQs (weighted KM sum)

Figure 11. ΣPCDD/F TEQs from DMMP (2009), Emphasizing Nonurban Areas

c. PBDE

Ross et al. (2009) state the following.

> "…the single congener BDE-209, the main ingredient in the Deca-BDE formulation, has surpassed the legacy PCBs and DDT as the top contaminant by concentration. Limited biomagnification of BDE-209 in aquatic food webs reflects its high log Kow and preferential partitioning into the particle phase. As a result, large environmental reservoirs of BDE-209 are being created in sediments, and these may present a long-term threat to biota: BDE-209 breaks down into more persistent, more bioaccumulative, more toxic, and more mobile PBDE congeners in the environment."

Information in Figure 12 and Figure 6 are excerpted from a poster by Dutch and Aasen (2007). They indicate that, in terms of PBDE tissue concentration, and a predominance of higher molecular weight congeners, Central Sound is more highly contaminated than North Sound, which is more contaminated than South Sound.

> "In April 2005, the 5 penta-BDE congeners measured in 2004 … BDE-209, the primary congener in commercial deca-BDE mixtures; and BDE-49, -66, -71, -138, -183, and -184, were measured at ten PSAMP temporal stations located throughout Puget Sound. Of 422 measured values, 16% were detected, while 83% were undetected. As in Hood Canal, BDE-47 and -99 were detected most frequently. Congener BDE-47 was detected at all 10 stations; while BDE-99 was detected at 5 stations, including the deep, depositional Shilshole Bay (sta. 29) and Point Pully (sta. 38) stations, and the stations near urban/industrial areas including Port Gardner (sta. 21), Sinclair Inlet (sta. 34), and the Thea Foss Waterway (sta. 40). Congener BDE-209 was also detected at these 5 stations, and at the station in Budd Inlet (sta. 44). Congeners BDE-49, -66, -71, and -100, were detected at 3, 1, 2, and 1 station(s), respectively."

An EIM query for marine sediments in Puget Sound produced the following statistics. Sample-wise ND=0 and Kaplan-Meier statistics were used due to inconsistent reporting (many samples only list a subset of congeners without showing associated detection limits for the non-reported ones), and variable detection limits.

Table 7. Statistical Summary of PBDEs from Recent EIM Query for Puget Sound Sediments (dry weight).

Data Set	n	Percent Detect	Minimum Detect µg/kg	Maximum Nondetect, µg/kg	50th Percentile µg/kg	90th Percentile, µg/kg	Maximum, µg/kg
ΣPBDE	201	91.54	0.069	5.5	3.7 ± 0.496	12.69	42.67

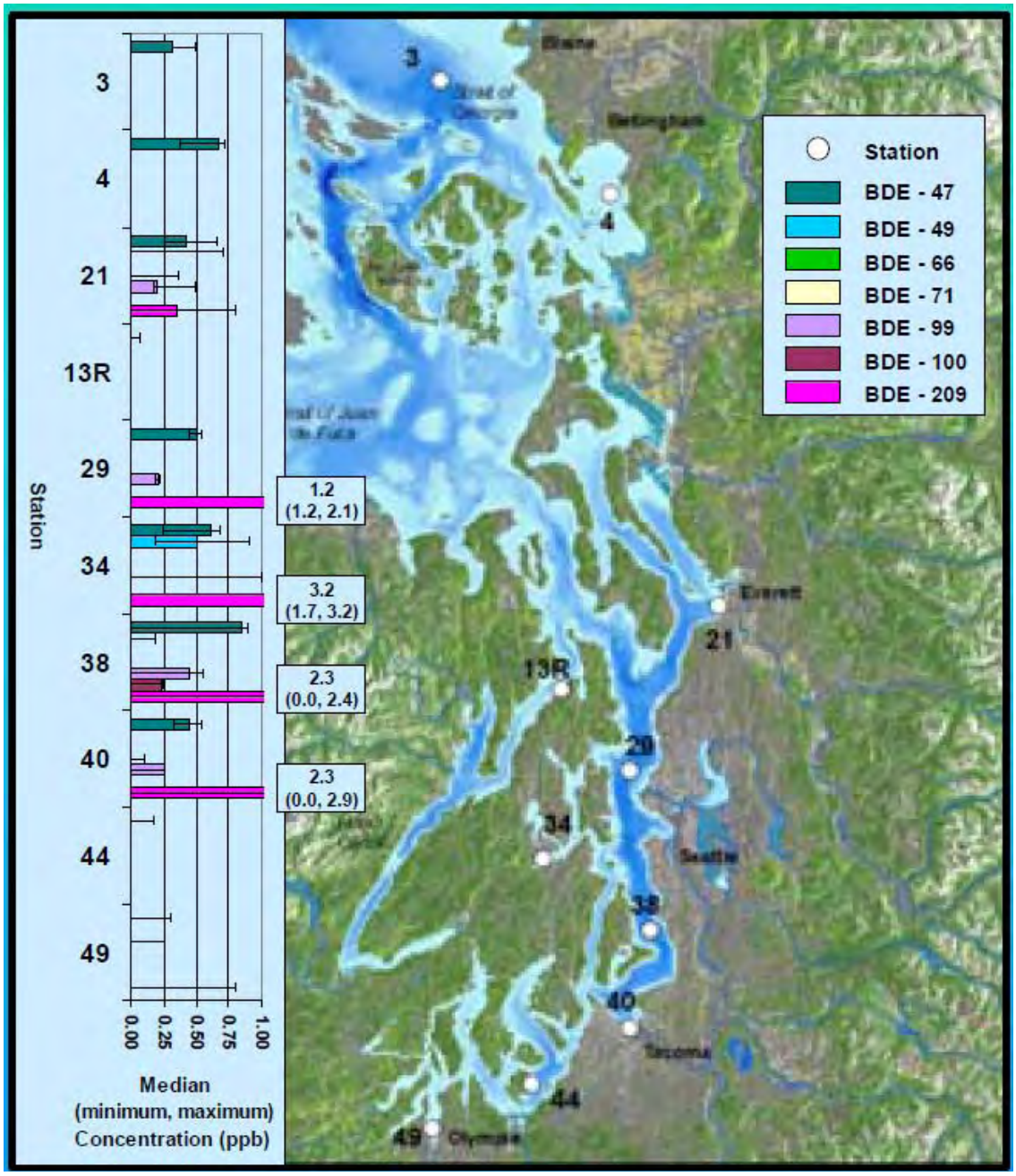


Figure 12. Distribution of PBDE congeners in Puget Sound Sediments (from Dutch and Aasen, 2007)

4. Current Programmatic DMMP Considerations of PCB, PCDD/F, and PBDE

Under the DMMP, disposal-site-related effects including toxicity and bioaccumulation are limited to "minor adverse" effects, as determined through testing for chemistry, toxicity, and (for persistent bioaccumulative toxicants) bedded bioaccumulation tests, and at times site specific evaluations including risk assessment and trophic modeling are used as tools for making this determination. The *Users' Manual* (Corps 2009) describes dredged material testing procedures. Sediments proposed for disposal associated with an unacceptable level of adverse effect must be disposed of at an approved upland confined disposal site, or in an approved confined aquatic site. For PCBs, testing for benthic toxicity is required above the screening level; and testing for bioaccumulation potential above a bioaccumulation threshold. For PCBs these consist of a benthic toxicity triggered by 130 µg/kg-dry, and human health effects triggered by the bioaccumulation threshold of 38 mg/kg (organic carbon normalized). Significance of bioaccumulation is presently determined by comparison to a tissue-based toxicity threshold, based upon subsistence fishers' consumption of seafood.

The DMMP list of Bioaccumulative chemicals of concern follows.

Metals/Organometals:
Arsenic
Cadmium
Chromium
Copper
Lead
Mercury
Nickel
Selenium
Silver
Tributyltin
Zinc

PAH:
Pyrene
Fluoranthene
Phenols:
Pentachlorophenol
Volatile Organic:
Hexachlorobenzene
Pesticides:
Alpha-Benzene Hexachloride
Chlordane
DDT (total)
Other:
PCB (total)
PCDD/PCDF*

*PCDD/F are chemicals of concern for limited in the DMMP, and as such have not been tested in all projects; but have become routine for all projects in DMMP within reason-to-believe areas since 2007.

In accordance with recent program developments, DMMP is significantly increasing the frequency of analysis of PCDD/F. Because safe sediment values that relate to human health for seafood consumption appear to be below background values, the DMMP has proposed a "background-based" sediment management goal for nondispersive and dispersive sites. The DMMP agencies (DMMP, 2010) have proposed a Puget Sound non-urban-background-based criterion for the placement of sediments at dispersive

sites, and for non-dispersive sites a background-based goal that would be adaptively managed. This is 4 ng TEQ/kg, which approximates the 90th percentile of nonurban sites. [3]
[http://www.nws.usace.army.mil/PublicMenu/documents/DMMO/DMMP_Proposed_Changes_to_Interim_Guidelines_for_Dioxins_4-19-2010.pdf]

In addition, in keeping with the intent of the program to remain scientifically up-to-date, a programmatic review of bioaccumulative compounds is proposed.
[http://www.nws.usace.army.mil/PublicMenu/documents/DMMO/DMMP_Dioxin_Project_Additional_Steps_4-19-2010.pdf]

The DMMP actively seeks to update the list of PBTs that are chemicals of concern, based on emergent information regarding bioaccumulation, biomagnification and toxicity. A list of "candidate" chemicals of concern currently (DMMP 2003) includes PBDE; but this compound suite has not been determined necessary to test in dredged material to date. [http://www.nws.usace.army.mil/PublicMenu/documents/DMMO/Final_BCOC_lists.pdf]

Materials proposed for placement at Puget Sound open-water sites are tested to assure that they do not exceed contaminant thresholds. Striplin et al. (1991) showed that non-dispersive site concentrations predicted based on volume-weighted averages from characterization were similar to actual monitoring data from these sites. The DMMP has committed to adaptively managing the non-dispersive sites for PCDD/F, and is considering additional revisions to address PCBs.

