



# Los Angeles and Long Beach Harbor Complex Framework for Calculating TMDLs

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## Introduction

This document summarizes information on TMDL considerations pertaining to the waterbodies within the Los Angeles and Long Beach Harbors Complex (LALB) that are included on California’s 2002 303(d) list of impaired waters (Table 1 and Figure 1).

**Table 1. Summary of Listed Waterbodies and Pollutants**

Water Body Name	Number of Listings				
	Bacteria	Metals	Other <sup>1</sup>	Toxics	Total
Cabrillo Beach (Inner) LA Harbor Area <sup>2</sup>	1			2	3
Cabrillo Beach (Outer)	2			2	4
Dominguez Channel (above Vermont)	1	4	NH4	7	13
Dominguez Channel (Estuary to Vermont)	1	3	NH4, BCE	6	12
Long Beach Harbor Main Ch., SE, W Basin, Pier J, Breakwater			ST, BCE	4	6
Los Angeles Fish Harbor				3	3
Los Angeles Harbor Consolidated Slip		7	ST, BCE	7	16
Los Angeles Harbor Inner Breakwater				3	3
Los Angeles Harbor Main Channel <sup>2</sup>	1	2		4	7
Los Angeles Harbor Southwest Slip				3	3
Los Angeles River Estuary (Queensway Bay)		2		3	5
Machado Lake (Harbor Park Lake)			A, NH4, EU, O, T	5	10
San Pedro Bay Near/Off Shore Zones		3		4	7
Torrance Carson Channel	1	2			3
Wilmington Drain	1	2	NH4		4
San Gabriel Estuary			AFH		1
<b>Total</b>	<b>8</b>	<b>25</b>	<b>14</b>	<b>53</b>	<b>100</b>

<sup>1</sup> “Other” includes Algae (A), Ammonia (NH4), Benthic Community Effects (BCE), Eutrophication (EU), Odors (O), Sediment Toxicity (ST), Trash (T), and Abnormal Fish Histology (AFH)

<sup>2</sup> The bacteria TMDLs for Cabrillo Beach and the LAH Main Channel have been completed.

These waterbodies have been included in a single assessment because they share the following common traits that make their collective assessment efficient:

- Hydrologic connectivity
- Similarity of land uses and pollutants, and potential pollutant sources
- Stakeholders and regulatory oversight

Because of these shared traits, several agencies and stakeholders are developing strategies for identifying and accounting for pollutant sources and developing plans for ensuring that the sources are reduced (or eliminated) to an amount that leads to attainment of designated beneficial uses and their water quality objectives. This document provides the following:

- Summary of impaired waterbodies in the LALB
- Summary of the requirements for calculating approvable TMDLs
- Summary of ongoing efforts to support TMDLs
- Options and recommendations



Figure 1. Location of Listed Waterbodies in the San Pedro Bay Watershed

## Regulatory Background

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Section 303(d)(1)(A) of the Clean Water Act (CWA) requires that “Each State shall identify those waters within its boundaries for which the effluent limitations...are not stringent enough to implement any water quality standard applicable to such waters.” The CWA also requires states to establish a priority ranking for waters on the 303(d) list and establish Total Maximum Daily Loads (TMDLs) for the waters. The elements of a TMDL are described in 40 CFR 130.2 and 130.7 and Section 303(d) of the CWA, as well as in EPA guidance documents (e.g., EPA 1991 and EPA 2001). A TMDL is defined as “the sum of the individual waste load allocations for point sources and load allocations for nonpoint sources and natural background” (40 CFR 130.2) such that the capacity of the water body to assimilate pollutant loadings (the Loading Capacity) is not exceeded. A TMDL is also required to be developed with seasonal variations and include a margin of safety to address uncertainty in the analysis. In addition, pursuant to the regulations at 40 CFR 130.6, states must develop water quality management plans which incorporate approved TMDLs and implementation measures necessary to implement the TMDLs.

Upon establishment of TMDLs by EPA or the State, the State is required to incorporate the TMDLs along with appropriate implementation measures into the State Water Quality Management Plan (40 CFR 130.6(c)(1), 130.7). The Regional Board Basin Plan and applicable statewide plans serve as the State Water Quality Management Plan governing the LALB waters. In general, TMDLs include the following seven elements:

- Problem Statement—a description of the waterbody setting, beneficial use(s) impairment of concern, and pollutants causing the impairment(s).
- Numeric Targets—for each pollutant addressed in the TMDL, appropriate measurable indicators and associated numeric target(s) based on numeric and/or narrative water quality standards that express the target or desired condition for the waterbody that will result in protection of the designated beneficial uses of the waterbody.
- Source Analysis—an assessment of relative contributions of pollutant sources or causes of the impairment.
- Loading Capacity/Linkage Analysis—a connection between the numeric targets and pollutant sources that yields calculations of the assimilative capacity of the waterbody for each pollutant.
- TMDL and Allocations—an expression of the total allowable pollutant loads divided between the sources through allocation to nonpoint sources (load allocations) and point sources (waste load allocations). The TMDL is defined as the sum of the allocations and cannot exceed the loading capacity for each pollutant.
- Margin of Safety—an explicit and/or implicit accounting of technical uncertainties in the TMDL analyses.
- Seasonal Variation/Critical Conditions—an account of how the TMDL addresses various flows and/or seasonal variations in pollutant loads and effects.

## Problem Identification

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The information presented in this section is intended to summarize much of what has already been presented in other documents. The LARWQCB's chapter of the Watershed Management Initiative (WMI) contains detailed information on the environmental setting and pollutant sources within the Dominguez Channel and Los Angeles/Long Beach Harbors Watershed Management Area (the full text of the WMI is available on the internet at: [http://www.waterboards.ca.gov/losangeles/html/programs/regional\\_programs.html#Watershed](http://www.waterboards.ca.gov/losangeles/html/programs/regional_programs.html#Watershed))

All of the waters of the LALB area ultimately drain to San Pedro Bay (SPB), an open coastal embayment situated on the southern coast of Los Angeles County (Figure 1). The Ports of Los Angeles and Long Beach were both established in the early 1900's and they make up the majority of the LALB complex. The primary freshwater, watershed-based pollutant, and sediment input to the Ports and SPB are the Dominguez Channel and the Los Angeles River. The Dominguez Channel watershed is approximately 260 square kilometers and is a highly urbanized watershed. The Los Angeles River (LAR) watershed is approximately 2,100 square kilometers and has a diverse land use composition, including significant open and forested land in the upper third of the watershed and the remainder composed of various highly urbanized land uses. It appears that flows and pollutant loads from the LAR influence conditions in San Pedro Bay and in the LALB Harbors, especially during high-flow events. The San Gabriel River also flows into SPB, approximately 5 miles east of where the LAR flows into the bay. Although the exact nature of how flows and pollutant loadings from the San Gabriel River affect conditions in SPB is unknown at this time, it is assumed that under certain conditions (i.e., south swell or storm events) both the hydrodynamics and water quality of SPB might be impacted.

The water quality concerns in the LALB complex are associated with a combination of past and present land use practices occurring in the basin. Some of the past pollutant sources are known (e.g., DDT from Montrose), although the extent of, and relative contribution to current conditions is less certain. A common practice in watershed and TMDL studies is the development of a conceptual model that is based on an understanding of the impairment and the associated dynamics between the designated use to be supported, the pollutants identified, the processes of source loading, and in-stream processes. A conceptual model should build on the understanding of what the impairment is, when the impairment occurs, and how the associated loading occurs or stressor affects the use. The conceptual model helps with developing an understanding of:

- **When** and under what environmental conditions does the impairment occur? (e.g., during a runoff event, during a dry, hot weather period). Understanding when the problem occurs leads to a determination of the critical environmental conditions defined by factors such as flow, temperature, or sunlight.
- **How** did the pollutant or related loading occur (e.g., legacy loading of toxics or pesticides, current loading of metals from storm water)? Understanding how the loading of the pollutant occurred also defines the types of sources that may ultimately contribute to the impairment (e.g., storm water runoff, point source discharges).

A gross level conceptual model is presented in Figure 2 to assist in the development of options for calculation of TMDLs for the listed waterbodies. A conceptual model should identify what are believed to be the primary sources of the pollutants and the relative magnitude of sources from the various transport pathways. Table 4 below summarizes the expected relative magnitude of pollutant loadings from different pollutant sources categories. In general, the following source categories are potentially contributing pollutants to waterways:



- Storm water runoff
- Sediment transported during runoff events
- Sediment within receiving waters mobilized and transported within the system
- Point sources
- Ground water
- Urban runoff (dry-weather)

In addition to identifying and articulating the important (major) pollutant transport pathways, the conceptual model should provide some guidance on the fate of the transported pollutants. This information will drive the decisions on identifying appropriate technical approach options.

