TETRA TECH, INC.
1230 Columbia Street, Suite 520
San Diego, CA 92101
Telephone (619) 525-7015
FAX (619) 232-2392

MEMORANDUM

DATE: May 5, 2006

TO: Peter Kozelka, USEPA Region 9
L.B. Nye, LARWQCB

CC: David Smith, UESPA Region 9

FROM: John Craig and Stephen Carter

SUBJECT: Technical approach for estimating pollutant loadings from the Los Angeles River watershed, San Gabriel River watershed, areas draining directly to Los Angeles and San Gabriel estuaries, Los Angeles and Long Beach Harbors, and San Pedro Bay – DRAFT

Estimation of pollutant loadings to the Los Angeles and San Gabriel estuaries, Los Angeles and Long Beach Harbors (Harbors), and San Pedro Bay (SPB) requires development of approaches that address both wet and dry conditions. Previous modeling studies performed by Tetra Tech for Los Angeles River (LAR) and San Gabriel River (SGR) supported calculation of metals loadings to those waterbodies. Ongoing modeling of Dominguez Channel (DC) by SCCWRP will be based on consistent modeling approaches for metals. For the remaining watershed area not included in the LAR, SGR, and DC models (hereafter referred to as nearshore areas), including areas draining to estuaries of LAR and SGR, Tetra Tech worked with SCCWRP, Regional Board staff, and EPA to develop and implement an approach to calculate pollutant loadings from the nearshore areas (see Figure 1).

This memo provides a summary of the approach Tetra Tech proposes for estimation of metals and organic pollutant loads from LAR, SGR, and nearshore areas. Pollutant loadings from the DC and Consolidated Slip to LA Harbor will be estimated in separate studies performed by SCCWRP and Port of Los Angeles (POLA).

MODEL DOMAIN

The entire watershed modeling domain for the current study is depicted in Figure 1. As discussed, this study utilizes previously developed models of LAR and SGR, as well as a model of DC developed through a separate study performed by SCCWRP. The remaining nearshore areas require development of new models for simulation of runoff pollutant loads to SGR and LAR estuaries, the harbors, and SPB (depicted in red in Figure 1). As opposed to the LAR, SGR, and DC models of major watersheds and associated rivers/channels discharging to estuaries, the nearshore watersheds are representative of smaller tributaries and sewersheds discharging directly to receiving waters.

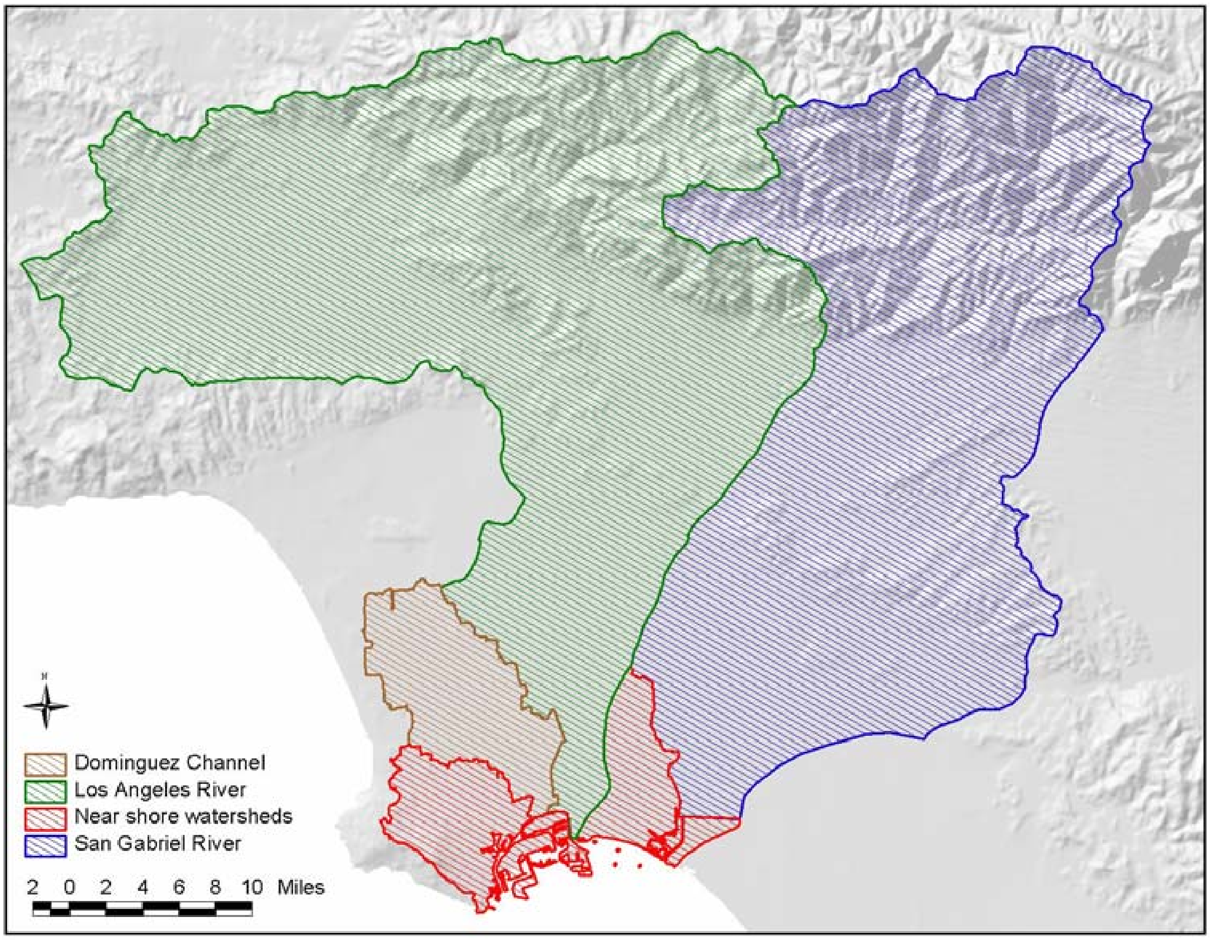

Figure 1. Watersheds of the Harbors and San Pedro Bay

Tetra Tech has delineated the nearshore subwatersheds based on a combination of sewersheds provided by the POLA and the Port of Long Beach (POLB); monitoring locations; model domains of LAR, SGR, and DC watersheds; receiving water model domain of the Harbors and SPB; and a USGS digital elevation model (Figure 2). These subwatershed boundaries are being used in development of hydrologic and water quality models of these areas.

Because the pollutant sources and their means of transport to receiving waters vary between wet and dry conditions (McPherson et al., 2005a; LARWQCB, 2005a, 2005b, 2005c, Stein et al., 2003), Tetra Tech developed technical approaches that are consistent with our understanding of the processes for each weather condition—this assumption is consistent with most other TMDLs adopted in the Los Angeles Region. The following sections outline our technical approach to estimate pollutant loads for each condition.

WET WEATHER

The transport of metals and organic pollutants during wet-weather events is generally believed to be associated with the detachment and transport of sediment (Buffleben et al., 2002; CALTRANS, 2003; Hoffman et al., 1982; Lau and Stenstrom, 2005; Logonathan et al., 1997; Stein et al., 2005; Yunker et al., 2002). Specific watershed sources vary based on location and pollutant and for some pollutants, concentration “hot spots” are present. These “hot spots” are typically associated with spills or other events that lead to higher pollutant concentrations and their presence and impact to receiving waters are difficult to identify/characterize. Additionally, available data to characterize the pollutant sources is often limited.