The DMMP addressed bioaccumulation and biomagnification for PCDD/F in fish and crabs for the first time in 2006-7, and used both a trophic model (Gobas, 1993) and subsequent monitoring for the non-dispersive South Sound Anderson-Ketron site; model predictions were within 200% of the findings, although the model tended to predict high. The only analyte suite considered was PCDD/F, due to low concern for PCBs at this site. Crab were evaluated using published biota-sediment accumulation factors, but not modeled. Higher trophic modeling (for instance, from benthos to plankton to pelagic predators) was not believed warranted. Biomagnification for herring and Chinook did not occur. The Corps (2007) White Paper Supplement to the Biological Evaluation cited water depths greater than adult Chinook frequent while feeding, and the scarcity of the site(s) benthic fauna, the water depth, and the low solubility of PCDD/F (as determined from the literature). The conclusions were discussed above, under Problem Formulation.

For SRKW, a small proportion (<4%) of benthic prey species such as halibut, haddock, and sablefish are present in the diet. For Steller Sea Lions and seals, the proportion of bottom fish and other benthic species is higher. However, it is unlikely that either Steller sea lions or seals would spend time foraging at the depths of the sites. The pathway to their food would likely include migrating fauna; such migration patterns confound and attenuate the influence of each site on higher predators. Additionally, Steller sea lions are only present in Puget Sound for a short portion of their annual cycle.

[3] The DMMP agencies added several existing reference studies to the OSV Bold data set in making this determination. This explains programmatic variance with Table 6.

Contribution of the dredged material placed at open-water sites to exposure by these animals is indirectly and indefinitely linked to the consumption by marine mammals, and where it occurs, should be considered in the context of the Puget Sound background levels for ΣPCB, ΣPCDD/F and PBDE. (As noted, PBDEs have not been subject of Suitability Determinations, and no dredging-related data are available at this time.)

5. DMMP Site Chemical Inventories for PCB, PCDD/F and PBDE

The purpose of this section is to review the quantities of dredged material placed at DMMP disposal sites in Puget Sound, and the inventory of PCB, PCDD/F, and PBDE in context of vicinity and background ranges of the chemicals. Cumulative site use statistics for volume of materials placed are shown in Figure 13.

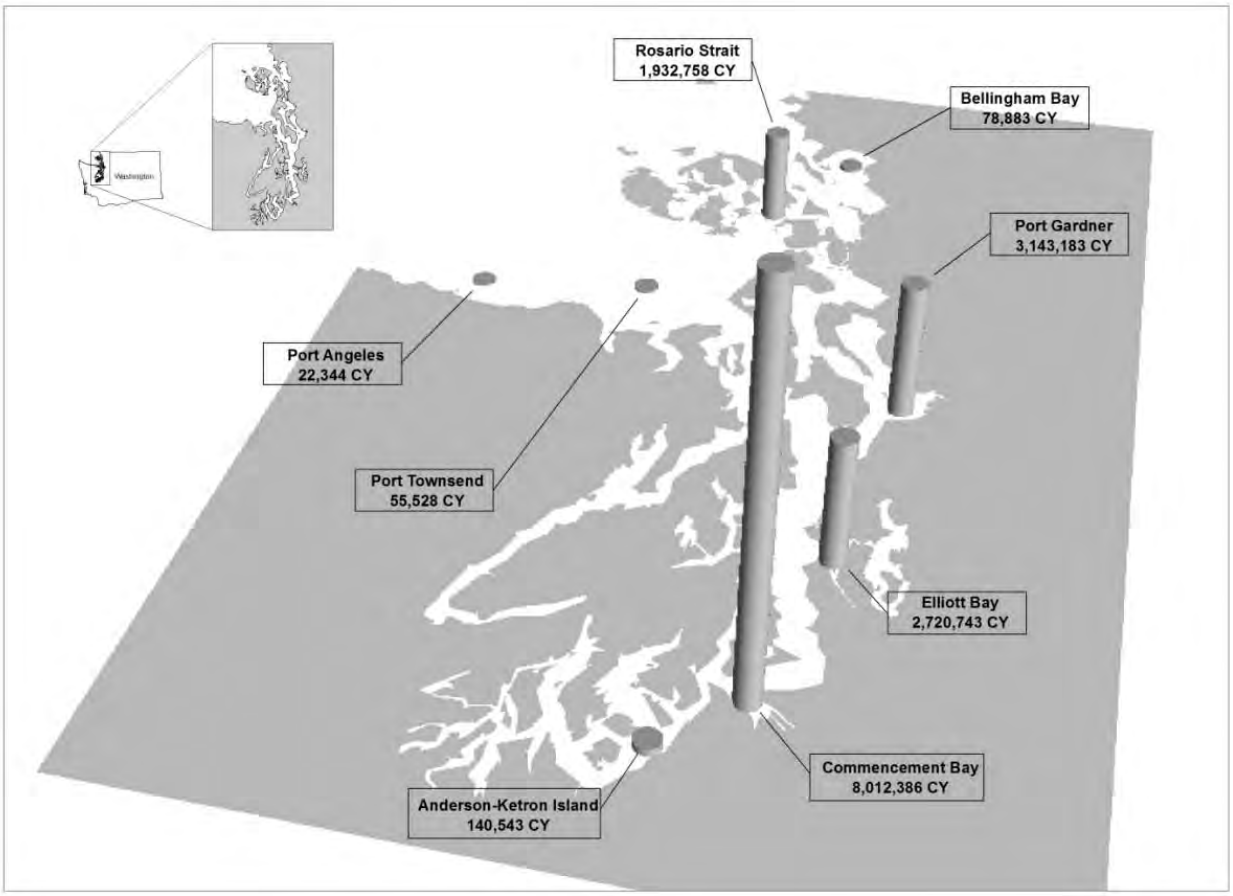


Figure 13. Cumulative disposal volumes for all sites as of May, 2010

a. Dispersive Sites

Under the program, no site monitoring occurs for DMMP dispersive sites, so the contaminant inventory relies upon the chemistry of the characterized materials for the

Suitability Decisions. The disposed materials rapidly migrate offsite due to strong currents. There are three sites: Port Angeles, Rosario Straits, and Port Townsend. Port Angeles has only been used once, 1n 1996. The other two sites are listed below for their entire disposal history, by DMMU characterization. It is notable that the mean value provided is well within the range of Puget Sound-wide means described in earlier tables.

Note also the low frequency of detected PCB in these samples. The method of summation (Dredged Material Management Unit or DMMU), as opposed to volume-weighted averaging, likely overestimates the Rosario Strait quantities, as many of the larger-volume DMMUs had nondetects and were from Swinomish Channel maintenance. The DMMU averages are in the low-end of the range of Puget-Sound-wide averages.

Table 8. Rosario Strait PCB Statistics by Dredged Material Management Unit (DMMU) Permitted for Placement

Parameter	Value	Units/Type
Number of Observations	102	Count
Proportion of Detections	12.75	%
Minimum Detected	0.4	µg/kg
Maximum Detected	193	µg/kg
Minimum Non-detected	2.8	µg/kg
Maximum Non-detected	130	µg/kg
Distribution	Non-parametric	--
Nonparametric Statistics for DMMU Data by the Kaplan-Meier (KM) Method		
Mean ± Standard Error	11.3 ± 3.4	µg/kg
95% KM Upper Tolerance Limit with 90% Coverage	54.2	µg/kg

Table 9. Port Townsend PCB Statistics by Dredged Material Management Unit (DMMU) Permitted for Placement

Parameter	Value	Units/Type
Number of Observations	9	Count
Proportion of Detections	0	%
Minimum Non-detected	9.6	µg/kg
Maximum Non-detected	35	µg/kg
Mean	N/C	µg/kg

Table 10. Rosario Straits PCDD/F Statistics by Dredged Material Management Unit (DMMU) Permitted for Placement (ND=0.5*DL method)

Parameter	Value	Units/Type
Number of Observations	9	Count
Proportion of Detections	100	%
Minimum	0.16	ng TEQ/kg
Maximum	1.8	ng TEQ/kg
Distribution	Normal	--
Mean ± Standard Error	0.69 ± 0.19	ng TEQ/kg
95% Upper Tolerance Limit with 90% Coverage (Normal)	N/A (greater than maximum)	--

The Port Townsend dispersive site has only one disposal event for which PCDD/F data are available. The DMMU had 1.4 ng TEQ/kg.

No dispersive site PBDE data exist from monitoring by the DMMP.

As can be seen, dispersive sites have received only low or undetected levels of PCDD/F, and the averages appear to be within regional background.

b. Non-dispersive Sites

The monitoring program for these sites is activated by volumes disposed according to the Management Plan for the sites, or accumulation of 3 cm of sediment at the perimeter line [4], or by special considerations including concern for site conditions. In what follows, unaffected perimeter and "benchmark" stations are considered offsite stations, and S and Z stations collected within the site perimeter are designated onsite. Programmatically, these stations are used to detect changes of the site that potentially affect site surroundings. A comparison is also made to the range of means and 50th percentiles from the general Puget Sound data sets described above.

<u>PCB</u>

Table 11 displays the results of site monitoring from 1990-present for four of the five nondispersive sites. Despite a range of Reporting Limits (RLs) for PCBs by the Aroclor method, there is no systematic difference between the onsite and offsite stations. Note that the programmatic use of RLs for characterizing nondetected values results in "less than" values that are typically 3 or more times above detection limits; and thus the sensitivity of the analyses is greater than shown. For example, estimated (J'd) values never appear in these data sets at values below the RL. In every case but Elliott Bay (shown in Figure 13 and following pages), the values shown are below the maximum reporting limits, and the site conditions are within the plausible range of Puget Sound average concentrations discussed above.