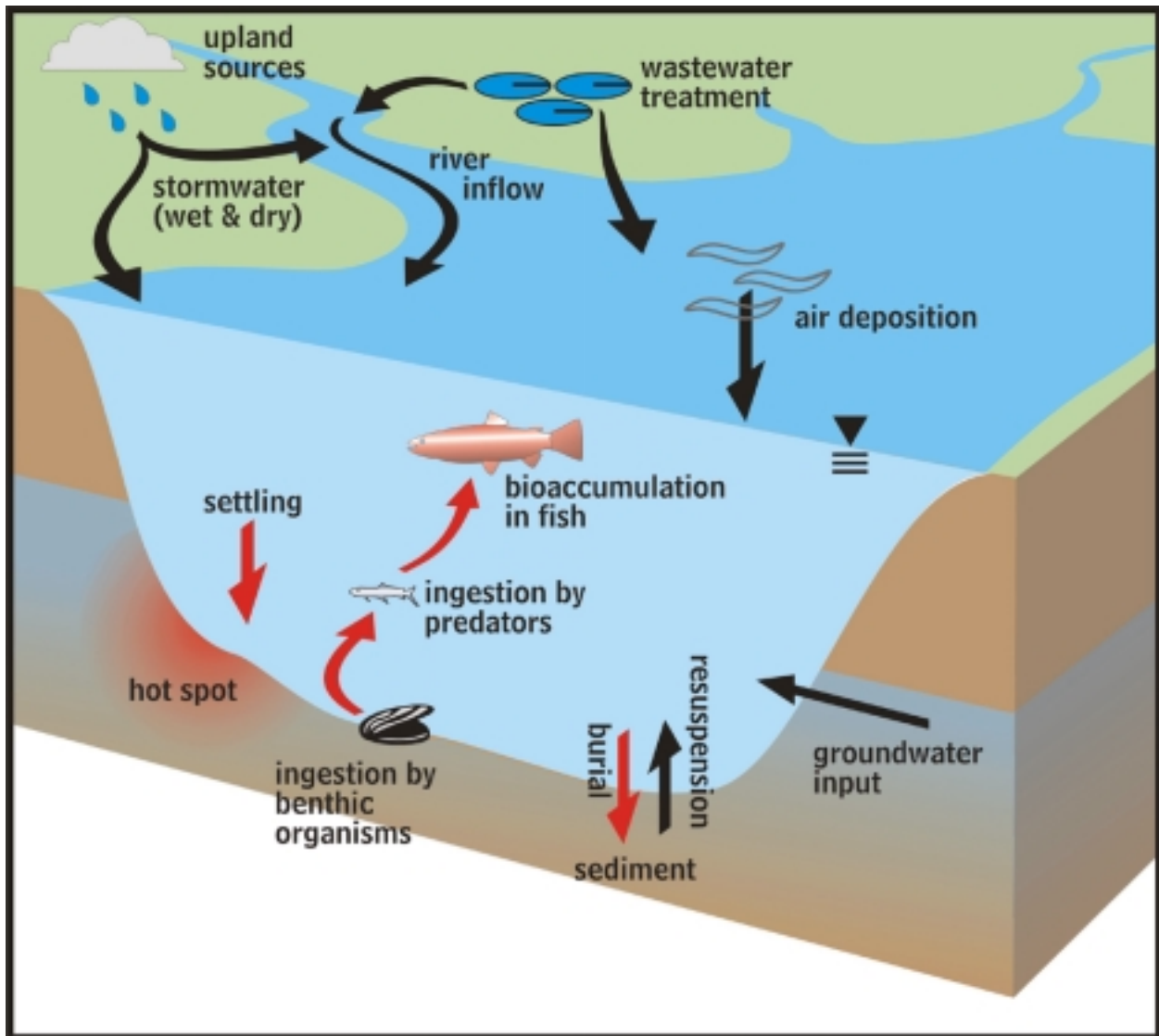


Figure 2. Generalized Conceptual Model of Pollutant Sources and Fate and Transport



## Numeric Targets

Numeric targets identify the specific water column, sediment, and/or tissue goals or endpoints for the TMDL that equate to attainment of the narrative and/or numeric water quality standards. In some cases, multiple indicators and associated numeric target values may be needed to interpret applicable water quality standards (e.g. where there is uncertainty that a single indicator is sufficient to measure protection of designated uses). In addition, some TMDLs may incorporate multiple numeric targets to account for differences in acceptable pollutant levels in a particular water body at different time scales (e.g., short term acute toxicity effects versus long term chronic exposure effects). Water quality standards are comprised of the designated beneficial uses made of water bodies, narrative and numeric water quality objectives, and anti-degradation policies. States may, but are not required to, formally adopted TMDL numeric targets as state water quality standards.

Impairments included on the 303(d) list for the LALB watersheds include several different pollutants, media, and waterbody types. Because the impairments found in the LALB system are associated with multiple environmental media (water column, sediment, and fish tissue), several sources of information are needed to develop candidate TMDL numeric targets. Table 2 presents a summary of listings for each pollutant and media (e.g., sediment, tissue, etc.). It is important to note that, with the exception of bacteria listings, none of the pollutants are associated with water column only. This fact has TMDL target implications because the available water quality objectives (EPA 2000a) for the metals and organics only apply to the water column and may not be appropriate as surrogate numeric targets for the sediment and fish tissue media.

**Table 2. Summary of Listings by Media**

Pollutant-Stressor	Number of Listings <sup>1</sup>		
	Based on Water Quality	Based on Sediment	Based on Tissue
<b><i>Bacteria Listings</i></b>			
Beach Closures	2		
Beach Closures (Coliform)	1		
High Coliform Count	5		
<b><i>Metals Listings</i></b>			
Cadmium (sediment)		1	
Chromium (sediment)		4	
Copper	3	3	1
Lead	2	2	2
Mercury		1	
Nickel		1	
Zinc		6	1
<b><i>Toxics Listings</i></b>			
Aldrin			2
ChemA <sup>2</sup>			3
Chlordane		2	4
DDT	5	6	7
Dieldrin			4
PAHs	2	6	1

	Number of Listings <sup>1</sup>		
PCBs	6	3	5
Sediment Toxicity		5	
Toxaphene			1

<sup>1</sup> Some listings are identified as 1 listing for “sediment and tissue.” For summary in this table, those listings were counted as 1 for “sediment” and 1 for “tissue.”

<sup>2</sup> ChemA refers to the sum of the chemicals aldrin, dieldrin, chlordane, endrin, heptachlor, heptachlor epoxide, HCH (including lindane), endosulfan, and toxaphene

Some of the listed pollutants in LALB have applicable water quality objectives (WQOs) established in the Basin Plan or through the California Toxics Rule (EPA 2000a). However, several pollutants do not have applicable numeric objectives (for any media) and appropriate targets must be identified for the TMDL. Table 3 presents sources of information to identify candidate WQOs or numeric targets when WQOs are not available or do not address the media of concern. These candidate targets require careful consideration but have been applied in other southern California waters impaired by the same pollutants. For sediment and fish tissue guidelines, there are several sources of information that provide selection guidance, including:

- Contaminated Sediment Task Force (<http://www.coastal.ca.gov/sediment/sdindex.html>), which was established by the California Coastal Commission and the LARWQCB. The CSTF has conducted LALB-specific research and has developed management strategies for addressing many of the issues associated with contaminated sediments.
- SWRCB Final Functional Equivalent Document (FED): *Water Quality Control Policy for Developing CA’s Clean Water Act Section 303(d) List* (September 2004). [http://www.waterboards.ca.gov/tmdl/303d\\_listing.html](http://www.waterboards.ca.gov/tmdl/303d_listing.html). This document includes a summary of possible guidelines for both sediment and fish tissue and includes references to the original studies.
- SWRCB is developing Sediment Quality Objectives for Enclosed Bays and Estuaries of California. <http://www.waterboards.ca.gov/bptcp/sediment.html>. Draft objectives and a state policy are expected by August 5, 2005.

**Table 3. Sources of Information to Identify and Select WQOs and Numeric Targets**

Listed Pollutant	Water Column	Sediment	Tissue
Bacteria	LA RWQCB Basin Plan	Not applicable	Not applicable
Metals and Toxics	California Toxics Rule (EPA 2000a)	Fairey et. al. 2001; MacDonald et. al. 1996; MacDonald et. al. 2000; Long and Morgan 1990; CASWRCB 2004	OEHHA, 1999; EPA 2000b,c; CASWRCB 2004

## Source Assessment

An understanding of pollutant loading sources and the amounts and timing of pollutant discharges is vital to the development of effective TMDLs. These TMDLs will require estimates of the amounts of pollutants entering the receiving water of concern or, in some cases, the amount of pollutant that is bioavailable based on historic loadings stored in the aquatic environment. These pollutant source estimates should be developed using available data and new data if available, and should be supplemented as necessary by past, ongoing, or future predictive modeling studies. Source loading estimates can be categorized in many ways, including but not limited to discharge source, land use category, ownership, pollutant production process (e.g. sedimentation processes), and/or tributary watershed areas. The conceptual model will provide a framework for developing working hypotheses of the major sources of each pollutant and the relative importance of their contribution to the overall pollutant load from the watershed. In general, pollutants in the LALB basin can be transported to or within a waterbody via one of the following pathways (additional or variants of these may exist as well and these should be considered as well):

- Overland flow (wet- or dry-weather)
  - Particulates attached to suspended sediment detached from the land surface (wet-weather)
  - Dissolved phase (wet-weather)
  - Dissolved phase (dry-weather)
- Transport within the receiving water
  - Sediment Diffusion/re-suspension
  - Uptake by biota
- Groundwater
- Atmospheric deposition (wet and dry) directly to receiving water surface
- Point Sources (permitted)
- Direct discharge (spills or other accidents)

For each pollutant listed in the LALB watershed, the pollutants can be assigned, based on their physical properties, to one or more of the transport pathways identified above (see Table 4). This table is based largely on the physical properties of these pollutants and their “typical” fate in the environment based on studies of pollutant sources in other watersheds. In some cases, these assumptions may be incorrect and would need to be corrected based on local information. Based on the information presented in Tables 2, 3, and 4, it is apparent that a significant component of these TMDLs will be developing an understanding the role sediment plays in these systems, both as a transport mechanism for the various pollutants and as the ultimate depositional location.