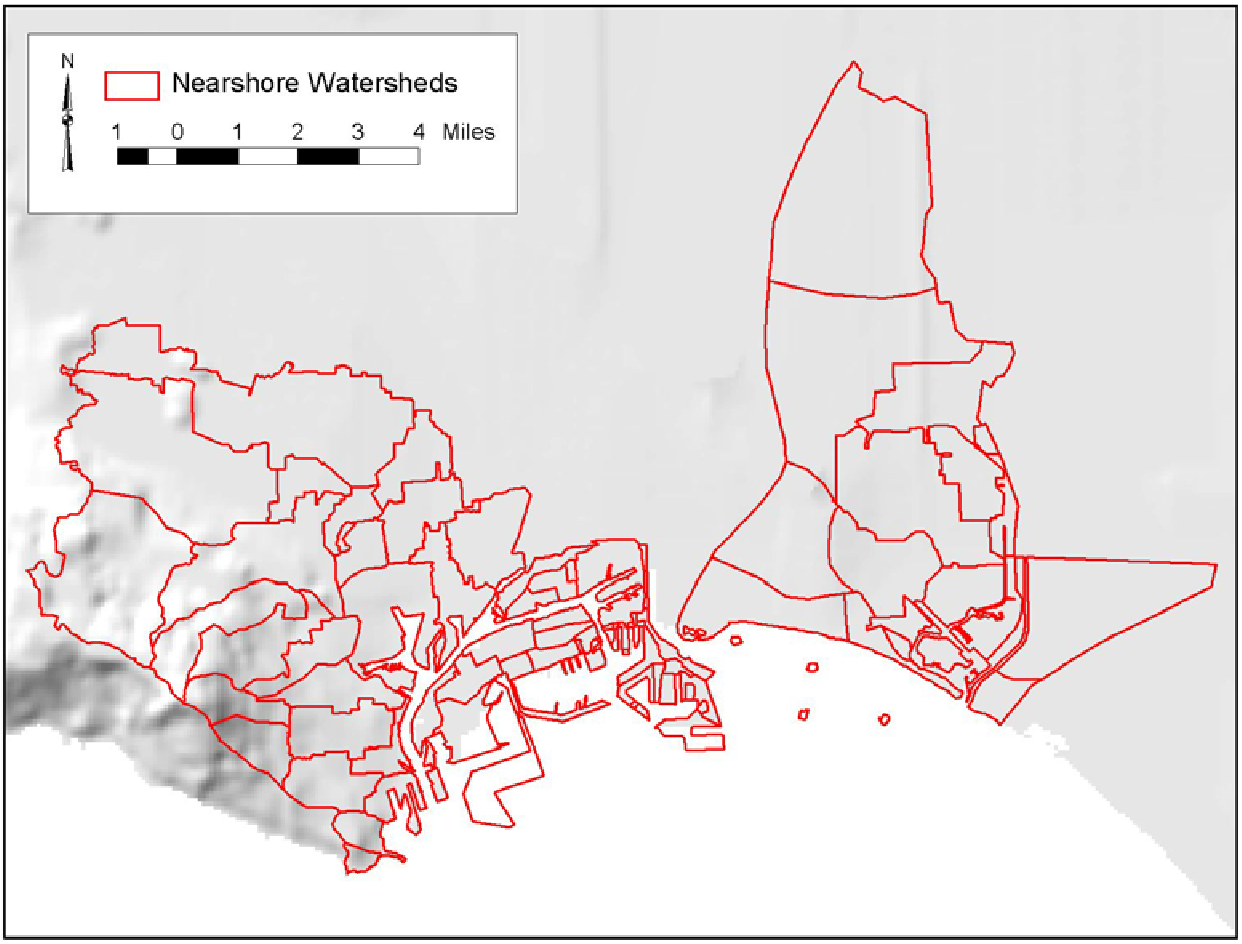

Figure 2. Model Subwatersheds for Nearshore Areas

Previous wet-weather watershed modeling and TMDL efforts by Tetra Tech and SCCWRP have led to the development of a regional watershed modeling approach to simulate hydrology, sediment, and metals transport in Los Angeles watersheds. The regional modeling approach assumes that metals loadings can be dynamically simulated based on hydrology and sediment transported from land uses in a watershed. Development of the approach resulted from application and testing of models for multiple small-scale land use sites and larger watersheds in the LA Region. SCCWRP developed watershed models, based on the Hydrologic Simulation Program – Fortran (HSPF) (Bicknell et al., 2001), of multiple homogeneous land use sites in the region. Sufficient stormflow and water quality data were available at these locations to facilitate calibration of land-use-specific HSPF modeling parameters. These parameters were validated in an additional HSPF model of Ballona Creek (Ackerman et al., 2005a; SCCWRP, 2004), and similar models of LA River (Tetra Tech, Inc., 2004) and San Gabriel River (Tetra Tech, Inc, 2005a) based on the

Loading Simulation Program C++ (LSPC) (Shen et al., 2004). These models were used to calculate TMDLs for each of these waterbodies (LARWQCB, 2005a and 2005c; draft San Gabriel River TMDL currently under development).

Wet-weather events for the study areas will be simulated using previously calibrated LSPC models of the LA River and San Gabriel River watersheds (illustrated in green and blue in Figure 1, respectively) and newly developed LSPC models for the nearshore areas (Figure 2). The simulation time frame for the LA River and San Gabriel River watershed models will be extended to overlap with the current study period. To perform this temporal extension, updated flow, copper, lead, and zinc point source data for the major dischargers in the watershed are required. The dischargers and time periods associated with this data gap are presented in Table 1. Once this data gap has been addressed and these data are incorporated in the model, simulations will be performed to obtain flow and total suspended solid (TSS) model output for the LA River and San Gabriel River watersheds.

Table 1. Point Source Dischargers and Date Ranges for Data Gaps

San Gabriel River			
NPDES#	**Facility**	**Pipe**	**Timeframe**
CA0053619	Pomona WWRP	PO001	April 2004 - present
CA0053716	Whittier Narrows WWRP	WN001	April 2004 - present
CA0053911	San Jose Creek WWRP	SJC001e	April 2004 - present
		SJC001w	April 2004 - present
		SJC002	April 2004 - present
		SJC003	April 2004 - present
CA0054011	Los Coyotes WWRP	LC001	April 2004 - present
CA0054119	Long Beach WWRP	LB001	April 2004 - present
Los Angeles River			
NPDES#	**Discharger**	**Facility**	**Timeframe**
CA0001309	The Boeing Company	Rocketdyne Div. - Santa Susana	October 2001 - present
CA0052949	Southern California Edison	Dominguez Hills Fuel Oil Facility	October 2001 - present
CA0053953	LA City Bureau of Sanitation	L.A.-Glendale WWRP, NPDES	October 2001 - present
CA0055531	Burbank, City Of Public Works	Burbank WWRP, NPDES	October 2001 - present
CA0056227	LA City Bureau of Sanitation	Tillman WWRP, NPDES	October 2001 - present
CA0064271	Las Virgenes MWD	Tapia Park WWRP, NPDES	October 2001 - present

The nearshore models were initially populated using hydrologic parameters for the LA River watershed model (LARWQCB, 2005c; Tetra Tech, Inc., 2004). These parameters are in the process of being refined as part of model calibration since there were some relevant hydrology and water quality data available in the nearshore watersheds. These data include stormwater sampling by POLA and POLB during a single storm event at three stations (Forest, Pier A, and Maritime Museum), which are identified in Figure 3. Forest was selected as a sample subwatershed and preliminary results for this watershed are presented in each section of this document. The preliminary hydrology calibration results are presented in Figure 4. This watershed drains a new land use, which is characterized by a "Port Activities," and the hydrology parameters associated with this land use were adjusted during model calibration. As shown in Figure 4, the predicted flow for the Forest subwatershed has a similar pattern, but slightly higher peaks than the observed flow at the POLA stormwater sampling station. This small discrepancy in flow is well within acceptable modeling ranges.

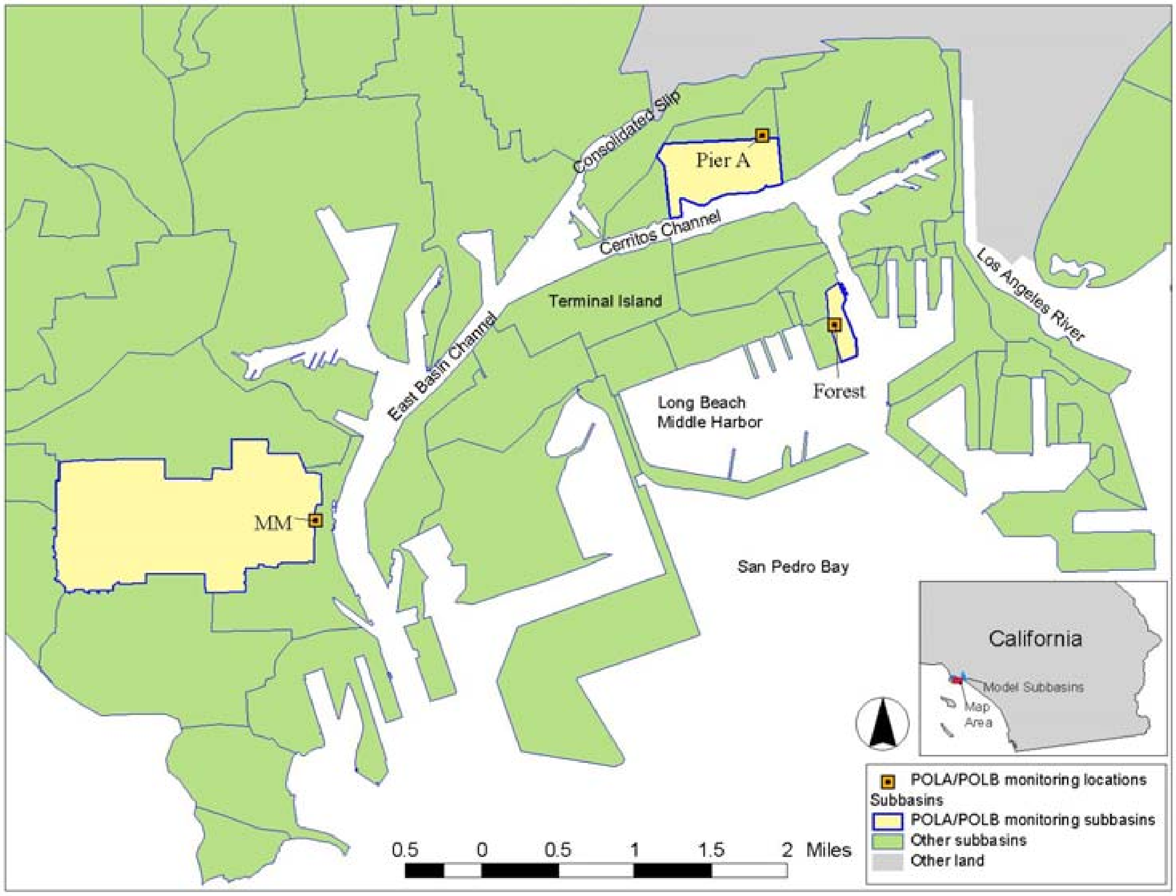

Figure 3. POLA/POLB Stormwater Sampling Stations and Their Associated Subwatersheds