[4] The Perimeter line boundary extends 1/8 nautical mile outside the disposal site boundary

Table 11. PCB Statistics from Monitoring at Nondispersive Sites Except Elliott Bay

	Anderson-Ketron		Bellingham Bay		Commencement Bay		Port Gardner		Units
	Onsite	Offsite	Onsite	Offsite	Onsite	Offsite	Onsite	Offsite	
Number of Observations	4	20	1	6	16	135	8	28	Count
Proportion of Detections	0	0	0	0	0	0	0	0	%
Minimum Non-detected	<3	<3	<20	<20	<2	<7	<6	<6	µg/kg
Maximum Non-detected	<3	<3	<20	<20	<51	<86	<49	<67	µg/kg

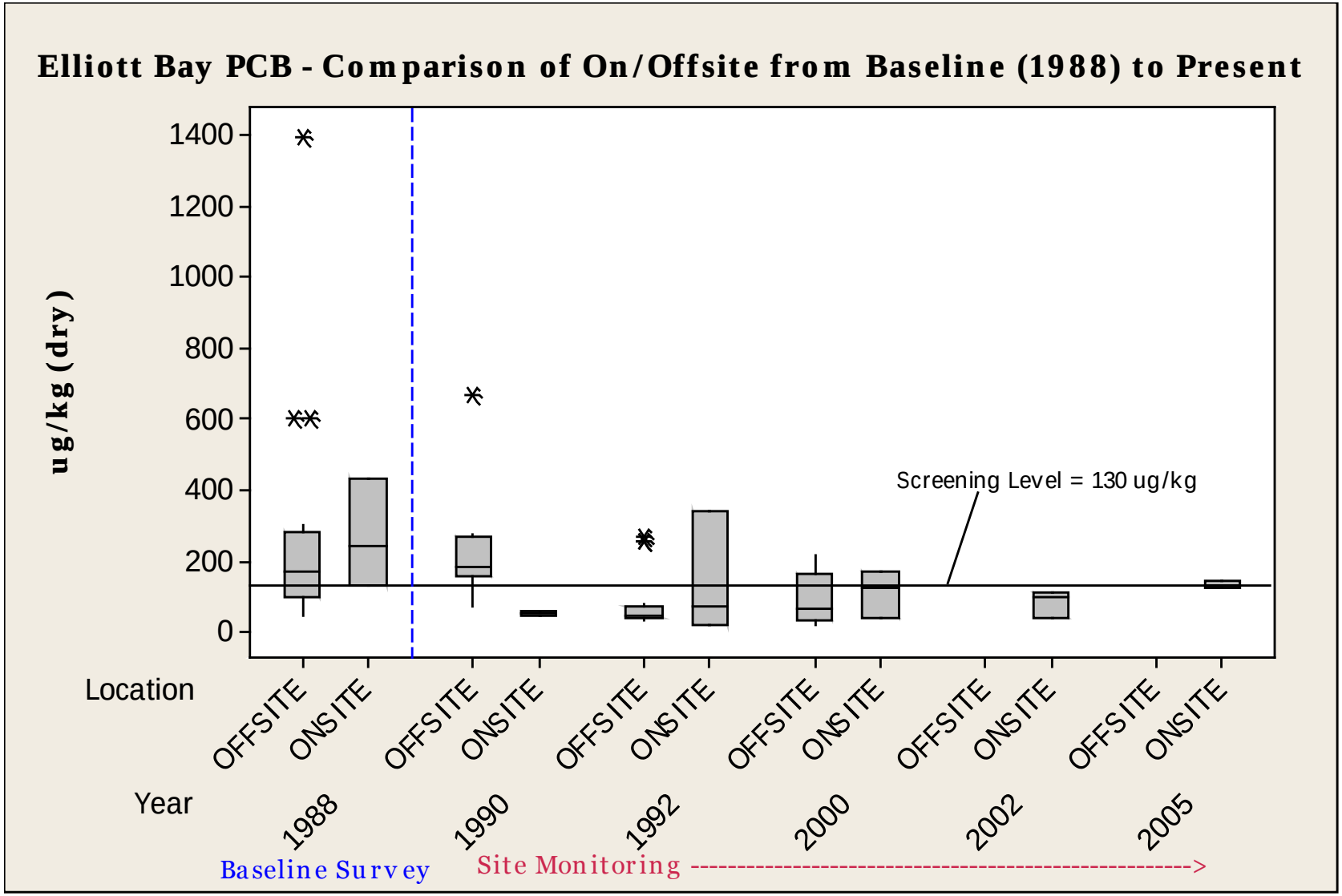


Figure 13. Comparison of On/Offsite Elliott Bay PCB from Baseline (1988) to Present

Figure 13 and Table 12 portray the Elliott Bay nondispersive site data. Both onsite and offsite central tendency metrics were greater than the ranges of means in Puget Sound (Tables 2-4). Elliott Bay site surroundings, as represented by the offsite perimeter and benchmark stations, have been higher or comparable to onsite stations since the disposal sites began use in 1990. (Note that the baseline from 1988 is displayed for comparison, but is before site use for disposal.) The following paragraphs compare the on- and offsite conditions. Data used are those collected 1990-present (that is, not including the 1988 baseline survey). The 0-2 cm data from 2005 were used; other years' data are 0-10 cm intervals.

Table 12. PCB Statistics from Monitoring at Elliott Bay

Parameter	Onsite Value	Offsite Value	Units/Type
Number of Observations	14	36	Count
Proportion of Detections	88.6	87.6	%
Minimum Detected	34	19	µg/kg
Maximum Detected	339	670	µg/kg
Minimum Non-detected	14	40	µg/kg
Maximum Non-detected	72	40	µg/kg
Median	83.5	65.0	µg/kg
Distribution	Non-parametric or Lognormal	Non-parametric	--
Nonparametric Statistics by the Kaplan-Meier (KM) Method			
Mean ± Standard Error	99.8 ± 22.37	111.2 ± 19.0	µg/kg
95% KM Upper Tolerance Limit with 90% Coverage	202.1	264.8	µg/kg

In light of the variable RLs, nonparametric distributions, the fact that the means exceed the medians and indicate an opposite trend direction than the medians, we conducted a Mann-Whitney test on the difference of medians, with the null hypothesis that the difference between Offsite and Onsite medians is zero. At 95% confidence, the onsite and offsite median concentrations for PCBs were not significantly different.

The Elliott Bay onsite medians have also always met Washington State Sediment Quality Standards (12 mg/kg organic-carbon normalized) in all monitoring events.

To provide additional context for Elliott Bay and its non-dredging-related inputs, the Lower Duwamish Waterway Work Group's (WindWard 2008) draft Phase 2 Remedial Investigation estimated a generalized Elliott bay PCB mean background to be 135 µg/kg. Regarding the Lower Duwamish Waterway itself, the citation provides the following PCB statistics, which are considerably higher.
[http://www.ldwg.org/assets/phase2_ri/ri/draft_ri.pdf]

Table 13. Lower Duwamish Waterway ΣPCB Statistics

n	Median, µg/kg	Mean, µg/kg	95th Percentile µg/kg	Maximum, µg/kg
1,327	137	1,170	4,170	220,000

PCDD/F

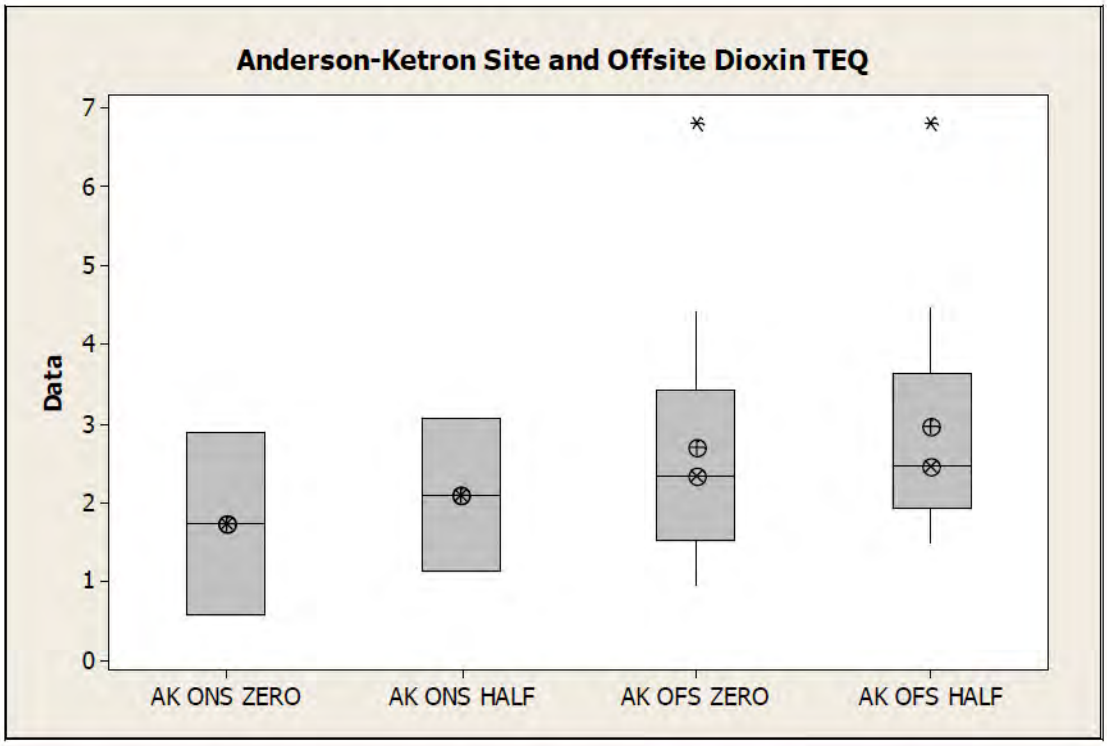
Both the ND=0.5*DL and ND=0 methods were used to compare on- and offsite ΣPCDD/F TEQs, and to the 4 ng TEQ/kg background value in the Revised Interim Dioxin Guidelines. Figures 14a through 14e show these comparisons. The key to the illustrations follows:

- Site codes: *AK* = Anderson-Ketron. *BB* = Bellingham Bay, *CB* = Commencement Bay, *EB* = Elliott Bay, and *PG* = Port Gardner.
- Location designations: *ONS* = onsite, *OFS* = offsite.
- The methods for summation of toxicity equivalents are *Half* = one-half of DL substituted for non-detected values, and *Zero* = zero substituted for non-detected values.