**Table 4. Potential Transport Pathways of the Pollutants in the LALB Watersheds**

Pollutant	Overland Flow		Receiving Water		Groundwater	Atmospheric Deposition	NPDES	
	Dissolved	Particulate	Sediment	Biota			Stormwater	Discharger
Bacteria	●	○	○		○		●	○
Cadmium	●	●	●	●	○	○	●	○
Chromium	●	●	●	●	○	○	●	○
Copper	●	●	●	●	○	○	●	○
Lead	●	●	●	●	○	○	●	○
Mercury	●	●	●	●	○	○	●	○
Nickel	●	●	●	●	○	○	●	○
Zinc	●	●	●	●	○	○	●	○

Pollutant	Overland Flow		Receiving Water		Groundwater	Atmospheric Deposition	NPDES	
	Dissolved	Particulate	Sediment	Biota			Stormwater	Discharger
Aldrin	○	●	●	●		○	●	
ChemA	○	●	●	●		○	●	
Chlordane	○	●	●	●		○	●	
DDT	○	●	●	●		○	●	
Dieldrin	○	●	●	●		○	●	
PAHs	○	●	●	●	○	○	●	
PCBs	○	●	●	●		○	●	○
Toxaphene	○	●	●	●		○	●	

●: Major potential pathway  
○: Minor potential pathway

Permitted discharges in the Dominguez Channel watershed include (LARWQCB, 2004a):

- Nine major NPDES discharges: one POTW, two generating stations, and five refineries; 48 minor discharges; 60 discharges covered by general permits
- 399 dischargers covered under an industrial storm water permit
- 134 dischargers covered under the construction storm water permit

About one-half of the 117 NPDES discharges to Dominguez Channel; the rest go to the LA/LB Harbor complex. Of the 399 dischargers enrolled under the general industrial storm water permit in the watershed, the largest numbers are located in the cities of Gardena, Wilmington, Torrance, and Carson, along Dominguez Channel. Trucking & warehousing, auto wrecking, and metal plating are a large component of these businesses. There are 134 sites enrolled under the construction storm water permit. The majority are along Dominguez Channel and are a mix of residential, industrial, and commercial sites; about one-half of the sites are five acres or larger or larger in size. The larger parcels of up to 500 acres in size are mostly located in the ports (LARWQCB, 2004a).

In addition to permitted discharges, other potential nonpoint sources exist. To determine the relative magnitudes of each pathway, as well as accounting for the timing of each, a review of available data will need to be conducted along with a review of literature on the subject. Once an understanding of the relative relationships among the sources, the magnitude and timing of their transport, and their ultimate fate in the system is determined, a suite of technical options is typically identified and used to determine the suite of available approaches. In general, the technical options should be in sync with the available data and the understanding of how the natural system works. For the LALB watersheds and receiving water systems, it is apparent that for most of the pollutants (Bacteria are an exception), an approach that can account for sediment movement and deposition through the system will be required.

Although there is substantial data available concerning pollutant contamination of harbor sediments (particularly in “hot spot” areas) and wet weather-related pollutant loads from some watershed areas, little data appear to be currently available to characterize pollutant loads during dry periods and from less-monitored areas of the watershed. Existing data sources should be carefully reviewed to better assess whether existing data are sufficient to characterize pollutant loads in different areas and under different hydrologic conditions. Data gaps should then be identified and modeling plans developed to fill these gaps to the extent feasible. The scope of follow-up monitoring needed to support these TMDLs is likely to be substantial.

## Approaches Applied In Other Southern California Watersheds

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In other southern California watersheds, separate modeling approaches have been applied to wet- and dry-weather conditions. Modeling of wet-weather conditions has been accomplished through development of a regional approach that utilizes land-use specific data collected throughout the region for model calibration, and additional data collected within modeled streams for further model testing and validation. Data collection has been performed through collaborations of Los Angeles County Department of Public Works (LACDPW) and SCCWRP, and included time series flow and water quality measurements. At various land-use specific sites located throughout the region, including high-density residential, low-density residential, commercial, agriculture, industrial, and open space sites, models were developed by SCCWRP using EPA's Hydrologic Simulation Program – Fortran (HSPF) (Bicknell et al., 1996) to develop modeling parameters specific to each land use and pollutant of concern (Ackerman et al., 2004). These calibrated parameters were then applied to models of impaired watersheds, and validated using local data. This approach was used for development of wet-weather metals TMDLs for Ballona Creek (LARWQCB, 2004b) and Los Angeles River (LARWQCB, 2004c), and is presently being applied to San Gabriel River. SCCWRP developed an HSPF model of Ballona Creek based on the regionally calibrated modeling parameters, and validated the model to in-stream data collected at a downstream location receiving runoff from approximately 74% of the watershed (Ackerman et al., 2004). To model the Los Angeles River, EPA's Loading Simulation Program C++ (a re-coded version of HSPF) (USEPA, 2003) was applied and validated based on data collected at multiple sites throughout the watershed (Tetra Tech, Inc, 2004a). An LSPC model is currently under development for San Gabriel River.

These models were used to simulated dynamic flows and metals concentrations over a 10-12 year period to provide analyses of variable conditions over the recent historic period. Model output were used to develop "load-duration curves" to facilitate comparison to TMDLs, based on numeric water quality targets, and calculate the necessary load reductions required from the watershed to meet these prescribed loads. Based on modeling analyses, source assessments were performed to guide implementation, including analyses of metals loading from each major land use in the watersheds (LARWQCB, 2004b & 2004c).

For wet-weather bacteria TMDLs, SCCWRP (Ackerman and Schiff, 2001) developed land-use specific HSPF modeling parameters to support TMDL development for Santa Monica Beaches. These modeling parameters have been utilized and validated successfully in similar TMDL modeling studies in southern California (SDRWQCB, 2004). Presently, the parameters are being used in an LSPC model of San Gabriel River to support TMDL development.

During dry weather, flows sustained in urban streams in the region are primarily the result of runoff from urban land uses (Stein and Tiefenthaler, 2004; Ackerman et al., 2003). Although studies have been performed that characterize flows and pollutant loads at the discharge of storm drains and within the streams during dry weather, detailed surveys that document sources of these flows to the storm water collection system have not been verified. Groundwater is likely a component to the in-stream base flows, but its relative contribution is small relative to the highly variable flows measured at storm drain discharges.

Ballona Creek is a 130-mi<sup>2</sup> highly urbanized bordering the northern edge of the Dominguez Channel watershed, and is the largest watershed draining to Santa Monica Bay (Ackerman et al., 2004). To support metals TMDL development for Ballona Creek and Ballona Creek Estuary, a detailed monitoring study was performed in the watershed during three dry days (Stein and Tiefenthaler, 2004). These data were used to develop a receiving water modeling system of Ballona Creek for analysis of dry weather conditions. This 2-dimensional modeling system was based on the U.S. Army Corps of Engineers' RMA2 (hydrodynamic) and RMA4 (water quality) models (USACE, 2000 and 2001), and was used to simulate total metals concentrations in the waterbodies during steady-state, low-flow conditions representative of average dry

weather conditions (Lai, 2004). This model serves two purposes: (1) it can serve as a foundation for future modeling work for Ballona Creek Estuary, and (2) it can be used as a management tool for assessment of alternative management schemes. Until future models are developed for the estuary, the technical approach for this TMDL did not require model simulation. Rather, analysis of empirical data was determined sufficient in developing a TMDL for Ballona Creek, Ballona Creek Estuary, and Sepulveda Canyon Channel.

For Los Angeles River, a 1-dimensional modeling system was developed to support metals TMDL development for dry-weather conditions (Tetra Tech, Inc, 2004b). The 1-dimensional version of the hydrodynamic model Environmental Fluid Dynamics Code (EFDC) (Hamrick, 1996) linked with the Water Quality Analysis Simulation Program (WASP) water quality model (Ambrose et al., 1991) were selected for the Los Angeles River application. To support model development, a comprehensive set of in-stream flow and water quality data were collected over two dry periods in summer 2000 and 2001. Flow and water quality measurements collected at tributary stations (headwater or confluence stations) were used as model input to represent the tributary discharges into the river main stem. Flow and water quality data collected at discharges from storm drains were used as model input to represent inflows from dry urban runoff. The resulting modeling system was calibrated under steady-state conditions. As with the Ballona Creek TMDL study, models were not used for TMDL calculation, but rather provide a management tool and the first step towards configuration of a comprehensive modeling system of both the river and estuary to address sediment impairments.