Once hydrology was calibrated, the regional modeling approach was applied to simulate sediment in the nearshore areas. The robust calibration and validation process previously performed for land use sites, Ballona Creek, LAR, and SGR are considered sufficient for documenting the performance of modeling parameters and verifying the transferability of the parameters among models of adjacent watersheds in the region. The application of the regional modeling approach provides increased opportunity for verification as additional datasets become available for comparison with model predictions. Land uses for the nearshore LSPC model (based on Southern California Association of Governments [SCAG] 2000 land use data) were reclassified to maintain consistency with the land use categories associated with the regional approach (Table 2). To represent unique sources and activities in the nearshore areas, an additional land use category, "Port Activities," was also included.

For this study, the sediment parameters from the San Gabriel River model (draft San Gabriel River TMDL currently under development, Tetra Tech, Inc, 2005a) were applied to the nearshore areas. Calibration of TSS for the Forest subwatershed required only minor adjustment to the "Port Activities" land use to obtain better model fit with observed data at the POLA stormwater sampling station. This methodology is consistent with the minor calibrations performed in the San Gabriel River model to more closely match the local conditions in the watershed. The preliminary sediment calibration results at Forest are presented in Figure 4. The modeled TSS has a lower peak and a more gradual decline than the observed data. Similar to the hydrology results, these discrepancies are well within acceptable modeling ranges.

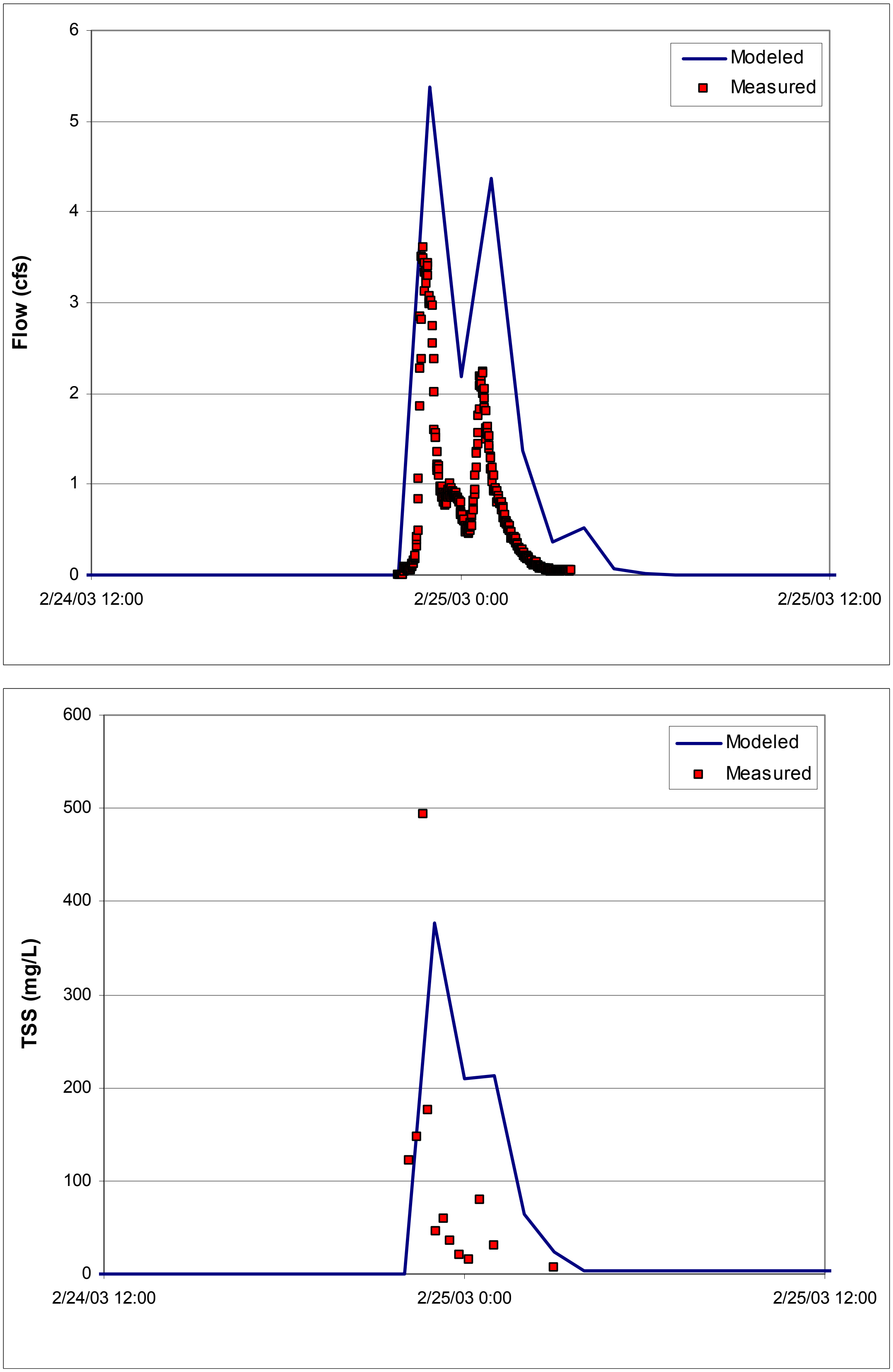

Figure 4. Modeled and Observed Flow and TSS Values for the Forest Subwatershed

Table 2. Land Use Categories

LSPC Watershed Model Land Use Categories	PAH Wet Weather Assumptions Land Use Categories
Industrial	Industrial
Commercial	Commercial
Low-Density Residential	Low-Density Residential
High-Density Residential	High-Density Residential
Agriculture	Agriculture
Open	Open
Port Activities	Recreational
Mixed Urban	Transportation

As described below, metals for both the watersheds and nearshore areas will be simulated directly using LSPC. To determine loadings for PAHs, DDT, PCBs, and chlordane, it was necessary to develop pollutant-specific approaches. These approaches, which are described in detail below, all use LSPC model output from the watersheds and nearshore areas. Specifically, for PAHs, the simulated flow is combined with land-use specific event mean concentrations (EMCs) to calculate loadings, while simulated TSS results are combined with pollutant concentrations associated with sediment samples to determine DDT, PCBs, and chlordane loads. The pollutant-specific wet-weather approaches and preliminary results for the Forest subwatershed are presented in the following sections.

Metals

The previously calibrated watershed models of the LA River and San Gabriel River (LARWQCB, 2005c; draft San Gabriel River TMDL currently under development, Tetra Tech, Inc, 2005a) will be expanded to determine metal loads to their respective estuaries for the entire LA Region modeling period. For modeling wet-weather metals loads from nearshore areas (Figure 2), Tetra Tech is developing LSPC models based on the regionally calibrated land use modeling parameters described above. SCCWRP is also using LSPC to simulate metals loads from DC.

The regional modeling approach described above for sediment was also applied to simulate metals in the nearshore watersheds. For this study, the metals parameters from the San Gabriel River model (draft San Gabriel River TMDL currently under development, Tetra Tech, Inc, 2005a) were applied to the nearshore areas. Calibration of metals in the Forest subwatershed was performed. Specifically, model results were compared to stormwater sampling data and slight adjustments were made to the metals parameters to more closely match the observed data at this station. This methodology is consistent with the minor calibrations performed in the San Gabriel River model to more closely match the local conditions in the watershed. Calibration only involved adjusting a single metals parameter for the “Port Activity” land use. Preliminary model results for metals concentrations in the Forest subwatershed are presented in Figure 5 and their associated loads are presented in Figure 6. These graphs illustrate that, for copper, lead, and zinc, the predicted concentrations and loads closely match the observed POLA/POLB stormwater data and are well within acceptable modeling ranges.