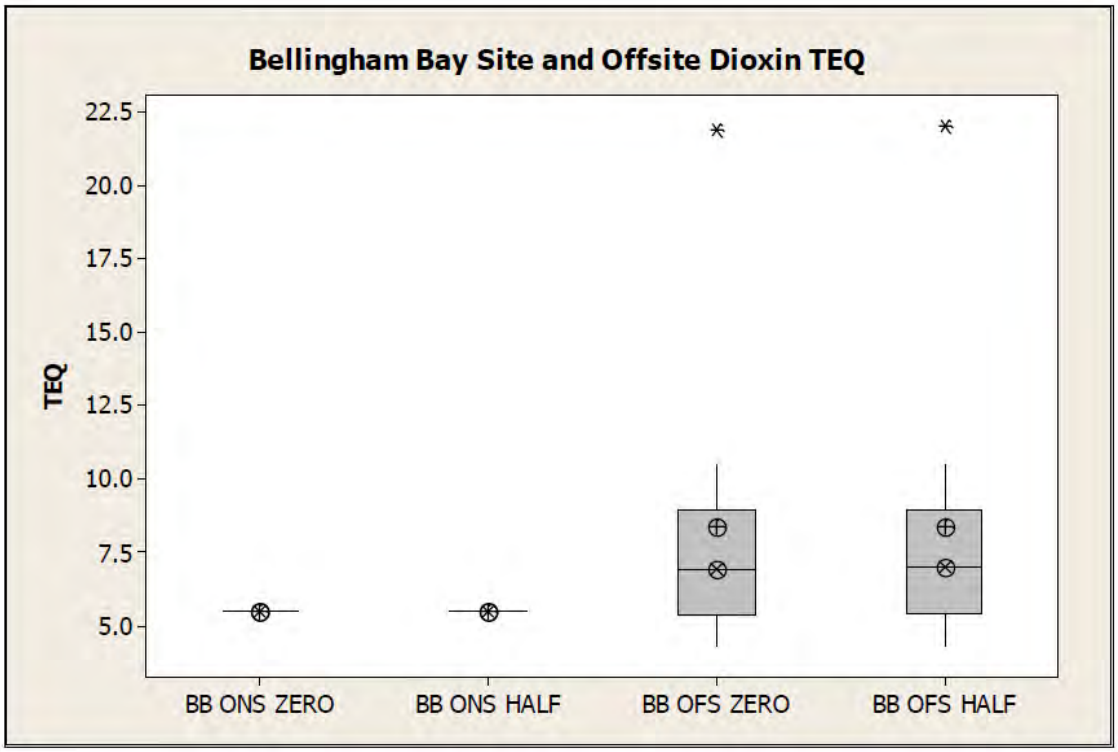
In the box-plots, the boxes shows the middle two quartiles of the data, the whiskers the first and fourth quartiles. Outliers are shown by an asterisk. Medians are shown by the line and ⊗, and means are shown by ⊕.

Figure 14 (includes pages following). Comparison between On- and Offsite Stations at 5 Nondispersive Open-water Dredged Disposal Sites