For San Gabriel River, a current study is underway for development of metals TMDLs. The dry-weather modeling approach is consistent with the steady-state models used for the Los Angeles River and Ballona Creek studies, based on linked EFDC and WASP models similar to the system applied to Los Angeles River. Consistency of approaches was determined important for technical validation of methodologies, and to encourage public understanding of methods based on education received in previous public workshops and reports for the Los Angeles River and Ballona Creek studies.

Currently, no estuary models have been developed in the region and used for TMDL calculation. A preliminary model was developed for the Ballona Creek Estuary by RWQCB staff based on RMA2 (hydrodynamics) and RMA4 (water quality), however, the estuary was determined to be stratified and therefore could not be accurately represented using the 2-dimensional framework of the modeling system. Also, the RMA4 modeling framework was incapable of simulating sediment bed and transport processes necessary for fully addressing and assessing the sediment impairments and the required load allocations to meet sediment TMDLs. The Port of Los Angeles (POLA) is currently developing a hydrodynamic and water quality model for the Dominguez Channel watershed. The project was recently initiated and the model selection process is ongoing. Preliminary information from POLA suggests that the candidate hydrodynamic models include CH3D, EFDC, and RMA10 and that the candidate water quality models include WASP6 and CE-QUAL-ICM/TOXI. At this point, other than the Dominguez Channel Estuary, the full spatial extent of the modeling to be conducted by the Port is unknown. Recent conversations with LARWQCB staff suggest that the POLA does not currently plan to extend the hydrodynamic portion of their modeling effort to include all of the LALB Harbor complex, including the Los Angeles River estuary and southern portions of San Pedro Bay (Personal Communication, Sam Unger, LA RWQCB, November 10, 2004).

Under the auspices of the U.S. Department of Energy, researchers at Lawrence Livermore National Laboratory (LLNL) and Lawrence Berkeley National Laboratory (LBNL) are currently developing two model applications for Dominguez Channel above Vermont that may assist in TMDL development. The first application is a HSPF model that estimates wet-weather flows and pollutant loads. The second application is a new coupled groundwater surface water model called CLM.PF (Maxwell and Miller, 2004). The CLM.PF model focuses upon water balances but may be capable of linking to pollutant loading models to be used to estimate watershed pollutant loads. Table 5 presents a summary of the current modeling efforts in the LALB

system [Preparer’s Note: Some of this information has not been confirmed by the agencies conducting the modeling].

**Table 5. Ongoing or Planned Modeling Efforts in the LALB System**

Model	Metals/Toxics/Bacteria			Los Angeles River and Estuary	San Gabriel River and Estuary
	Dominguez Channel	Dominguez Channel Estuary	Los Angeles Harbor Complex		
Dry-weather model for external loading to the LALB harbor	No efforts planned or underway	No efforts planned or underway	NA	Low flow model for metals and bacteria (EPA)	Low flow model for metals and bacteria (EPA)
Watershed model for wet-weather	HSPF (LLNL/LBNL)	No effort planned	NA	LSPC for metals and bacteria (EPA)	LSPC for metals and bacteria (EPA)
Coupled groundwater surface water model	CLM-PF (LLNL/LBNL)	None	None	None	None
Hydrodynamic model	NA	RMA10 by LA RWQCB; CH3D; EFDC, or RMA10 (POLA)		No efforts planned or underway	EFDC* (SCCWRP)
Sediment transport and deposition	?	RMA10 by LA RWQCB; CH3D; EFDC, or RMA10 (POLA)		?	EFDC* (SCCWRP)
Water quality model	HSPF by LLNL	RMA11 by LA RWQCB; CE-QUAL-ICM/TOXI; WASP6; or RMA11 (POLA)		LSPC (EPA)	WASP6* (SCCWRP)
Bioaccumulation model	?	?		?	?

EPA: US Environmental Protection Agency, Region 9 Water Division  
 LLNL: US Department of Energy, Lawrence Livermore National Lab  
 POLA: Port of Los Angeles  
 SCCWRP: Southern California Coastal Water Research Project  
 \*: Speculative  
 ?: Unknown  
 NA: Not applicable

### Options for the LALB Watersheds

The identification and selection of available approaches for TMDL development should consider the following factors:

- The pollutants and physical processes of interest (e.g., bacteria during wet-weather, sediment transport and deposition, or eutrophication).
- The spatial extent of the system to be assessed (e.g., the entire LALB watershed versus the Dominguez Channel watershed or anything between).
- The availability of data commensurate with the model complexity
- Proven success of the approaches and models in similar systems and/or similar pollutants

Other factors include the level of expertise available to design and implement the modeling approach, whether the model has been peer-reviewed or is proprietary, and the resources available to support the effort.

For all watersheds in the LALB basin, the HSPF/LSPC models or models of comparable sophistication will likely be sufficient for modeling watershed loadings of the listed pollutants to the receiving water systems. There is also a wet-weather LSPC model of the Los Angeles River (above the estuary) for metals and



bacteria. It is unclear whether the CLM.PM model currently being developed will be suitable for supporting TMDLs in the LALB area because it is currently under development and has not yet been linked with pollutant loading models. No other wet-weather watershed modeling efforts were identified for any pollutant. Also, it is not clear if the land surrounding each listed waterbody will require a separate watershed modeling effort. The TMDL development effort should include investigation of whether the impairments for metals and toxics in the Los Angeles Harbor Main Channel or the LA Fish Harbor are caused by pollutants generated in the adjacent land areas or transported from other waters upstream (or downstream) of the impairments. These issues will require review of available data before determining the appropriate approach.

For dry-weather TMDLs, the only modeling work conducted to date has been the modeling of bacteria and metals for the Los Angeles River (above the estuary). No other ongoing or planned modeling studies were identified. Unless compelling technical rationale is presented that identifies a better approach for dry-weather modeling, it is recommended that the same approach used for the LA River, Ballona, and San Gabriel be applied where appropriate in the LALB basin (e.g., Dominguez Channel above Vermont Avenue). This approach would rely more on evaluation of empirical data than on modeled estimates of dry weather pollutant loads.

## Linkage Analysis

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The loading capacity is the critical quantitative link between the applicable water quality standards (as interpreted through numeric targets) and the TMDL. The loading capacity reflects the maximum amount of a pollutant that may be delivered to the water body and still achieve water quality standards. The linkage analysis investigates the relationship between pollutant loadings and water quality effects in order to calculate loading capacities for each pollutant and water body. The loading capacity sections discuss the methods and data used to estimate loading capacity. A range of methods is available to derive the loading capacities for the various pollutants, including predictive water quality models and linkage methods based principally on data analysis.

Different options are available for modeling the LALB system to address metals and toxics impairments of the sediments. Hydrodynamic models already under development in the Dominguez estuary are available with both 2- dimensional and 3-dimensional capabilities. These hydrodynamic models must be linked to water quality models for simulation of pollutant transport and loading to sediments. The water quality modeling approach should possess the ability to simulate sediment bed accumulation and concentration to address the impairments.

### Hydrodynamics

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Surface water flow is fundamental to the simulation of pollutant transport and transformation in waterbodies. Some of the key physical factors affecting the health of a waterbody include the quantity and velocity of flow. Hydrodynamic models simulate the dynamic or time-varying features of water transport. For estuarine systems, mixing and flushing due to tidal influences and external freshwater inputs are essential to understanding internal processes. Hydrodynamic models can potentially represent the features of water movement in rivers, streams, lakes, reservoirs, estuaries, near-coastal waters, and wetland systems. Depending on the type of system and the model capabilities, spatial dimensions of the simulation can include 1-D longitudinal, 2-D in the vertical, 2-D in the horizontal or fully 3-D formulations. Some 3-D models can be effectively collapsed to simulate systems as 1-D or 2-D. Physical processes that may be included in hydrodynamic models include tidal, wind, and buoyancy or density forcing, and turbulent momentum and mass transport.

Some hydrodynamic models (RIVMOD, DYNHYD5, EFDC, CH3D-WES) are distributed as stand-alone models and can be externally coupled with water quality models such as WASP6 and CE-QUAL-ICM. Other hydrodynamic models are internally coupled, or connected, to the water quality and toxic simulation programs. For river modeling, a 1-D formulation is usually sufficient, although for certain applications (e.g., sediment transport) 2-D horizontal models have been used. Modeling of lakes is typically limited to 2-D vertical (x/z) models except in rare cases, such as shallow, well-mixed lakes, where a 1-D representation is sufficient. Estuaries are most frequently simulated using fully 3-D hydrodynamic grids to account for the complex mixing and transport processes.

Several hydrodynamic models have been identified for use in the LALB watershed. They include CH3D, EFDC, and RM10. Each can simulate the 3-D hydrodynamics and sediment transport likely to be needed for the listed waters. The strengths and limitations of these models are presented in Table 6.

The following models have been identified as options for simulating hydrodynamics and contaminant transport for the LALB system. These models have been selected based on historic success in modeling of similar systems, prior (or proposed) applications to the LALB system, and suitability of model capabilities to address key processes identified as important to pollutant transport and fate.