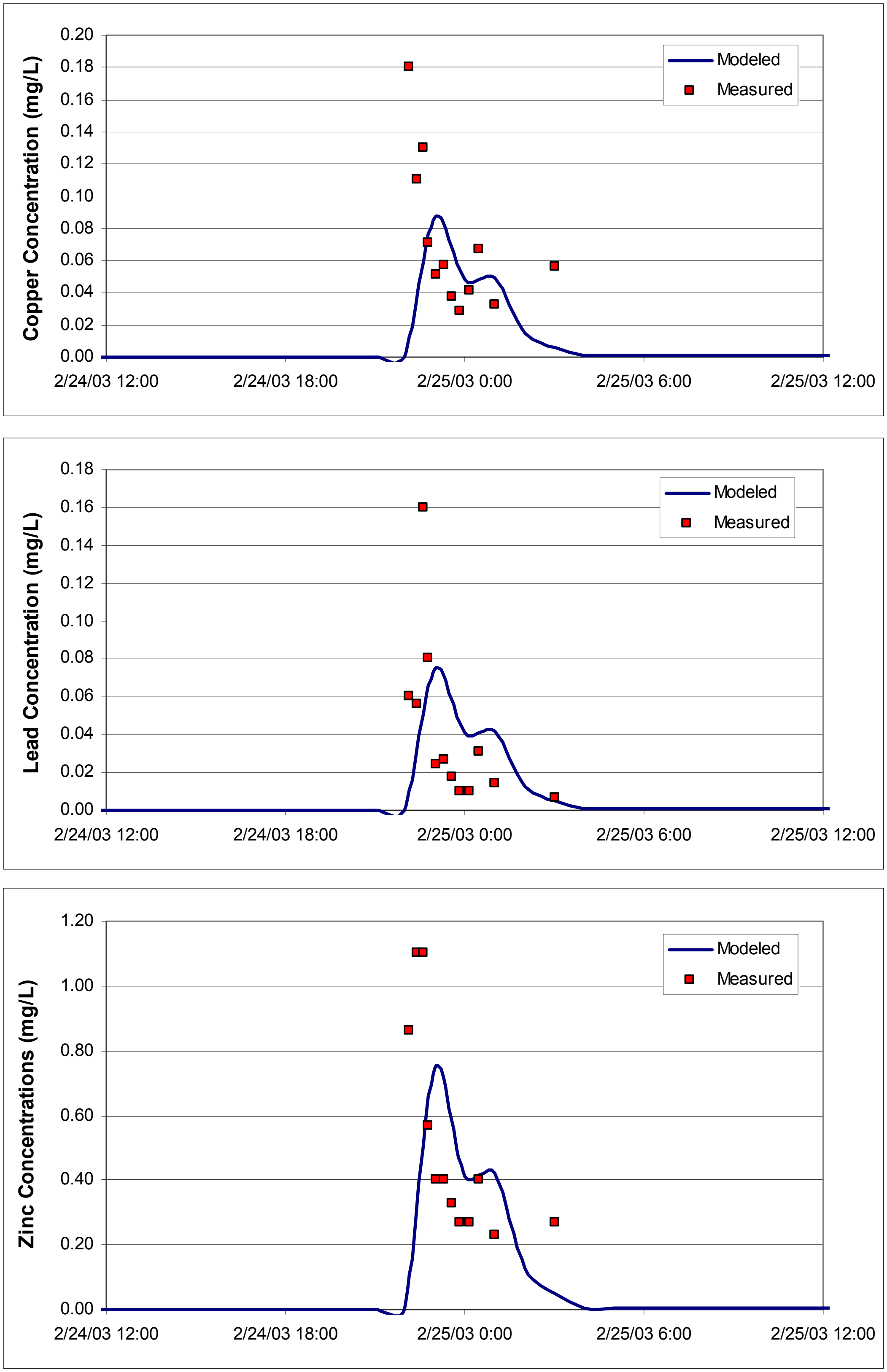

Figure 5. Modeled and Observed Copper, Lead, and Zinc Concentrations for the Forest Subwatershed

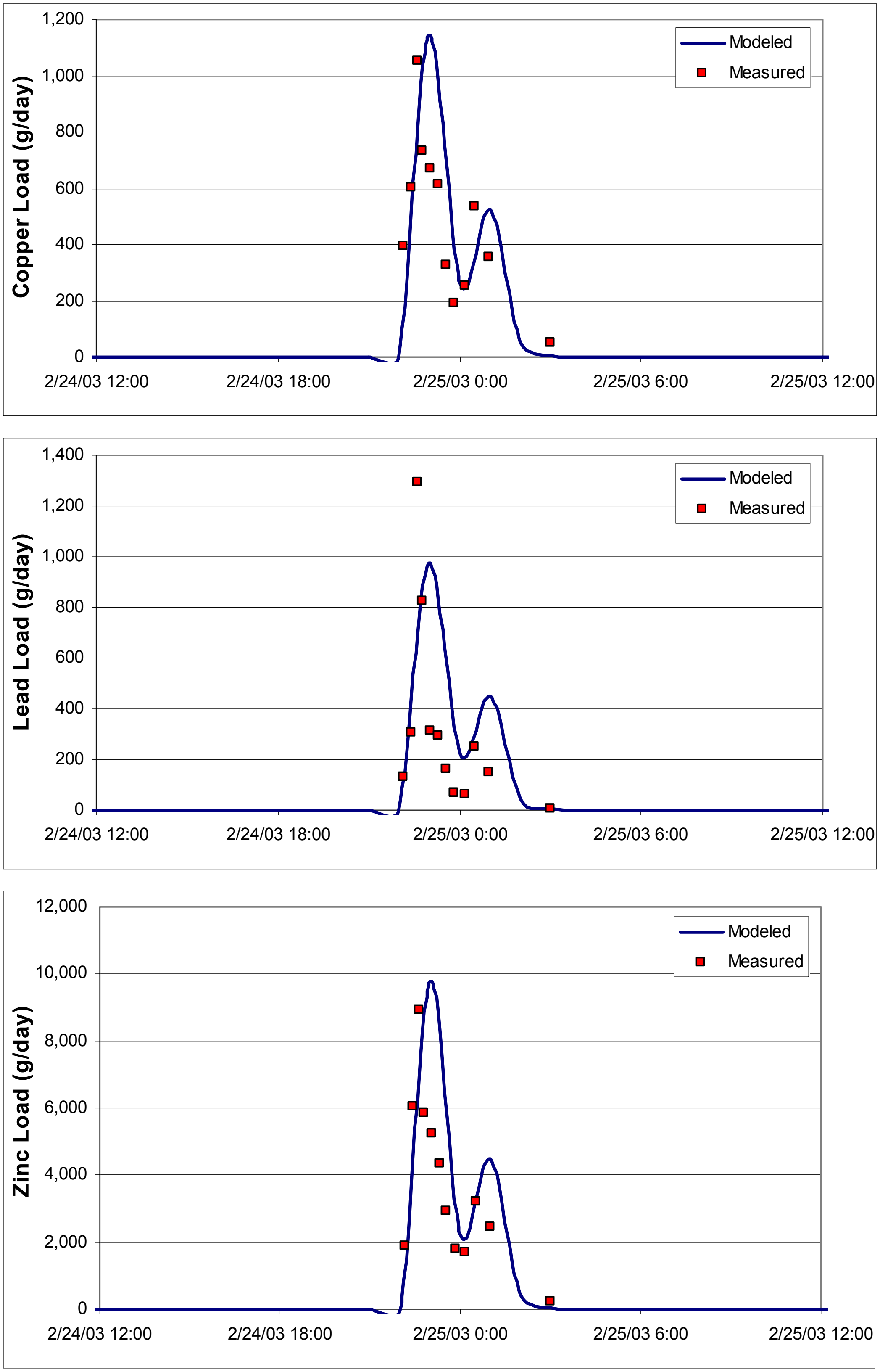

Figure 6. Modeled and Observed Copper, Lead, and Zinc Loads for the Forest Subwatershed

PAHs

Presently, no land-use-based watershed models have been developed for simulation of wet-weather sources of PAHs in the LA Region. However, monitoring at land use sites throughout the LA Region has yielded information that can be used for the present study. Stein et al. (2005) report EMCs of total PAHs for various land uses based on land use sites monitored in the LA Region. At each location, 10 to 15 grab samples were collected at a frequency of 30 to 60 minutes during storm events. The average EMCs and respective standard deviations reported by Stein et al. for each land use site are listed in Table 3. As shown in this table, PAH concentrations are commonly observed in stormflows from each land use. Stein et al. indicated that some apparent differences in PAH EMCs and fluxes were observed between land uses, with no significant differences in EMCs and fluxes among land use categories.