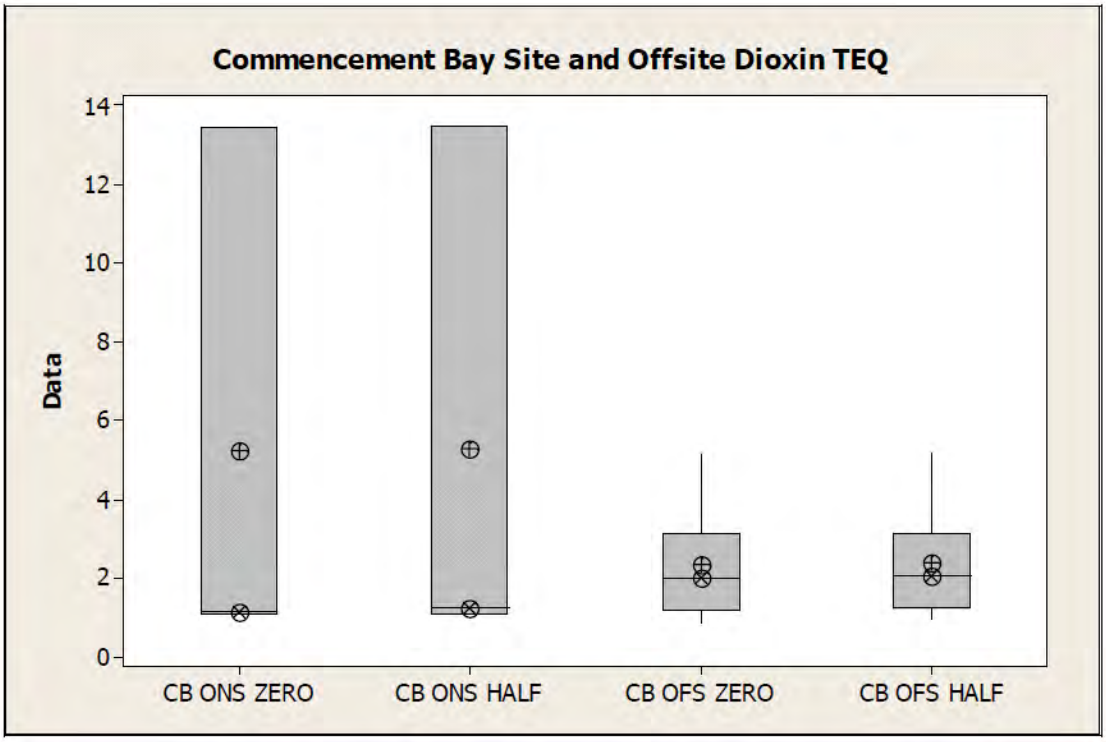
14a. Anderson-Ketron



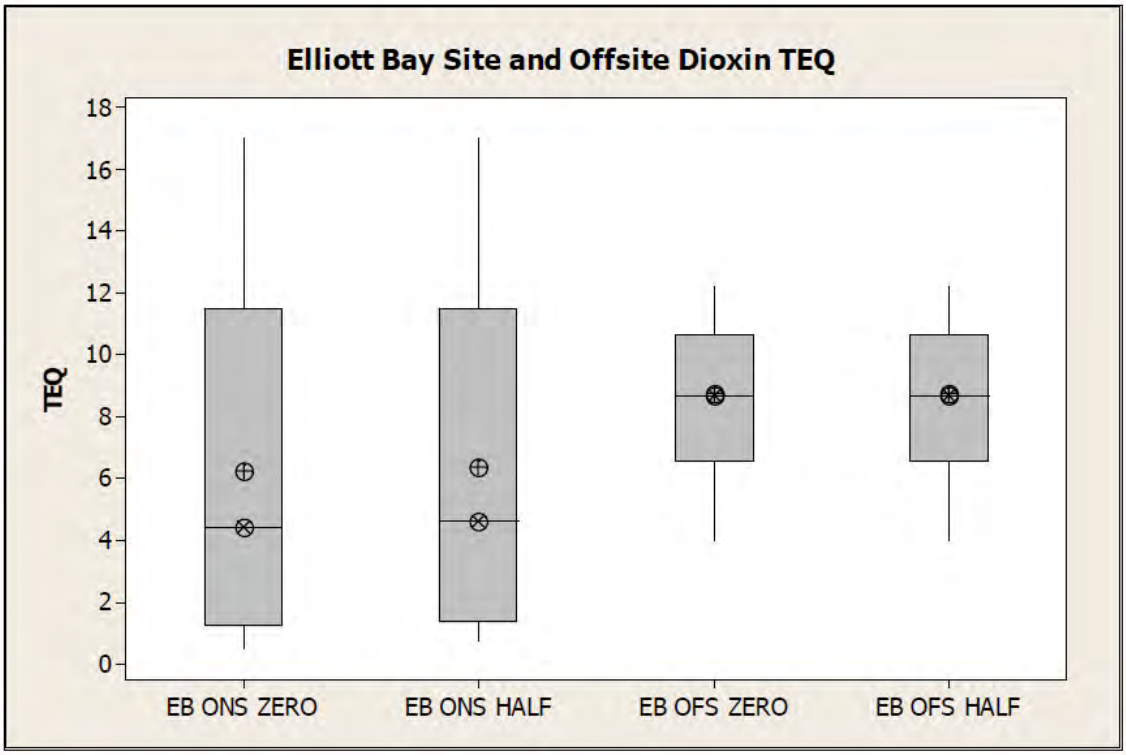
14b. Bellingham Bay



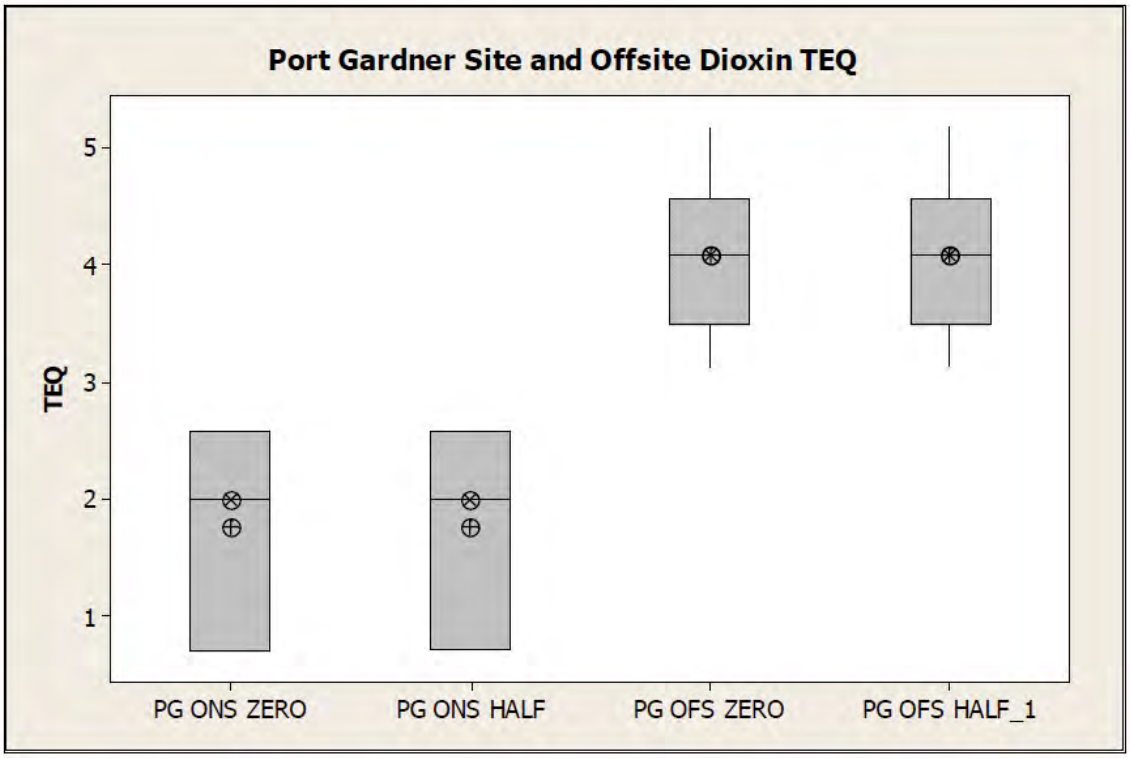
14c. Commencement Bay



14d. Elliott Bay



14f. Port Gardner



For Port Gardner and Anderson-Ketron Island sites, the onsite mean values are less than the offsite values, as well as less than the 4 ng TEQ/kg site management goal. For Elliott Bay and Bellingham Bay, the onsite mean is less than the offsite value, but both are greater than the management goal. For Commencement Bay, the onsite mean is above the goal and greater than the offsite mean, and the offsite mean is below the goal. Future management of these sites should bring onsite values near or below the background-based goal.

The onsite and offsite sediment data presented indicate that disposal of dredged material does not appear to have increased the contaminant inventory near any of the nondispersive sites, and in some instances for PCDD/F, may have improved the local area.

With one exception, the Puget Sound open-water dredged material disposal sites were placed in deeper waters and in faunally-sparse areas during the siting process. The Bellingham Bay site is in water of depths potentially reached by marine mammals and their prey; however, this site not likely to be used in future according to the Port of Bellingham. Therefore, it is anticipated that there would be low utilization by demersal grazers such as English sole and unlikely exposure of PCDD/F by pelagic fish including herring and Chinook.

PBDE

Although dredged material is not routinely tested for PBDE, site monitoring data for sediment and benthic tissue are available for the nondispersive sites, and are shown in Table 15 on the following page. All sediment values were non-detected, with the RLs displayed. In comparison with Table 7, the sediment RLs and DLs are elevated, and thus these data may not be informative of programmatic conditions. For tissue data, comparing to Figure 6 values for herring PBDE concentrations, all but the recent Anderson-Ketron site RLs are also too high to resolve the range reported for biota; for Anderson-Ketron, these values are in the range where information is useful. It is apparent that higher-resolution analytical methodologies should be used in the site monitoring program in future.

Summary

Non-dispersive dredged material disposal site monitoring is ongoing to determine whether there is a significant increase of PCBs and exceedance of sediment screening or maximum levels. The same is true of PCDD/F, for which a site-background-based site management goal is currently being proposed for use in the program. Site monitoring has demonstrated that the dredged material evaluation procedures are keeping sediment concentrations on-site below management thresholds for PCB, PCDD/F and other persistent bioaccumulative compounds such as Hg and DDT. A review of PCB and PCDD/F on- and offsite concentrations presented above shows that these compounds are not generally elevated relative to their surroundings in the post-disposal site environment, and are in the range of concentrations that typify Puget Sound urban and

Table 15. PBDE Statistics from Monitoring at Nondispersive Sites

	Anderson-Ketron		Commencement Bay		Port Gardner		Elliott Bay		Units
	Onsite	Offsite	Onsite	Offsite	Onsite	Offsite	Onsite	Offsite	
Sediment									
Number of Observations	3	21	3	12	3	12	3	4	Count
Proportion of Detections	0	0	0	0	0	0	0	0	%
Minimum Non-detected	<19	<19	<20	<20	<19	<19	<99	<55	µg/kg (dry)
Maximum Non-detected	<20	<20	<20	<20	<20	<20	<140	<130	µg/kg (dry)
Tissue									
Number of Observations	--	6 [a]	--	14	--	5		3	Count
Proportion of Detections	--	0	--	0	--	0		0	%
Minimum Non-detected	--	<3	--	<26	--	<33		<73	µg/kg (wet)
Maximum Non-detected	--	<3	--	<33	--	<33		<76	µg/kg (wet)

[a] Clam (*Compsomyax subdiaphana*)
[b] Sea Cucumber (*Molpadia intermedia*)

nonurban concenration. In one case, Elliott Bay, where the urban surroundings are significantly elevated relative to the rest of Puget Sound; but there is no significant difference between the on-site and off-site concentrations of PCBs. PCDD/F are also very similar on- and off-site. For PBDE, analytical insensitivity does not permit a determination.

6. Data Needs to Address Biomagnifying Compounds

This section discusses data needs to evaluate biomagnifying compounds, with reference to protection of marine mammals. In most instances, the level of effort is beyond what the DMMP program is capable of doing, since the needs are multidisciplinary, and the purview of other agencies.

a. Trophic modeling.

Accurate determination of bioaccumulation potential and ecological risk in Puget Sound biota is not possible without adequately considering the mechanisms of biotic interactions. Quantitative food-web models for predicting transfer of PCB from sediment to biota and subsequently through the food-web to higher consumers have been developed for the Great Lakes, San Francisco Bay, the Lower Duwamish Waterway Superfund Site in Seattle, and Lake Washington in Seattle (Gobas 1993, Arnot and Gobas 2002, Windward 2008, and Gobas and Arnot 2010, in press). These models use estimates (based upon equilibrium calculations from one environmental compartment to another. For example, PCB migration from sediment into into surface water, into benthos, into plankton, into fish, and into higher predators. The models are not constructed at a suitable scale to support decision-making with regard to sediment management. The Great Lakes, San Francisco Bay, Georgia Strait and Lake Washington models are at the ecosystem level, and utilize measures of central tendency for sediment; the Strait of Georgia or Puget Sound models are not available for review at this time of writing. The Lower Duwamish Food Web Model is constructed on the scale of 5 miles of the waterway.

Verifiable models combined with monitoring systems are generally acknowledged as tool to better understand the potential for biomagnification of chemical contaminants. However, no model has yet been constructed and calibrated for Puget Sound. Efforts by Condon and Gobas 2005; Shaw et al. 2005) are currently underway to explain and predict system loadings of PCB to SRKW in the Strait of Georgia, and this model may be extended to Puget Sound (Peter Ross, Canadian Division of Fisheries and Oceans, personal communication). Therefore, despite presence of potentially biomagnifying compounds in dredged materials placed in open water disposal sites, the currently available tools do not appear to suffice to support decision-making regarding open-water disposal. As models are developed, the DMMP will follow their progress and consider program implications.

The following paragraphs describe significant data needs.

- Site-specific conditions and biological interactions significantly affect a chemical's bioavailability and bioaccumulation potential (Ingersoll et al. 2002). At issue is whether a modeling approach accurately portrays these interactions at the scale of a DMMP site, for which fish behavior is an important variable. This appears necessary to determine the prospective exposure of SRKW from dredged material placement. As noted, the primary SRKW diet is Chinook, which are not usually present at open-water dredged material sites. Adult Chinook are sight-feeders on herring and squid, and feed preferentially in waters of shallower depth than most sites, and along shorelines. In general, Puget Sound open-water dredged material disposal sites are located in deeper water than Chinook feed (with the single exception, Bellingham Bay, not likely to be used again in future), and have been intentionally sited in areas of low faunal abundance. Behavior of the mammals is also a variable. Sole and other demersal fish constitute a minor part of SRKW diet. They are more important for Steller Sea Lions and Harbor Seals; however , the proportion of the fish in these mammals' diet that have been exposed the DMMP sites is expected to be small.

- Current models assume that all sediment (not just dredged material placed at open water sites) are emitting soluble contaminants of PCBs that are taken up by benthos, demersal fish, phytoplankton, zooplankton, herring and Chinook. Materials deemed suitable for placement at Puget Sound open-water sites are sediments in Puget Sound or adjacent fresh water lakes (e.g., Lake Washington) that have been tested to assure that they do not exceed contaminant thresholds, although these thresholds are not currently based upon biomagnification potential. Movement from one part of the Sound to another (e.g., from Elliott Bay to north Sound) would not affect the statistical distribution of the chemical suites at the system level.

- The relative contribution of the flux of PCB and PBDE in dissolved and particulate form in the open waters of Puget Sound and the Strait of Georgia need further evaluation as a step critical for understanding bioavailability of these compound suites for the trophic web. This information, when available, may be used to validate and refine models should address the relative importance of such sediments and surface water as sources. Promising information is becoming available on waterborne contamination (Shaw et al. 2007; Dangerfield et al. 2007; Gries [Washington Department of Ecology, personal communication] 2010). This information, once integrated into a regional and site-specific context, may be useful in validating regional and local models.