## **CH3D**

The Curvilinear Hydrodynamic-3D (CH3D-WES) model was developed and is maintained by the U.S. Army Engineer Research and Development Center (ERDC) (<http://sandbar.wes.army.mil/>) (formerly known as the Waterways Experiment Station (WES)). Currently, the model must be obtained directly from the ERDC as the model is continuously under development. A recently developed bed and suspended sediment transport model (CH3D-SED) has also recently been developed.

### **Hydrodynamics**

The CH3D-WES model employs a general curvilinear grid in the horizontal and can be applied in both two and three-dimensional modes. For three-dimensional applications both Cartesian and stretched vertical grid versions are available. The hydrodynamic model solves the depth averaged Reynolds approximation of the momentum equation for velocity, and the depth averaged conservation of mass equation for water surface elevation. The three-dimensional velocity field is determined by computing the deviation from the depth averaged velocity by solving the conservation of mass equation in conjunction with a k-e closure for vertical momentum diffusion.

### **Sediment/Contaminant Transport**

The newly developed mobile bed version CH3D-SED is capable of simulating the movement of sediment as either bed load or suspended load, as well as the exchange of sediment between these two modes of transport. The CH3D-SED hydrodynamic and sediment transport model is based on an extension of the stretched vertical coordinate version of the CH3D-SED by Spasojevic and Holly (1997) to include cohesive sediment transport. The model is capable of two or three-dimensional operation and employs standard formulations for settling, deposition, and resuspension.

## **EFDC**

The Environmental Fluid Dynamics Code (EFDC) is maintained by the USEPA's Office of Research and Development (ORD) and is available for download at <http://www.epa.gov/athens/wwqtsc/html/efdc.html>.

### **Hydrodynamics**

The EFDC (Environmental Fluid Dynamics Code) model (Hamrick, 1992a, 1997a) hydrodynamic component uses a 3-D finite difference spatial representation and is capable of reduced dimension execution in one-dimensional network and two-dimensional (horizontal or vertical plane) modes. Salinity and temperature transport are included in the model. The EFDC model has been applied extensively for circulation, discharge dilution, and water quality-eutrophication studies (Hamrick, 1992b, Hamrick and Mills, 2000; Jin et al., 2000; Tetra Tech, 1994,1995,1998). The model has also been applied for estuarine cohesive sediment transport simulation (Yang, 1996) and coastal noncohesive sediment transport (Zarillo and Surak, 1995) and the transport of heavy metals and organic contaminants (Schock and Hamrick, 1998).

## **Sediment/Contaminant Transport**

The EFDC (Hamrick, 1992a, 1997a) model's sediment transport component simulates a user-specified number of size classes of cohesive and noncohesive sediment in 1, 2, or 3 dimensions. Sediment settling is represented by concentration and ambient-flow-turbulence-dependent formulations to represent hindered settling of noncohesive sediment and approximately represent aggregation and disaggregation of cohesive sediment. Water column-bed sediment and sorbed contaminant exchange is represented by deposition and erosion fluxes. For noncohesive sediment, the net flux is represented as dependent on the bed stress, the near bottom and bed surface sediment concentration, and the critical Shield's parameter. For cohesive sediment, deposition and erosion fluxes are dependent on the bed stress, critical deposition and erosion stresses, and the shear strength of the bed. The sediment bed is represented by a time varying number of layers. Sediment in each layer is characterized by mass per unit area, void ratio and shear strength. The void ratio of the layers is specified or determined by a bed consolidation model with shear strength being determined as a function of void ratio. Vertical transport of sediment and sorbed contaminants between bed layers is implicitly represented by sediment particle displacement in response to layer thickness variations dynamically determined by the consolidation model. The model has also been applied for estuarine cohesive sediment transport simulation (Shock and Hamrick, 1996; Yang, 1996) and coastal noncohesive sediment transport (Zarillo and Surak, 1995) and riverine sediment transport (ji et al., 2000).

## **RMA10/RMA11**

The Resources Management Associates (RMA) has supported the ERDC in development of a multiple dimension hydrodynamic and sediment transport model. This model is proprietary and can be purchased from a vender. Special agreement may be made with the ERDC for use, however, transfer of the model to multiple users for peer review or public distribution would be limited because the model is reserved for use a ERDC or USACE field offices, and has not been released to the public. For more information, visit <http://chl.erd.c.usace.army.mil/CHL.aspx?p=s&a=ARTICLES;417> (accessed 10/04).

## **Hydrodynamics**

Hydrodynamics is simulated with the RMA10 finite element based three-dimensional hydrodynamic model developed by Resource Management Associates. RMA10 is a multi-dimensional (combining 1-D, 2-D either depth or laterally averaged, and 3-D elements) finite element numerical model written in FORTRAN-77. It is capable of steady or dynamic simulation of three dimensional hydrodynamics, salinity, and sediment transport. It utilizes an unstructured grid and uses a Galerkin based finite element numerical scheme. The model includes salinity transport and a turbulence closure scheme.

**Table 6. Hydrodynamic and Sediment/Contaminant Transport Models**

Modeling System	3-D	Sediment Bed	Strengths	Limitations
CH3D	√	√	<ul style="list-style-type: none"> <li>• CH3D has been successfully applied by the Corps of Engineers for assessment of sediment transport in the LA harbor system. Associated model grids and model parameters have been previously established</li> <li>• Includes higher order turbulence closure scheme for accurate representation of the mixing process.</li> <li>• Salinity and temperature transport are included in the model.</li> </ul>	<ul style="list-style-type: none"> <li>• Previous U.S. Corp of Engineers applications must be resurrected and modified for simulation of the entire spatial domain and linkage to water quality models.</li> <li>• Model must be linked to separate water quality models for simulation of sediment bed toxicity. Previous successful link to CE-QUAL-ICM</li> <li>• Model is semi-proprietary. Access to the model and code may be limited an reliant upon the availability of USCOE staff to access the model. Model and code may not be available for placement in TMDL administrative records.</li> </ul>
EFDC	√	√	<ul style="list-style-type: none"> <li>• Simulates hydrodynamics, sediment, and contaminant transport within a single modeling framework. EFDC can also function as a 2-D depth averaged model if simplification is required.</li> <li>• Includes higher order turbulence closure scheme for accurate representation of the mixing process.</li> <li>• Salinity and temperature transport are included in the model.</li> <li>• Previously developed model grids of the harbor system (based on CH3D) can be utilized for EFDC model configuration and the model can be readily linked to separate water quality models</li> <li>• Model and code are publicly available and maintained by USEPA.</li> </ul>	<ul style="list-style-type: none"> <li>• Potentially long computation time for detailed simulations, depending on number on cells and processes defined.</li> </ul>
RMA10 & RMA11	√	√	<ul style="list-style-type: none"> <li>• Includes salinity transport and a turbulence closure scheme.</li> <li>• RMA10 can also function as a 2-D depth averaged model if simplification is required.</li> </ul>	<ul style="list-style-type: none"> <li>• Two separate models must be linked for simulation of hydrodynamics and sediment/contaminant transport.</li> <li>• Detailed documentation describing RMA11's sediment formulations are not available, and the model applications for sediment transport have not been reported in the open literature. RMA 11's ability to characterize pollutant flux between sediment and water column are limited</li> <li>• The finite element formulation of the RMA models can result in problems conserving mass in a 2-D or 3-D system</li> <li>• RMA models are proprietary and must be licensed. Model and code may not be available for placement in TMDL administrative records.</li> </ul>

## **Sediment/Contaminant Transport**

The RMA11 sediment transport model (King, 1995; King and DeGeorge, 1996) is a three-dimensional finite element model that can also function as a two dimensional depth averaged model. The sediment transport component of RMA11 is based on process representations from the STUDH sediment transport model (Ariathurai and Krone, 1976). Detailed documentation describing RMA11's sediment formulations are not available, and the model applications for sediment transport have not been reported in the open literature.

## **Water Quality and Sediment Deposition**

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Water quality models can simulate the chemical and biological processes that occur within a waterbody system, based on external and internal inputs and reactions. Eutrophication models include those that simulate biological inputs, nutrients, and algal growth in rivers, streams, lakes, reservoirs, and estuaries. Other receiving water models specialize in the simulation of toxic constituents and their transformation and degradation in waterbodies. Water quality models can also be grouped by how they address changes over time. As mentioned above, some models employ a steady-state formulation for simulation purposes. Typical steady-state applications include use of design flow, or preselected critical conditions, for the assessment of steady-state water quality impacts. Steady-state formulations are the most commonly used and the easiest to implement. However, steady-state applications are limited when addressing time-variable inputs such as nonpoint source loads or examining waterbodies that experience short-term violations of acute criteria (e.g., storm or CSO events).

For more detailed assessments of time-varying conditions in receiving waters, water quality models can be linked with hydrodynamic models. The use of dynamic water quality models allows for a more detailed evaluation of time-varying inputs, such as nonpoint sources, and the examination of the short- and longer-term receiving water response. Fully dynamic applications require a significant level of effort to prepare data input files; set up, calibrate, and validate the model; and process output data. Dynamic models can also be applied to steady-state conditions. In some cases, because of their detailed algorithms and capabilities, dynamic models are used in steady-state applications for testing and analysis of constituent interactions.