To estimate loading of PAHs from subwatersheds, our approach includes a combination of LSPC flow predictions and EMCs listed in Table 3 from Stein et al. (2005). Specifically, stormwater total PAH concentrations for each model subwatershed will be predicted using weighted averages of land use EMCs based on area and runoff potential of each land use in each subwatershed. The following equation (1) will be used to determine representative EMCs for each subwatershed:

$$EMC_{avg.} = \frac{\sum_{i=LU} A_i C_i (EMC_i)}{\sum_{i=LU} A_i C_i} \qquad (1)$$

where, EMC_{avg} = average subwatershed EMC
LU = land use category
A = land use area
C = runoff coefficient

The land use categories associated with the EMCs described by Stein et al. (2005) are slightly different than those from the regional modeling approach for metals. Therefore, the SCAG 2000 land use data were used to represent the study area and were reclassified to maintain consistency with the EMC land use categories (Table 2) (Ackerman and Schiff, 2003). Runoff coefficients for each land use are based on values reported by Ackerman and Schiff (2003) for modeling stormwater mass emissions in Southern California and are presented in Table 4. These land uses do not correlate exactly to the EMC land use categories. To overcome this limitation, the residential runoff coefficient was assigned to both the high density and low density residential land uses, the open runoff coefficient was assigned to the recreation land use, and the other urban runoff coefficient was assigned to the transportation land use.

EMCs determined for each subwatershed are assumed to be constant for all stormflows. These EMCs will be multiplied by hourly flows predicted by LSPC models for estimation of dynamic loads of total PAHs from the watersheds. Although the total PAH concentrations are assumed to be constant, variability of model-predicted stormflows will result in likewise variable loadings to the Harbors and SPB. Table 5 presents the average PAH EMC calculated for the Forest subwatershed. This information is also illustrated in Figure 7, which shows the time-variable flows, constant EMC, and resulting time-variable loads for Forest. In addition, the graph with the constant concentration presents the observed PAH measurements from the stormwater monitoring. This figure illustrates that the predicted PAH concentrations are within the range of observed data. This methodology will be applied to the model output from all other model subwatersheds (LA River, San Gabriel River, and other nearshore subwatersheds).

Table 3. Average EMCs for PAHs at Land Use Sites (Stein et al., 2005)

Land Use	EMC (ng/L)	SD
Industrial	1.50E+03	8.60E+02
Commercial	1.20E+03	5.80E+02
Low-density residential	1.40E+03	6.00E+02
High-density residential	4.40E+03	2.60E+03
Agricultural	8.60E+02	1.00E+03
Open	1.38E+02	0.00E+00
Recreational	4.60E+02	3.00E+02
Transportation	4.80E+02	2.80E+02

Table 4. Runoff Coefficients by Land Use (Ackerman and Schiff, 2003)

Land Use	Runoff Coefficient
Industrial	0.64
Commercial	0.61
Residential	0.39
Agriculture	0.10
Open	0.06
Other Urban	0.41

Table 5. Wet-Weather Pollutant Concentrations Included in Loading Analyses for the Forest Subwatershed

Pollutant	Concentration
Wet-Weather PAHs	1.50 ± 0.86 (range 0.64-2.36) (ug/L)
Wet-Weather DDT	24.41 (ug/kg)[a]
Wet-Weather PCBs	0.38 (ug/kg)[a]
Wet-Weather Chlordane	0.29 (ug/kg)[a]

a. Values presented are the Bight 03 sediment concentrations for the Forest subwatershed. Associated wet weather DDT, PCBs, and Chlordane water quality concentrations are calculated by multiplying sediment concentrations with the LSPC modeled TSS concentrations. The resulting water quality concentrations are variable, depending upon the TSS concentrations.

Although in reality total PAH concentrations are typically higher during the rising limb of the storm hydrograph due to first flush, mass loading exhibits only a moderate first flush for storms monitored in LA (Stein et al., 2005). Therefore, assuming constant total PAH concentrations for stormflows is reasonable. Based on a similar method of using EMCs assigned to dynamic flows predicted for Ballona Creek using EPA's Storm Water Management Model (SWMM) to predict wet-weather nutrient loads, McPherson et al. (2005b) state that in most cases, the total load estimated using EMCs for long-term simulation can have similar accuracy as more complex models (e.g., HSPF/LSPC).

To assess the uncertainty of model predictions based on EMCs, sensitivity analyses of assumed values will be performed. For each subwatershed, upper and lower ranges of average EMCs (based on equation 1) will be determined using land-use-specific EMCs plus/minus one standard deviation, as listed in Table 3. Resulting ranges of wet-weather loadings to the Harbors and SPB will be quantified to provide understanding of the sensitivity of loads potentially due to uncertainty of modeling assumptions. For the Forest subwatershed, the PAH EMC and upper and lower ranges are provided in Table 5 and presented graphically in Figure 7.

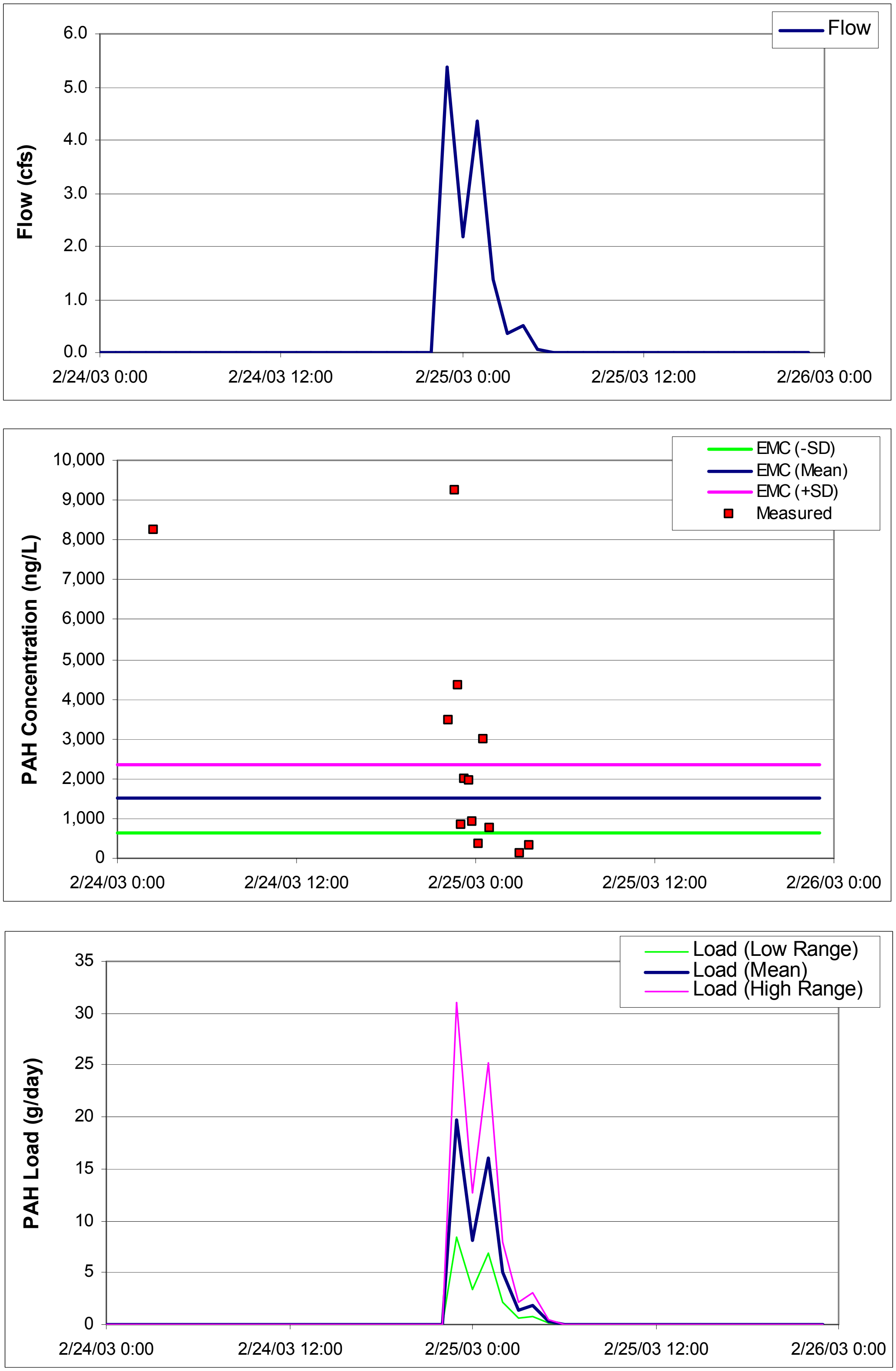

Figure 7. Modeled and Predicted PAH Concentrations and Loads for the Forest Subwatershed

The benefit of this approach is the simplicity of assumptions, and the resulting ease at which these assumptions can be understood and utilized in following efforts for modeling to support TMDL implementation and BMP planning. Although the use of EMCs assumes no variability in storm concentrations, first flush, and indication of sediment association that are important considerations for planning and assessment of BMP effectiveness, they are regularly used by municipalities for assessment and planning activities, and reduce the need for using more-complex watershed models for load estimation.