- Since it is difficult to calculate regional or area averages for substance suites such as PCB and PCDD/F using existing data, consistent methodologies and consensus-based methods for dealing with non-detected values should be adopted. Since Puget Sound sediment distribution of PCB and PCDD/F appears

highly skewed, with extreme values in the Lower Duwamish Waterway and the associated Elliott Bay in Seattle, and in Everett Harbor. Several orders of magnitude exist between such areas and the near-urban or non-urban areas of the Sound. An approach to fairly represent the contributions by area weighted averages should be considered. Setting and enforcing a consistent methodology across programs would exceeds the scope and resources of the DMMP

- alone. For example, Ecology (as a future action mostly unrelated to the DMMP) is currently contemplating close "screening" of the EIM information to develop regional sediment and tissue background ranges. Regarding PBDEs, the DMMP will consider what level of testing should be required, and for which projects. Central Puget Sound sediments appear to have elevated PBDEs as compared to other areas. In addition, lower detection limits for PBDEs are clearly required.

b. Monitoring

Non-dispersive dredged material management sites are monitored to determine whether there is a significant increase of ΣPCB and exceedance of sediment screening or maximum levels. The same is true of ΣPCDD/F, for which a background-based site management goal is currently being pursued in the program. Programmatic non-dispersive site monitoring logic assures that site chemicals remain below management thresholds for ΣPCB, ΣPCDD/F, and for other persistent bioaccumulative compounds such as ΣDDT. More sensitive congener methods are needed in the program for measuring PCB and PBDE.

7. Conclusions

The above review of ΣPCB and ΣPCDD/F on and offsite nondispersive site concentrations, and an inventory of these compounds for the dispersive sites indicates that the compounds are generally not elevated relative to their surroundings, and their surroundings fall (with the notable exceptions of urban Elliott and Commencement Bays) within in the range of concentrations that typify Puget Sound. Thus, the programmatic actions of transport, placement, and disposal of dredged materials with biomagnifying substances is not likely to increase the existing levels of contamination to the food web.

It is noted that evidence suggests that the existing range of Puget Sound sediments (as opposed to the dredged materials managed in the DMMP) likely affects SRKW, Steller Sea Lions, and Harbor seals.

We are aware of no other related Federal decisions that would cause cumulative damages in conjunction with the DMMP activities.

Continued disposal of approved sediments at the DMMP open-water disposal sites in Puget Sound will have discountable effects on ESA-listed species, including SRKW and

Steller Sea Lions. Continued disposal will also have discountable effects on Harbor Seals regulated under the Marine Mammals Protection Act.