In addition to the physical/hydrologic essentials discussed above, the principal differentiating factors for characterizing water quality models is how they address the processes of advection, dispersion, and reaction. Advection is the primary transport mechanism in a downstream and/or lateral direction. Advective transport is often the dominant net transport mechanism, except in certain tidally mixed systems. Dispersive transport represents mixing (lateral and longitudinal) caused by local velocity gradients. Although dispersive transport is present to some extent in all bodies of water, it is typically minimal in rivers, lakes, and reservoirs. Dispersive transport can dominate, however, in tidally mixed systems. Reactions include the processes and transformation of constituents within a waterbody. For assessment of toxics, models can include transformation, speciation, and degradation of constituents. For toxics, the interactions of constituents with the bottom sediments are of concern. In some cases users can define fluxes from the bottom sediments. Other models use sophisticated simulations of sediment diagenesis.

Hydrodynamic and contaminant transport models may be suitable for simulation of contaminant concentrations of the water column of the LBLA system. However, to address the ultimate fate of those contaminants in sediments and resulting impairments related to sediment toxicity, simulation of the sediment quality may be determined necessary that require linkages to separate water quality models. The following discussions outline water quality models that can be linked to the 3-dimensional hydrodynamic models for simulation of sediment quality. Table 7 provides a comparison of the water quality models outlined.

## **CE-QUAL-ICM/TOXI**

CE-QUAL-ICM/TOXI is maintained by the ERDC and is available for download by USACE only (<http://www.wes.army.mil/el/elmodels/index.html#wqmodels>).

The ICM/TOXI model is the toxic chemical model with routines from EPA's WASP (Water Analysis Simulation Program). The CE-QUAL-ICM/TOXI model utilizes the arbitrarily linked control volume formulation and data structure of the CE-QUAL-ICM (Cercio and Cole, 1993) water quality model. The model is capable of operation in two or three dimensions and requires advective and diffusive transport as well as bed stress from an external hydrodynamic model. The model includes standard bed stress dependent deposition and resuspension formulation. The model uses a multiple layer bed formulation with layers added and removed in response to deposition and resuspension.

CE-QUAL-ICM/TOXI requires an external hydrodynamic model to supply flow and shear stress information for sediment or contaminant transport simulation. Such compatible hydrodynamic models include CH3D-WES and EFDC.

## **RMA11**

There are currently no capabilities for simulation of sediment quality within the three-dimensional RMA models. Furthermore, no successful linkages to separate sediment quality models are currently known. As a result, water quality simulation using RMA11 would be limited to the water column concentrations, with assumptions for fluxes of contaminants to/from the sediments based on modeling assumptions. RMA 11 is a proprietary model that must be licensed; therefore, it may not be possible to freely distribute the model to interested stakeholders.

## **WASP/TOXI**

WASP6 is maintained by USEPA and is available for download at the ORD's website, in addition to documentation, at <http://www.epa.gov/athens/wwqtsc/html/wasp.html>.

WASP is a generalized modeling framework based on finite-volume concept for quantifying fate and transport of water quality variables in surface waters. The model consists of three components: WASP for mass transport, EUTRO for DO, nutrients, and algal kinetics, and TOXI for toxic substance. It is capable of analyzing time-variable or steady state, 1-D, 2-D, or 3-D water quality problems. TOXI5, the sediment transport module of WASP6, simulates the transport and transformation of up to three organic chemicals and one to three types of solids classes. TOXI5 performs a simple mass balance on each solid variable in each compartment based upon specified water column advection and dispersion rates, along with special settling, deposition, erosion, burial, and bed load rates. WASP/TOXI requires an external hydrodynamic model to supply flow and shear stress information for sediment or contaminant transport simulation. EFDC is a compatible hydrodynamic model.



**Table 7. Water Quality Models for Simulation of Fate of Contaminants in Sediments**

Modeling System	3-D	Sediment Quality	Strengths	Limitations
CE-QUAL-ICM/TOXI	√	√	<ul style="list-style-type: none"> <li>• ICM/TOXI, though based on WASP, is a more detailed benthic sediment model and has enhanced linkages to sediment transport models</li> <li>• The unstructured, finite volume structure of the model facilitates linkage to a variety of hydrodynamic models.</li> <li>• The ICM/TOXI model has toxic chemical routines, which further enhance linkage with sediment transport models.</li> <li>• The control volume structure of promises the conservation of mass.</li> <li>• Can be linked to CH3D-WES and EFDC models for hydrodynamics</li> </ul>	<ul style="list-style-type: none"> <li>• CE-QUAL-ICM/TOXI is still under development by the U. S. Army Corp of Engineers Waterways Experiment Station and its availability is limited.</li> <li>• CE-QUAL-ICM/TOXI requires an external hydrodynamic model to supply flow and shear stress information for sediment or contaminant transport simulation.</li> </ul>
RMA11	√			<ul style="list-style-type: none"> <li>• Lacks capabilities for simulation of sediment quality</li> <li>• Model is proprietary and must be licensed</li> </ul>
WASP/TOXI	√	√	<ul style="list-style-type: none"> <li>• The WASP model is a very flexible modeling framework and it can simulate water quality in 1-D, 2-D, and 3-D space.</li> <li>• The control volume structure promises the conservation of mass.</li> <li>• The unstructured, finite volume structure of the model facilitates linkage to a variety of hydrodynamic models.</li> <li>• The TOXI model has toxic chemical routines, which further enhance linkage with sediment transport models.</li> <li>• TOXI5 is reasonably general. Users may develop new kinetic or reactive structures.</li> <li>• Can be linked to CH3D-WES and EFDC models for hydrodynamics</li> <li>• Models are publicly available and maintained by USEPA</li> </ul>	<ul style="list-style-type: none"> <li>• TOXI5 sediment transport processes are simply based on parameterization of settling and resuspension process. It is not simulated based on shear stress condition, thus it is not predictive. Requires linkage to separate sediment transport model for more detailed simulation.</li> <li>• WASP/TOXI requires an external hydrodynamic model to supply flow and shear stress information for sediment or contaminant transport simulation.</li> </ul>

## Receiving Water Approach Options

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To address pollutant impairments in the LALB system, a 3-dimensional hydrodynamic and water quality model is recommended. Several appropriate models have been identified for possible use by the POLA in addressing the Dominguez Channel Estuary modeling effort. These models include EFDC, CH3D, and RMA10 for hydrodynamics and WASP and CE-QUAL-ICM/TOXI for water quality. Each of these models have the capability to accept flow and pollutant concentration data from the HSPF/LSPC watershed models.

Several key factors must be confronted when determining the appropriate combination of hydrodynamic and water quality models. These include:

- The spatial extent of the system to be assessed (e.g., all of San Pedro Bay; the Dominguez Channel estuary or anything between).
- The data available to characterize watershed sources, currents within the system, and pollutant sources within the receiving water
- Resources available to conduct the study
- Degree of continued public access to models used for TMDL development

The recommended spatial extent of the modeling can be different for the hydrodynamic and water quality components of the receiving water modeling. The most efficient means of conducting the hydrodynamic model would be to develop a model grid that covers all of San Pedro Bay, the waters of the Ports of LA and Long Beach, and extends into the estuarine portions of the Los Angeles River and Dominguez Channel (and other estuarine areas as appropriate). The development of a single hydrodynamic model, assuming sufficient data are available on currents, tides, and flows from the watershed, would provide an efficient platform for the water quality modeling, even if the water quality component were done on a listing-specific basis. This approach would have several advantages, including the use of a single model for all waters and efficiencies in development, training, and updating as new data are collected.

For water quality, it would be possible to select and apply a comprehensive water quality model that addresses all waters and pollutants of concern in the system. However it may not be most efficient to conduct the modeling for the entire system at one time. Efficiencies could instead be recognized by designing technical approaches for waterbody and pollutant categories (e.g., estuary/metals, stream/toxics) and applying the approach to all waters where it is appropriate. This would ensure that the methodology was transferable across the basin and would permit “data-rich” areas to apply the approach first and to provide “lessons learned” to subsequent efforts. The planned effort for the Dominguez Channel estuary could serve as an approach template for other efforts, assuming the approach is defined and made available for review by others, including other stakeholders, the Regional Board, etc.

## Development of TMDLs and Allocations

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TMDLs are normally set equivalent to or somewhat lower than the pollutant loading capacity estimated through data and modeling analysis. Federal regulations require the inclusion of a “margin of safety” in TMDLs to account for analytical uncertainties; this margin of safety may be provided through inclusion of implicit conservative analytical assumptions and/or by deciding not to allocate all available loading capacity to existing pollutant sources.

TMDLs are divided among existing (and potentially future) loading sources through an allocation process. Point sources regulated under the NPDES program receive wasteload allocations; nonpoint sources receive load allocations. The sum of wasteload and load allocations may not exceed the TMDL.

Several approaches have been taken to set TMDLs and associated allocations for waters in Southern California. Many pollutants of concern in the LALB area (e.g. DDT, PCBs, other bioaccumulative pollutants, and some metals) are associated with sediments and cause adverse effects through long term loading and exposures (e.g. fish consumption effects). TMDLs and allocations for these types of pollutants are normally set in terms of long term mass loading levels. Other pollutants of concern (e.g. bacteria and some metals) are associated more with water column exposures of shorter duration. TMDLs and allocations for these types of pollutants are normally set in terms of short-term mass loading and/or concentration levels.