DDT, Chlordane, and PCBs

While the sources and land uses associated with DDT, chlordane, and PCBs differ, their transport mechanisms are generally similar. Therefore, these pollutants will be modeled using a similar approach and with similar data. DDT is considered a legacy pollutant because it is believed that active uses/sources of the pollutant do not exist. However, because of the persistence of DDT in the environment, reservoirs of the pollutant are often present in the watershed and in the receiving waters. Few detectable levels of DDT have been observed at mass emissions stations in the LA Region (4,4'-DDD, 4,4'-DDE, and 4,4'-DDT were measured, each with a detection limit of 0.1 ug/L) (LADPW, 2006). Ackerman and Schiff (2003) report EMCs for DDT for land use monitoring performed by San Diego, Ventura, and Los Angeles municipalities as part of their NPDES permit programs. These EMCs resulted from flow-weighted composite samples collected throughout the duration of storm events. Of the five land uses analyzed (agriculture, commercial, industrial, open, and residential), only agricultural land use was shown to have detectable levels of DDT in runoff. PCBs and chlordane are also referred to as legacy pollutants, and similar to DDT, watershed sources of these pollutants may exist. However, no detectable levels of PCBs and chlordane have been observed at County mass emissions stations (LADPW, 2006) (detection limits for PCBs and chlordane are 0.05 and 0.5 ug/L, respectively).

More-detailed study and collection of stormwater concentrations of DDT, PCBs, and chlordane (at lower detection limits) may provide necessary information for development of a detailed regional modeling approach similar to the metals or land use specific EMCs similar to the PAHs. In the absence of such datasets to characterize wet-weather loads from the watersheds, sediment concentrations will be used to model them for the current study. Similar to methods used in prediction of existing DDT, PCBs, and chlordane loads to support development of the Newport Bay Toxics TMDL (SARWQCB, 2000), loads can be predicted as a sediment concentration assigned to all sediment loads transported from watersheds to the receiving waters. For the current study, sediment loads to the Harbors and SPB are being predicted based on LSPC models developed by Tetra Tech of SGR, LAR, and nearshore areas (sediment modeled as a surrogate for metals load estimates).

Additional assumptions for sediment concentrations of DDT, PCBs, and chlordane, expressed as constant values for all sediment transported from each watershed, are required. Sediment concentrations for the Harbor region have been calculated for the Bight 03 sediment stations. Figure 8 through Figure 10 illustrate the range of sediment concentrations found at these stations for DDT, PCBs, and chlordane. These figures show that, for the Los Angeles River estuary, DDT, PCBs, and chlordane concentrations are all higher near the mouth of the river than throughout the rest of the estuary. This trend does not persist in the San Gabriel River estuary, which tends to have lower concentrations of all three organics compared to the rest of the Harbor and SPB, where, as expected, higher concentrations are generally seen in areas with reduced circulation and flushing.