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Appendix C

Disposal Sites

Figure B-1. Rosario Strait Disposal Site

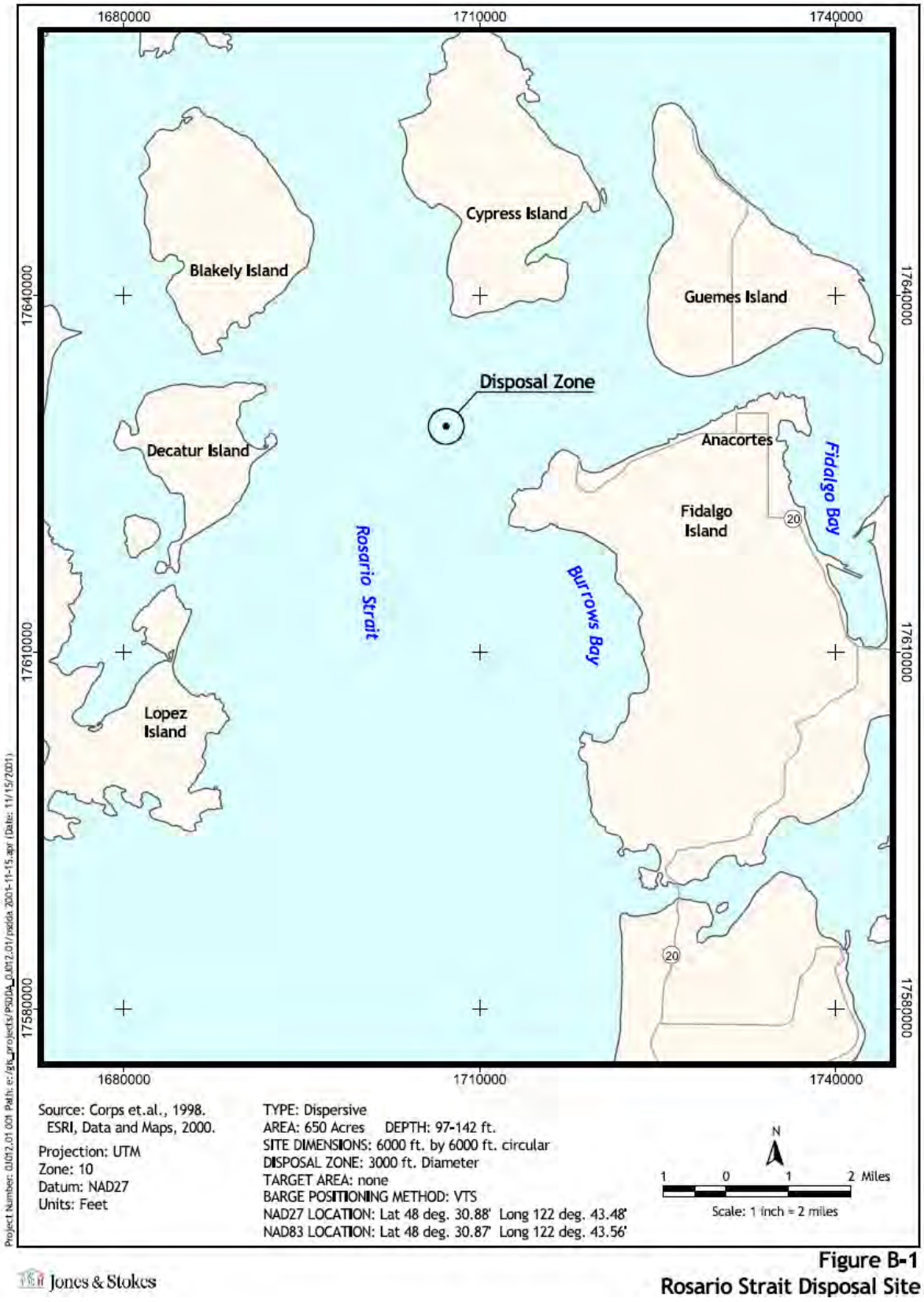


Figure B-2. Port Townsend Disposal Site

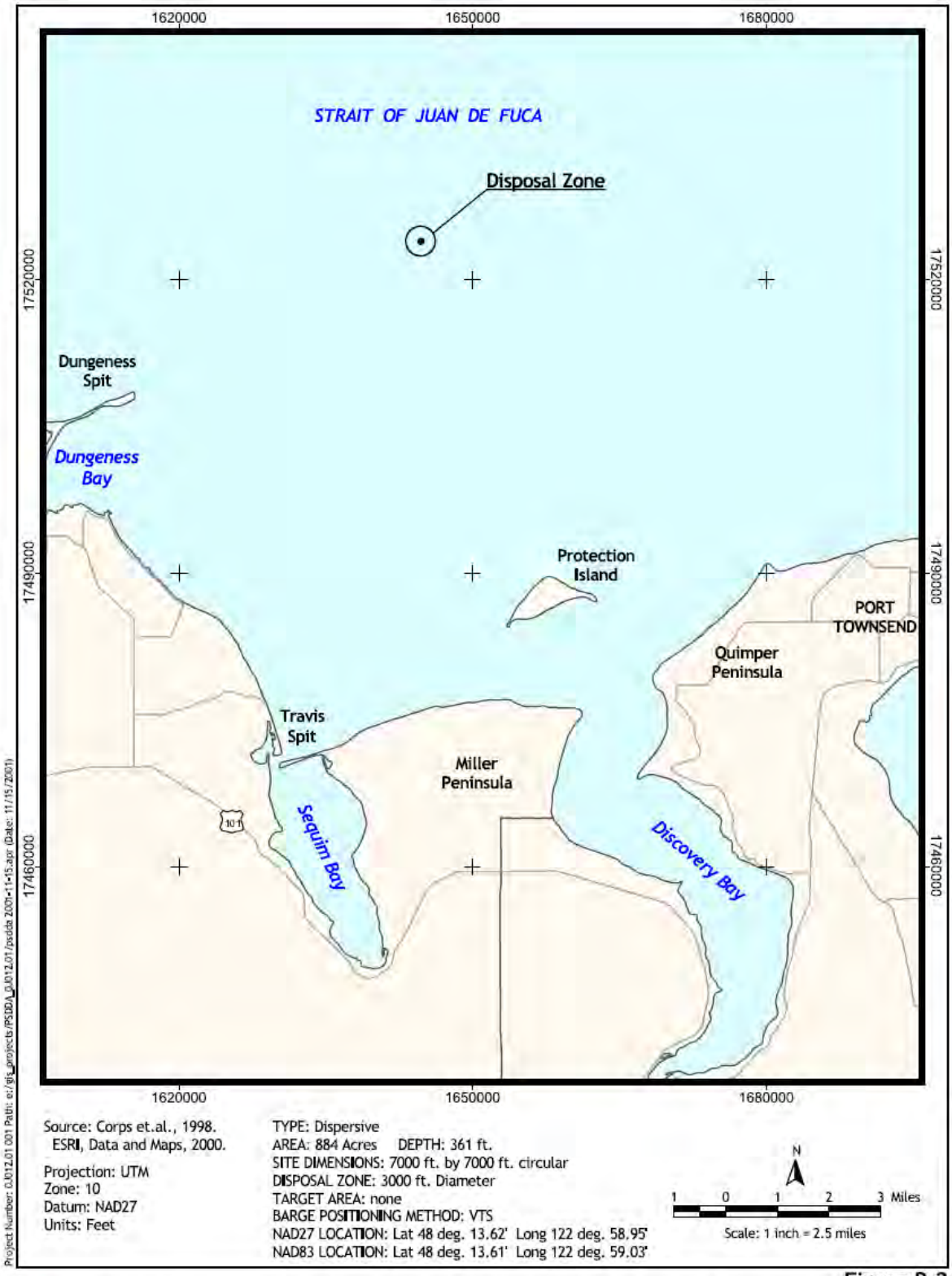


Figure B-3. Port Angeles Disposal Site

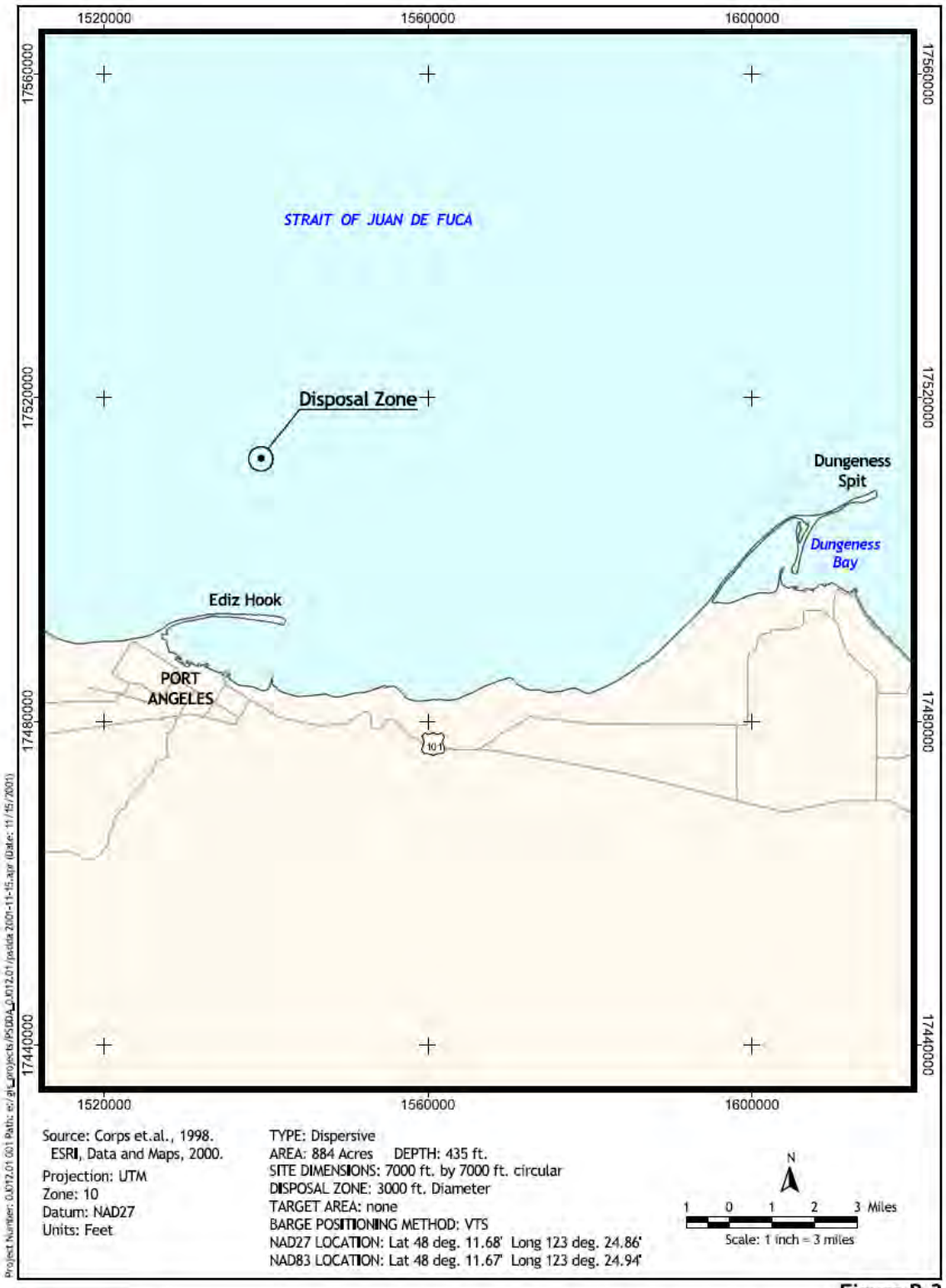


Figure B-4 Bellingham Bay Disposal Site

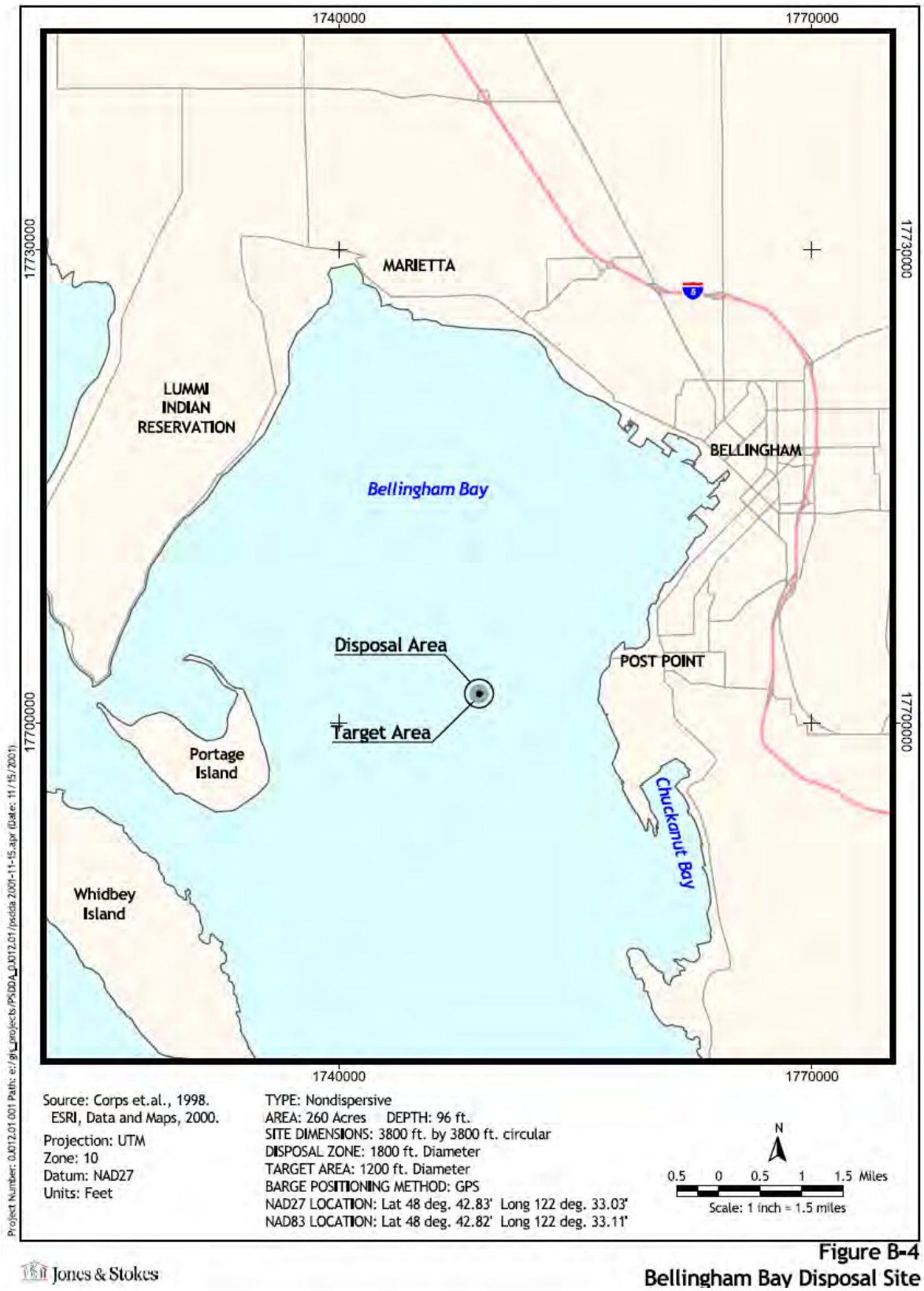


Figure B-5. Port Gardner Disposal Site

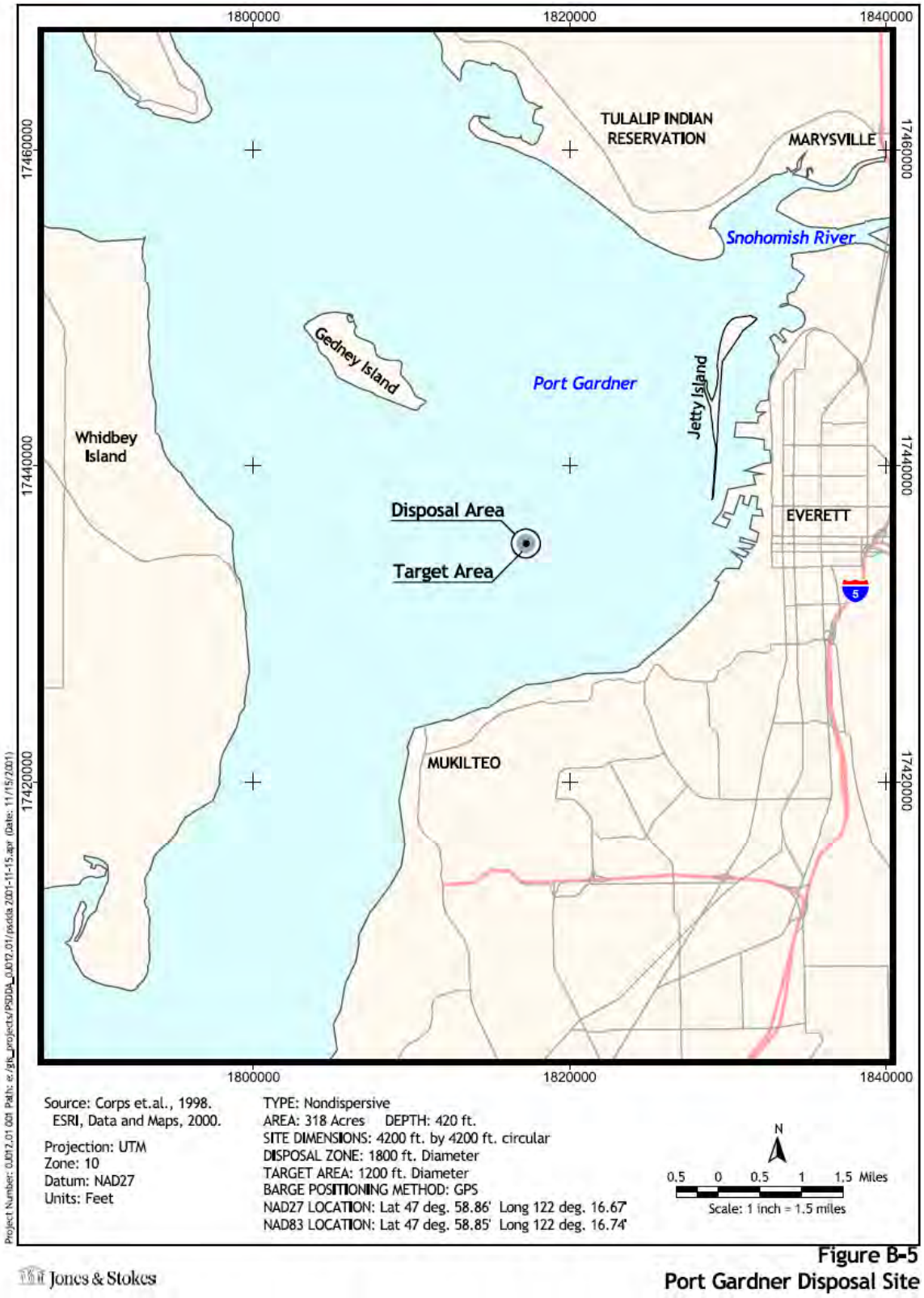