TMDLs and allocations often vary seasonally or under different flow conditions depending upon whether the loadings and water body effects are associated with wet or dry weather conditions. Moreover, the geographical scale at which TMDLs and individual allocations are set vary depending upon the nature of the impairment and characteristics of loading sources. Discrete point sources receive individual allocations. Diffuse pollutant sources associated with large areas drained by stormdrain systems or nonpoint sources often receive allocations that apply to larger land and drainage areas because it is difficult to calculate and apply the allocations at finer scales. Because the LALB area is geographically complex and the pollutants and effects of concern in the LALB area are varied, TMDL developers will need to determine the appropriate mix of TMDL calculation approaches to best address the pollutants, sources, and geographical scales of concern in the LALB area.

The State and EPA work with stakeholders to weigh many factors in setting wasteload and load allocations. Normally, the key factors considered in the allocation process are the:

- Technical feasibility of achieving different pollutant reduction levels from different sources
- Absolute and relative costs of implementing controls
- Existing control actions and requirements of other programs
- Proximity of loading sources to areas of pollutant effect
- Degree of assurance that needed pollutant reductions will occur

Watershed, hydrologic, and linkage models are often helpful in the allocation process because they assist in evaluating whether different mixes of pollutant reductions from sources located at different watershed locations will result in attainment of the numeric targets and hence the water quality standards. These allocations are often developed through an iterative process in which the State, EPA, and members of the public identify and test allocation options.

The allocation process usually involves the use of professional judgment to weigh competing goals in the allocation process. Under the auspices of the U.S. Department of Energy, researchers at LLNL are currently developing a “Stakeholder Value Model” to assist in evaluating various stakeholder and agency interests in

the TMDL allocation process (Stewart, 2004). This model may assist the State and EPA in working with stakeholders to identify such interests and to identify allocation options that best address the combined interests of agency and stakeholder groups.

The State of California is required to evaluate cost implications of TMDL and allocation decisions. Staff at the State and Regional Water Quality Control Boards usually conduct these analyses, often assisted by analysis conducted by dischargers and other interested parties. The U.S. Department of Energy is currently developing a TMDL Allocation Model to assist in evaluating different allocation strategies and the costs associated with allocation options. This model may assist in allocation decision making for the LALB area TMDLs.

Pursuant to State requirements, TMDLs in California are normally accompanied by detailed implementation plans that guide:

- The implementation of needed controls through different programs
- Follow-up monitoring and modeling studies that further evaluate issues and options raised in the TMDL
- TMDL review and revision in the future

The specific institutional mechanisms for working with and considering input from stakeholder groups in developing the LALB area TMDLs and implementation plans should be carefully identified early in the TMDL process in order to ensure that interested parties understand how the TMDLs will be developed and how they will be involved in the development process.

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## **Appendix A: Summaries of National Efforts with Similar Issues**

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# PCB TMDL for Delaware Estuary, Delaware, New Jersey and Pennsylvania

Approved December 2003

## Background

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Tidal portions of the Delaware River (Delaware Estuary) are included in Delaware, New Jersey and Pennsylvania. The estuary is designated as Zones 2 through 5 by the Delaware River Basin Commission (DRBC) and extends from Trenton, NJ, to the head of Delaware Bay. The TMDL for the estuary for PCBs is developed as a Stage 1 TMDL, to be enhanced (for Stage 2) based on information to be collected and analyzed over the next few years. The Stage 1 and Stage 2 TMDLs provide for adaptive implementation through execution of load reduction strategies while additional monitoring and modeling efforts proceed.

At the request of the states and EPA, the DRBC took the lead in developing the technical basis for the estuary PCB TMDLs, in consultation with its Toxics Advisory Committee (TAC), comprised of representatives from the states, EPA Regions 2 and 3, municipal and industrial dischargers, academia, agriculture, public health, environmental organizations and fish and wildlife interests. The DRBC established a panel of scientists expert in the modeling of hydrophobic contaminants such as PCBs to advise it and the TAC on the development of the complex hydrodynamic and water quality model required to develop the TMDLs. The DRBC also initiated an extensive program of scientific investigations and data collection efforts.

In consultation with the TAC, the DRBC staff and the Delaware Estuary Program developed a strategy to address contamination of the Delaware Estuary by PCBs (the PCB Strategy). The PCB Strategy includes the following nine components: (1) determination of the water quality targets for PCBs; (2) characterization of PCB concentrations in the estuary ecosystem; (3) identification and quantification of all point and nonpoint sources and pathways of PCBs; (4) determination of the transport and fate of PCB loads to the estuary; (5) calculation of the TMDLs, including the wasteload and load allocations required for a TMDL; (6) development of an implementation plan to reduce PCBs entering the estuary; (7) initiation of an effort to increase public awareness of toxicity issues in the estuary; (8) long-term monitoring of PCB concentrations in air, water and sediments of the estuary; and (9) long-term monitoring of PCB concentrations in living resources of the estuary and impacts upon living resources of the estuary. In a cooperative effort, EPA, the DRBC, the states, municipal and industrial dischargers and other stakeholders, have now completed the PCB Strategy components necessary for issuance of the TMDLs.

## 303(d) Listing Information

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Delaware Estuary is included on 303(d) lists in Delaware, New Jersey and Pennsylvania based on elevated levels of PCBs in fish tissue.

## TMDL Targets

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Applicable DRBC water quality criteria are summarized in Table 8.

**Table 8. DRBC Water Quality Criteria for Zones 2 to 5 of the Delaware Estuary**

Estuary Zone	Exposure Route	
	Water & Fish Consumption	Fish Consumption Only
Zone 2 & 3	44.4 picograms per liter	
Zone 4 and upper Zone 5		44.8 picograms per liter
Lower Zone 5		7.9 picograms per liter

Water quality criteria for toxic pollutants, including Total PCBs, differ between the zones of the estuary depending on the designated uses of the zone. In Zones 2 and 3, use of the water for public water supply after reasonable treatment is a designated use. In these two zones, human health criteria are based upon exposure to PCBs through ingestion of water and fish taken from these estuary zones. In Zone 4 and upper Zone 5 (above River Mile 68.75), use of the water for public water supply is not a designated use. In these two zones, human health criteria are based solely upon exposure to PCBs through ingestion of fish taken from these estuary zones. Current DRBC criteria assume a consumption rate of 6.5 grams per day (~½ pound meal every 35 days) is used in Zones 2, 3, 4, and the upper portion of Zone 5. This rate was the default national rate for freshwater fish consumption utilized in EPA’s 1980 methodology for deriving human health criteria, and was used by the States in developing their freshwater water quality criteria. A consumption rate of 37.0 grams per day (~½ pound meal every 6 days) is used in the lower portion of Zone 5. This consumption rate is consistent with the rate utilized by the State of Delaware following a recent evaluation of available information on consumption rates.

### Technical Approach

DRBC developed and calibrated a water quality model for only one of the PCB homologs and used it to develop a set of TMDLs from which TMDLs for total PCBs were extrapolated. Since pentachlorobiphenyls (penta-PCBs) were the dominant homolog in fish tissue monitored in the estuary, and since ambient data indicated that throughout the estuary this homolog represents approximately 25 percent of the total PCBs present, the penta-PCBs were selected. Therefore, the Stage 1 TMDLs, WLAs and LAs for total PCBs were extrapolated, using a factor of 4 to 1, from TMDLs and allocations developed for penta-PCBs.

The TMDLs were calculated using both a conservative chemical model (TOXI5) and a penta-PCB water quality model run until equilibrium was observed. This procedure was used because hydrophobic contaminants like PCBs sorb to particulates and interact significantly with the sediments of the estuary. Sediments respond more slowly than the water column to changes in PCB concentrations in either medium, and allowing the water column and sediments to come into equilibrium is necessary to ensure that water quality criteria are met.

A modified version of the TOXI5 water quality model was used. Both models utilized outputs from a DYNHYD5 hydrodynamic model and cycled inputs for a one-year period representative of long-term hydrologic conditions.

Penta-PCB TMDLs were calculated in a four-step procedure, as follows:

1. Calculate the contribution factor (CF) for each of the estuary zones and two of the tributary model boundaries to that critical location in Zone 5 where the criterion of 7.9 picograms per liter (approximately 2.0 picograms per liter of penta-PCBs) is controlling.
2. Calculate the allowable loadings from each of these sources that will still ensure that the water quality target is met at the critical location utilizing the CF and the proportion of the assimilative capacity at the critical location allocated to each source. Iteratively determine the amount of

assimilative capacity (in picograms per liter) provided by the sediments, and add this concentration to the penta- PCB water quality target. Recalculate the allowable loadings from each of the six sources using this revised water quality target.

3. Utilize the water quality model for penta-PCBs with these allowable loadings to confirm that the sediment concentrations have reached pseudo-steady state, and confirm that the penta-PCB water quality target is met in Zones 2 through 5.
4. Estimate the gas phase concentrations that would be in equilibrium with the penta-PCB water concentrations when the water quality targets are met, include these in the water quality model, and then iteratively adjust the gas phase concentration of penta-PCBs in the air until the water quality target is reached.