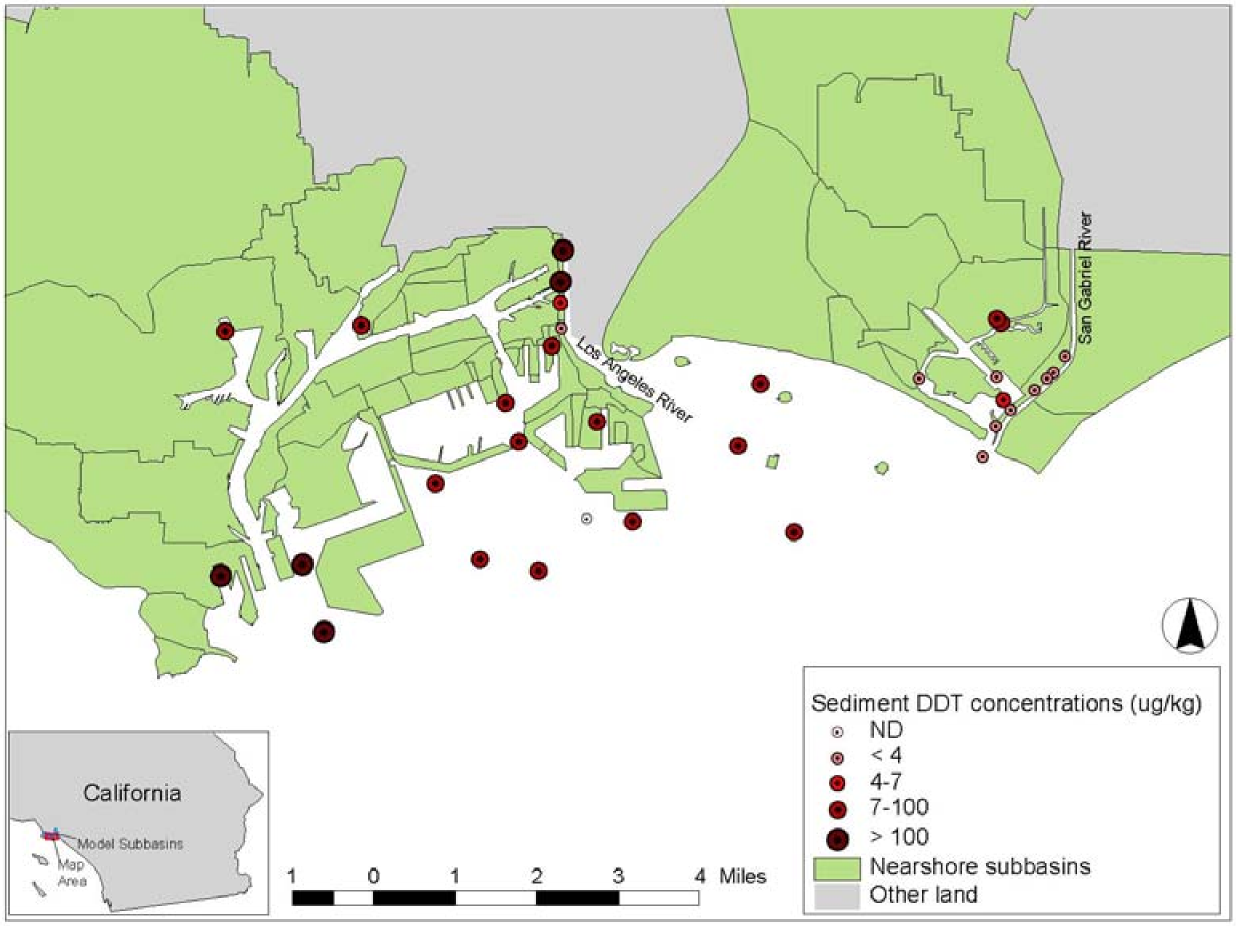

Figure 8. DDT Gradients at the Harbor Bight 03 Sampling Stations

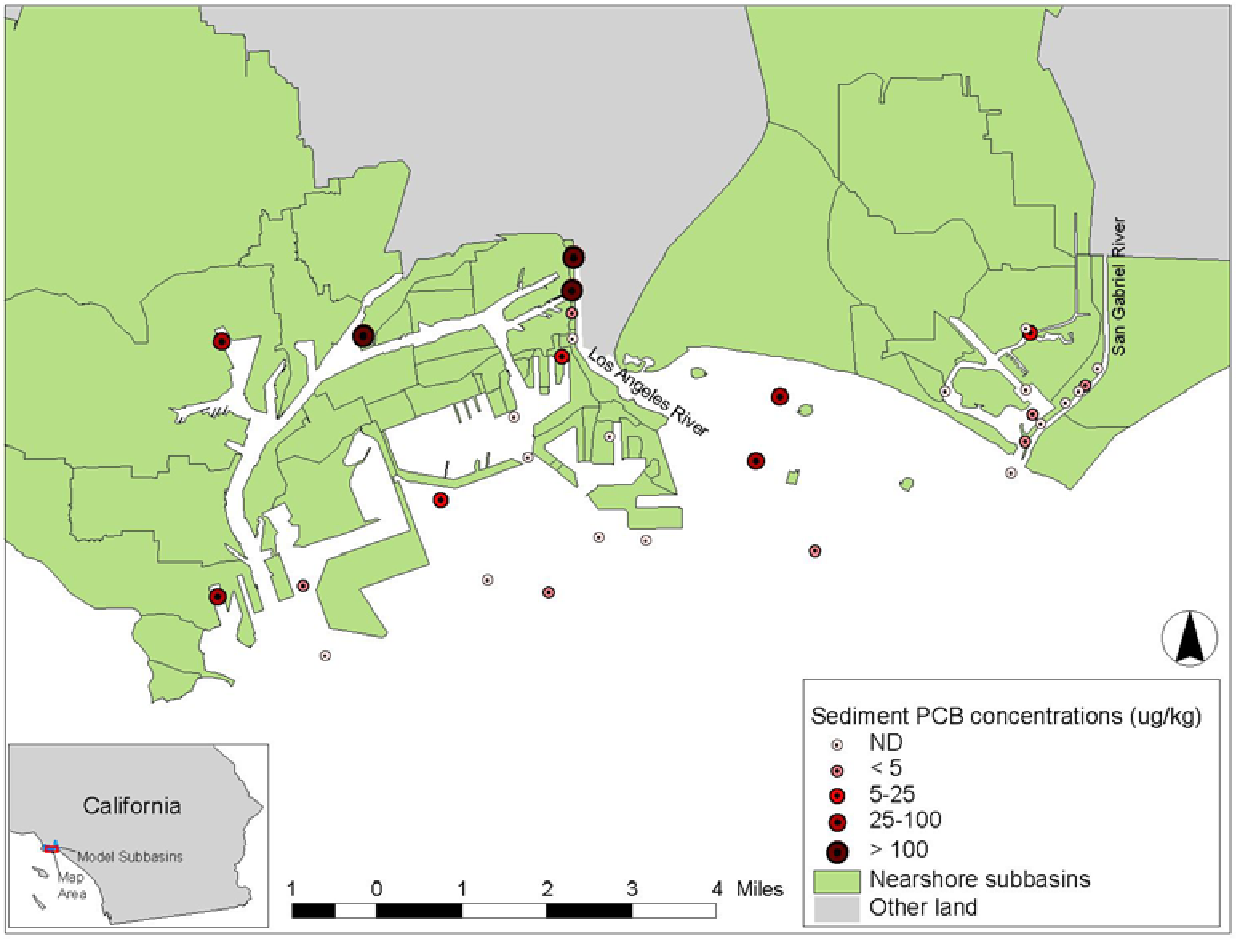

Figure 9. PCBs Gradients at the Harbor Bight 03 Sampling Stations

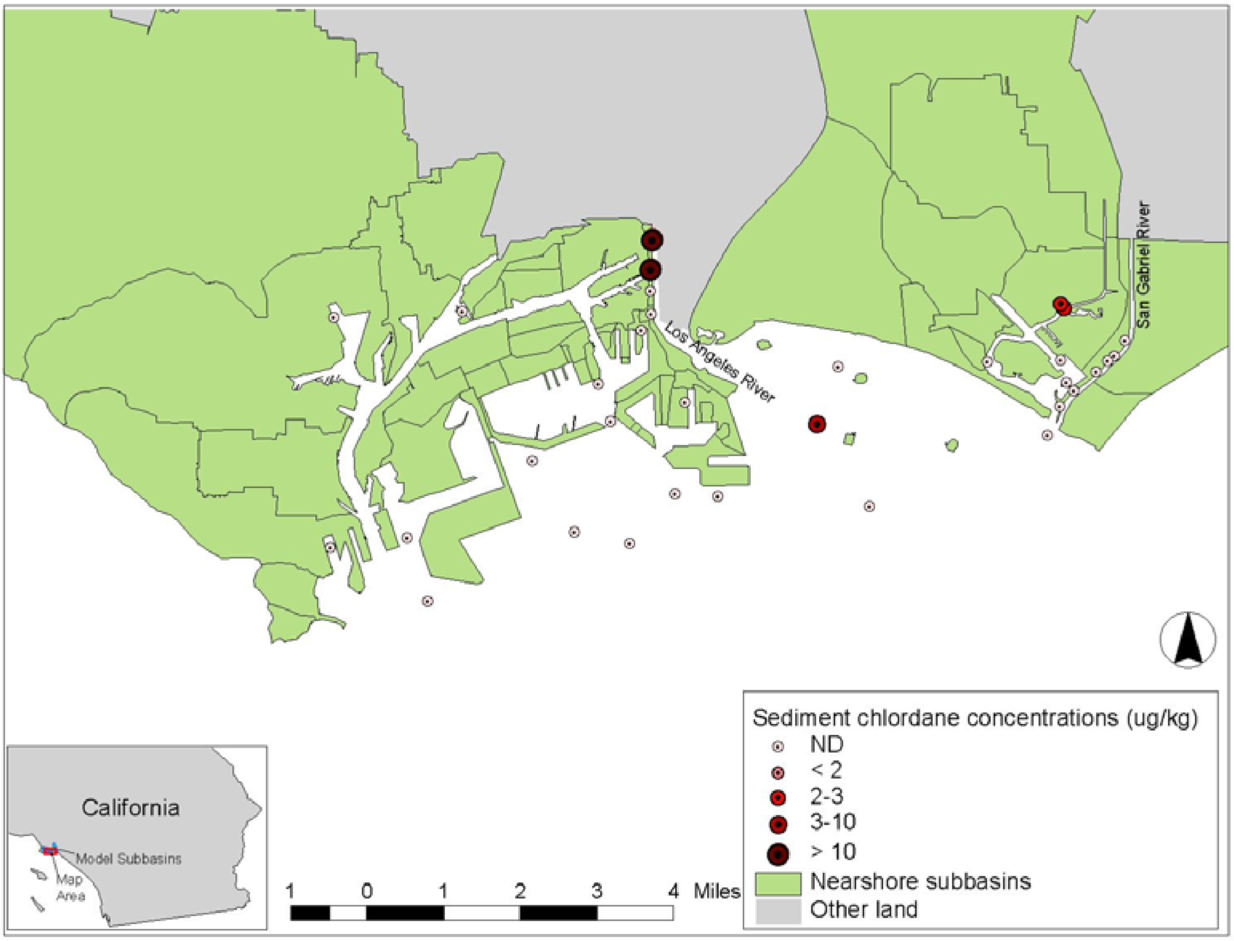

Figure 10. Chlordane Gradients at the Harbor Bight 03 Sampling Stations

Each subwatershed was assigned a representative station based on geographic proximity (see Figure 11 for a map identifying the station assigned to each subwatershed). Specifically, the station closest to the subwatershed or the mouth of the reach was assigned to that particular subwatershed and the associated sediment concentration would be applied. The sediment concentration value from the Bight 03 data will be multiplied by the subwatershed's in-stream sediment concentrations, resulting in an estimated in-stream concentration of DDT, PCBs, and chlordane. For non-detected results, one-half of the Bight 03 detection limit was assigned as the representative sediment concentration for that subwatershed.

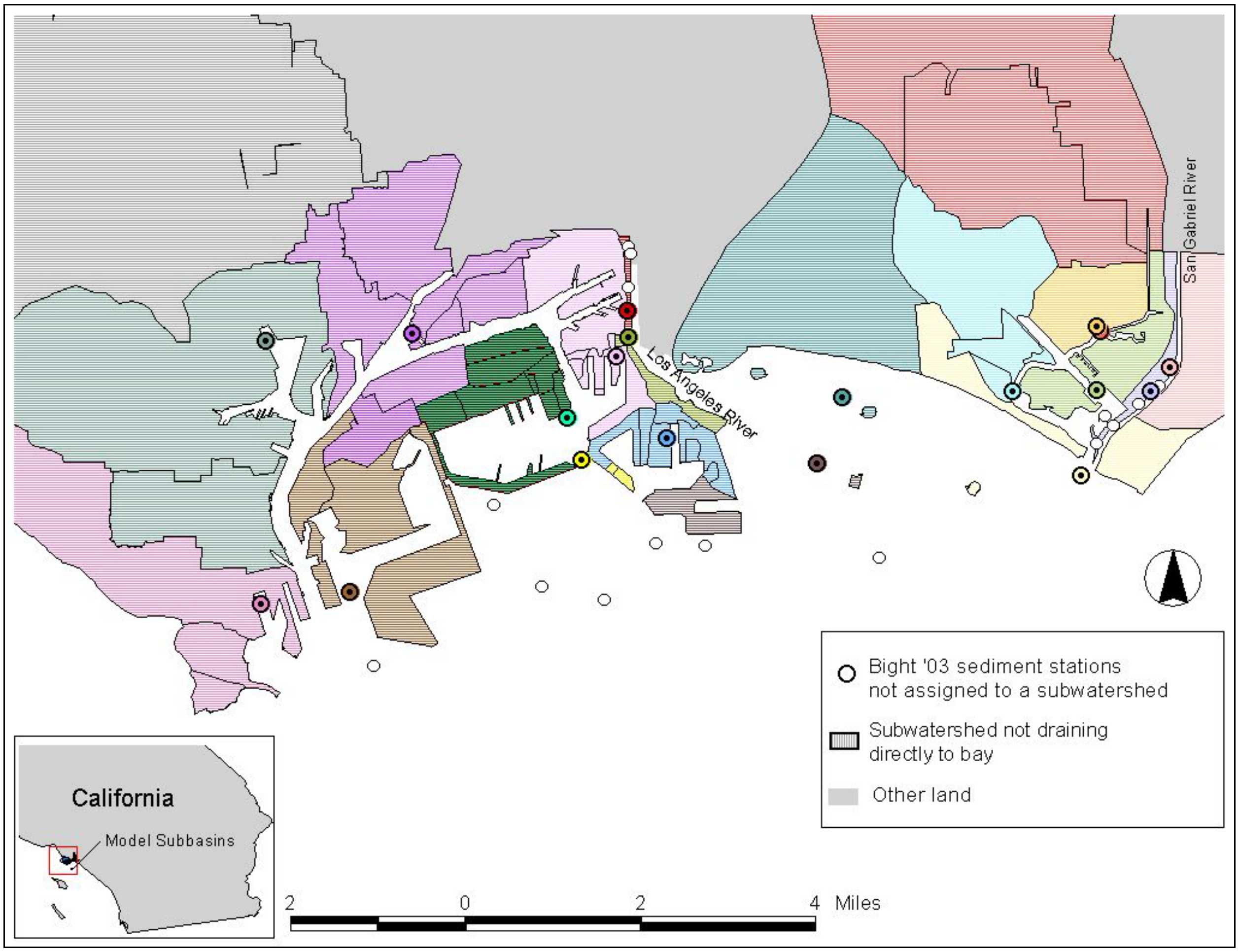

Figure 11. Bight 03 Monitoring Stations Assigned to the Nearshore Model Subwatersheds