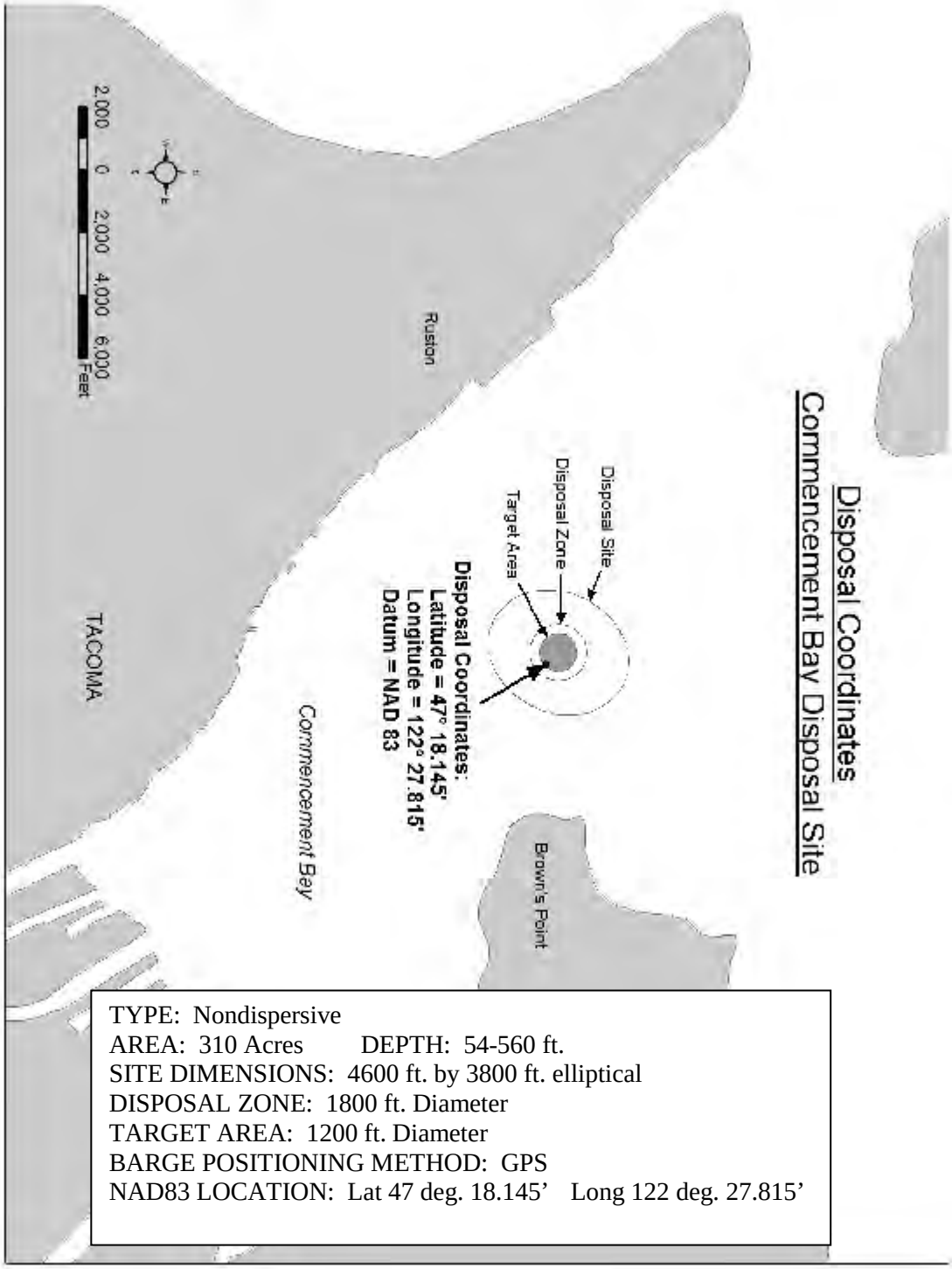


Figure B-6. Elliot Bay Disposal Site

Figure B-7. Commencement Bay Disposal Site



TYPE: Nondispersive
AREA: 310 Acres DEPTH: 54-560 ft.
SITE DIMENSIONS: 4600 ft. by 3800 ft. elliptical
DISPOSAL ZONE: 1800 ft. Diameter
TARGET AREA: 1200 ft. Diameter
BARGE POSITIONING METHOD: GPS
NAD83 LOCATION: Lat 47 deg. 18.145' Long 122 deg. 27.815'

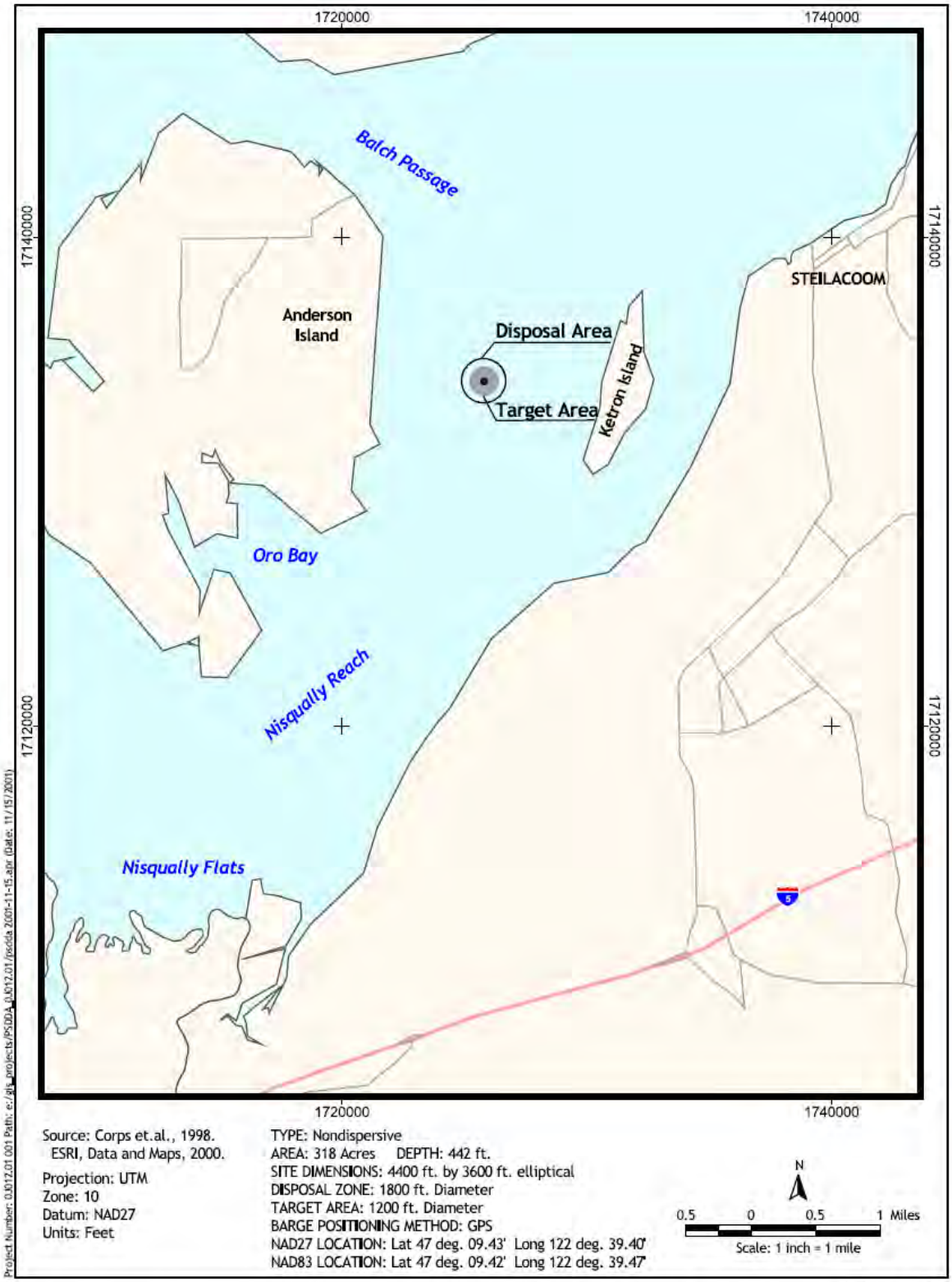



Figure B-8. Anderson/Ketron Island Disposal Site