For purposes of calculating the TMDLs, the model assumes that PCB loads from the ocean, the major tributaries and the air are at levels that ensure that the water quality standards are achieved, rather than at the actual levels, which are higher.

### **Allocations**

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Each of the zone TMDLs were divided into the WLA, LA and MOS components. EPA based these allocations upon recommendations of the DRBC's TAC for an explicit MOS of 5 percent in each estuary zone and for the Stage 1 TMDLs to allocate WLAs and LAs based on the current proportion of loadings from the various PCB source categories to each of the zones during the one-year model simulation period.

The LA was further divided for consideration of MS4s based on the ratio of MS4 loads to other nonpoint source loads. To determine what portion of Non-Point Source Runoff volume corresponds to MS4 service areas, the DRBC computed both MS4 and non-MS4 runoff volumes for the simulation period using the methodologies in *Urban Hydrology for Small Watersheds*, Technical Release 55, Soil Conservation Service (Natural Resources Conservation Service), June 1986 and including several assumptions about land use distribution and MS4 coverage.

### **For More Information**

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Several reports related to the development of the Delaware Estuary PCB TMDLs are available online at [http://www.epa.gov/reg3wapd/tmdl/pdf/delaware\\_tmdl/index.htm](http://www.epa.gov/reg3wapd/tmdl/pdf/delaware_tmdl/index.htm). Reports include:

- Executive Summary
- TMDL Report
- Hydrodynamic Model Report
- Water Quality Model Report
- Model Calibration Report
- Response to Comments

# Contaminated Sediment TMDL for Bellingham Bay, Washington

September 2001

## Background

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Bellingham Bay is an urban bay in the city of Bellingham in northwest Washington. The TMDL for contaminated sediment in the bay is developed as part of the Bellingham Bay Demonstration Pilot Project, an initiative of the Cooperative Sediment Management Program. The Pilot Work Group has been working to provide a comprehensive approach to addressing the contaminated sediments in the bay and is comprised of 15 federal, state and local entities charged with addressing or coordinating contaminated sediment cleanup needs. The Pilot Project is designed to expand opportunities for achieving multiple goals in Bellingham Bay beyond sediment cleanup and sediment disposal to include source control, habitat restoration, and aquatic land use.

The Pilot Project generated a Comprehensive Strategy identifying a range of remedial alternatives for priority cleanup sites and provides guidance for cleanup activities that coincide with 303(d)-listed areas in the bay. The Strategy goes beyond the scope of the TMDL and the TMDL was developed to be consistent with the plans identified in the Strategy.

The sediment contamination is the result of historic discharges. All current sources discharging to the bay have undergone evaluation to assess compliance with state sediment management standards and no ongoing sources have been documented as contributing to the contamination of sediment in the bay.

## 303(d) Listing Information

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The TMDL addresses impairments due to potential toxic effects from contaminated sediments in the bay as included on the 1998 303(d) list. The list includes 31 separate parameters at several locations in Inner Bellingham Bay. (New data demonstrates that state standards are met for the majority of the listed parameters; only 10 parameters are currently exceeding sediment quality standards.)

## TMDL Targets

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The Washington water quality standards incorporate Sediment Management Standards (SMS) by reference at WAC 173-201A-010(3) to identify and designate sediments that have adverse effects on aquatic organisms or pose significant health risk to humans. The standards established a sediment quality goal for Washington State. The standards also include the requirements for how the standards are applied in source control and cleanup actions. The regulation includes numeric chemical and biological standards to address ecological effects of impaired marine sediment quality in Puget Sound. The narrative sediment quality goal of the SMS is defined as no acute or chronic adverse effects to biological resources and no significant risk to humans (WAC 173-204-100). The Sediment Quality Standards (SQS) (WAC 173-204-320) include the Puget Sound marine numeric chemical and biological standards based on the goal of no acute or chronic adverse effects. The chemical standards are sufficient to identify priority areas and define areas warranting further investigation. The parameters addressed in this TMDL are those that currently exceed the applicable SQS, summarized in Table 9.

**Table 9. Sediment Quality and Cleanup Screening Levels**

SMS Parameter	Marine Sediment Quality Standards (SQS)	Marine Cleanup Screening Level (CSL)
	mg/kg dry weight	mg/kg dry weight
Mercury	0.41	0.59
Copper	390	390
Zinc	410	960
Lead	450	530
Arsenic	57	93
	mg/kg carbon	mg/kg carbon
PCBs	12	65
	µg/kg dry weight	µg/kg dry weight
Phenol	420	1200
4-methylphenol	670	670
Sediment bioassay	(1)	(2)
Wood waste		50% by volume <sup>3</sup>

- <sup>1</sup> The biological effects criteria under SQS are based on the premise of “no adverse effects on biological resources”, defined by specific test results for any one of five marine sediment biological tests. The specific tests and target endpoints can be found in WAC 173-204-320(3). Under the SMS, if a sediment sample exceeds the numeric criteria, but passes the confirmatory biological tests, the sample location is considered “clean” or in compliance with the SQS.
- <sup>2</sup> The biological effects criteria under CSL are based on “minor adverse effects in marine biological resources” and are designed to screen sediment station clusters to define clusters of potential concern using the results of two acute and one chronic effects tests. The specific tests and target endpoints for CSL biological effects criteria for Puget Sound marine sediments can be found in WAC 173-204-520(3).
- <sup>3</sup> The Sediment Management Standards provide authority in WAC 173-104-520(5) to require cleanup of “other deleterious substances” on a case-by-case basis. The Department of Ecology has determined that a 50% wood waste by volume criteria is a level below which only minor adverse effects may result in marine sediments (Kendall and Michelsen, 1997).

## Technical Approach

The TMDL draws information from two modeling efforts conducted to assess source inputs and sediment recontamination potential.

The first modeling effort was completed as part of a remedial investigation for the Whatcom Waterway site for the Georgia-Pacific site. The analysis included WASP5 and a near-field dilution zone mixing model. The models were used to perform mass balance and mass transfer calculations for contaminants in the water column and sediments. The models incorporate mixing and chemical partitioning phenomena and include local currents, tidal dispersion, sedimentation and resuspension. This modeling work provides the primary tool used in this TMDL to define the Waste Load Allocation (WLA) for the Georgia Pacific facility.

The second modeling effort was designed as a screening and evaluation tool for other potential ongoing sources in Bellingham Bay to identify, plan, and prioritize source control activities. In this analysis, sediment concentrations resulting from identified Bellingham Bay sources were estimated using a model that incorporated receiving water dispersion and sedimentation processes. The model conservatively evaluated sediment recontamination potential using measured flows and maximum concentrations from each source and the gross sedimentation rate measured in Inner Bellingham Bay. Local background concentrations of chemicals in incoming sediments were also used as inputs. The results of this recontamination modeling indicates that for all sources for which input data are available, SQS chemical criteria are not likely to be exceeded beyond short distances from the shoreline discharge location (tens of feet). This analysis predicts that sediment quality impairment or recontamination from existing sources is relatively localized near a potential source and should not hinder the large-scale sediment remediation plans.

## Allocations

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The majority of listed parameters do not have corresponding allocations in this TMDL. Many are proposed for delisting because sediment standards are now being met and many are not provided allocations because sources are currently or expected to be controlled and/or eliminated. WLAs were allocated to two sources, as discussed in the following paragraphs.

A WLA is allocated to Georgia Pacific based on current permit limits for mercury. Recent data confirm that SQS for mercury are no longer exceeded in the area of the outfall and further discharge controls have been implemented at the facility (e.g., closure of a chlor-alkali plant) that will continue to improve discharge quality. For the purposes of the TMDL, a WLA was established to be consistent with modeling input parameters for the effluent and NPDES permit limitations. The WASP analysis showed a mass loading of 0.043 kg/day mercury would be protective of sediment quality. The current permit limit of 0.03 lbs/day (0.014 kg/day) is more restrictive than the allowable mercury release determined in the WASP model and is established as the WLA for Georgia-Pacific in this TMDL, providing a margin of safety.

The other WLA established by this TMDL is for “C Street stormwater and combined sewer overflow (CSO)” for 4-methylphenol and phenol. The WLAs are set equal to the SQS for these pollutants, as follows:

*The WLA for this source is the discharge level that does not exceed a level of 670g/kg for 4-methylphenol and 420 µg/kg for phenol in receiving water sediments.*

Note: Allocations are not established for several pollutants still identified as violating sediment standards. The TMDL states that the discharge sources “are currently effectively controlled through NPDES Permit” and that under the next NPDES permit, the facility will be required to collect and treat all industrial stormwater. After the facility completes the stormwater project, the WLAs will be zero.

## For More Information

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Inner Bellingham Bay Contaminated Sediments TMDL - Submittal Report—  
<http://www.ecy.wa.gov/biblio/9958.html>

Inner Bellingham Bay Contaminated Sediments TMDL - Detailed Implementation Plan—  
<http://www.ecy.wa.gov/biblio/0310057.html>

Bellingham Bay Demonstration Pilot—[http://www.ecy.wa.gov/programs/tcp/sites/blhm\\_bay/blhm\\_bay.htm](http://www.ecy.wa.gov/programs/tcp/sites/blhm_bay/blhm_bay.htm)