Table 5 presents the DDT, PCBs, and chlordane sediment concentrations for Bight 03 station 4210, which was assigned to the Forest subwatershed. These concentrations were multiplied by the variable TSS values from the LSPC model to obtain a water column concentration, which are presented in Figure 12. The graphs showing concentrations for each pollutant are on the left side of the figure. These graphs illustrate the predicted concentrations based on the modeled TSS and the Bight 03 sediment concentrations. The observed DDT, PCBs, and chlordane data at the Forest stormwater sampling station were non-detects, so the associated detection limits are also presented. In all cases the detection limits associated with LADPW data were much too high to show on the graph. For PCBs and chlordane, the predicted concentrations were below the observed POLA/POLB detection limits; however, for DDT, the predicted concentration was initially below the observed detection limit, but it increased as the TSS peaked during the storm. The resulting loads are also presented for each pollutant on the right side of Figure 12. This methodology will be applied to the model output from all other model subwatersheds (LA River, San Gabriel River, and other nearshore subwatersheds).

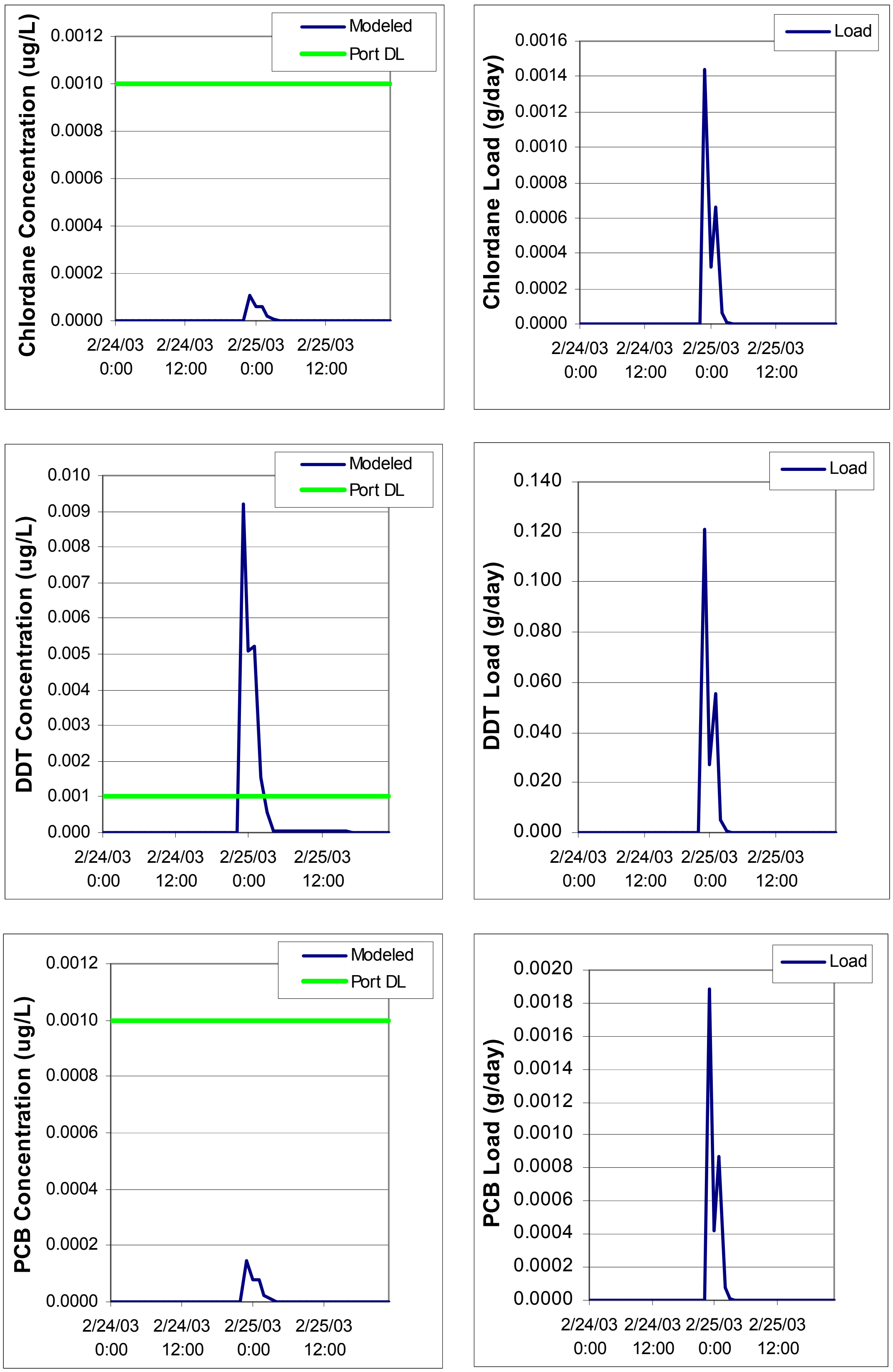

Figure 12. Modeled and Observed Chlordane, DDT, and PCBs Concentrations and Loads for the Forest Subwatershed

DRY WEATHER

During dry weather, watershed flows are dominated by wastewater reclamation plants (WRP) effluent, groundwater inflow, and discharges to the stormwater conveyance system from illicit connections, excess irrigation, and other residential and commercial practices (McPherson et al., 2005a; Stein and Ackerman, in press). Although dry-weather flows are substantially less than stormflows in the region, their long-term contribution of pollutants can be substantial (McPherson et al., 2005a; Stein et al., 2003). Model representation of dry-weather pollutant loads in the region for calculation of TMDLs has been typically based on steady-state assumptions for flows and pollutant concentrations (LARWQCB, 2005a and 2005c; Tetra Tech, Inc, 2005b). Thus far, these approaches have relied heavily on robust monitoring efforts in LAR (Ackerman et al., 2003), SGR (Ackerman et al., 2005b), and Ballona Creek (Stein and Tiefenthaler, 2005). Results of these studies, combined with dry-weather monitoring performed at LADPW mass emissions sites, can be extrapolated for prediction of pollutant loads from the remaining watersheds of the Harbors and SPB.

Assumptions for steady-state, dry-weather flows are based on a combination of monitoring data and simplified methods based on land use. For estimation of dry-weather river flows into estuaries of LAR and SGR modeled in the current study, we will use average flows reported in monitoring results. Similar monitoring efforts have not been performed for most nearshore areas, so additional assumptions are required for prediction of dry-weather loads from these areas.

A regional comparison of dry-weather flows performed by Stein and Ackerman (in press) provides insight into patterns for dry urban runoff in the region. For six watersheds in the LA Region, measured flows were reported for multiple sampling events. These watersheds include the LAR, SGR, Coyote Creek, San Jose Creek, Walnut Creek, and Ballona Creek. Ballona Creek was monitored during a single day during the dry season, whereas the remaining watersheds were monitored twice during consecutive dry seasons. Dry flows in LAR, SGR, Coyote Creek, and San Jose Creek were influenced by WRP effluent flows. For each watershed, Stein and Ackerman summarized the relative contribution of flows from WRPs, stormdrains, and upstream boundaries of the study domain. Adding the measured boundary and stormdrain flows, and averaging the combined flows for those watersheds with two sampling events, we determined a single representative flow for each watershed. These flows represent a combination of all runoff, baseflow, etc. that does not include WRP contributions. A regression analysis of these flows verses urban area (summation of commercial, high-density residential, low-density residential, industrial, and mixed urban land uses) in each watershed revealed a noticeable relationship ($R^2 = 0.96$) between dry-weather flows and urban land use (Figure 13). We will estimate dry-weather flows for all nearshore areas based on the following Equation 2 determined through the regression analysis.

$$Flow = 0.0024 \times (UrbanArea) \qquad (2)$$

where, *Flow* is in m^3/s and *UrbanArea* is in km^2. The Forest subwatershed has an urban area of 0.1589 km^2. Using this equation, the estimated dry-weather flow for the Forest subwatershed is 0.0004 m^3/s or 0.014 cubic feet per second (cfs).

Assumptions for dry-weather flows for LAR and SGR will be consistent with assumptions used in the metals TMDLs developed for each watershed (LARWQCB, 2005c; draft San Gabriel River TMDL currently under development).

To calculate pollutant loads based on the above flow predictions, additional assumptions for water quality concentrations are required. The availability of water quality data varies by pollutant; therefore, resulting assumptions for water quality predictions are discussed separately.

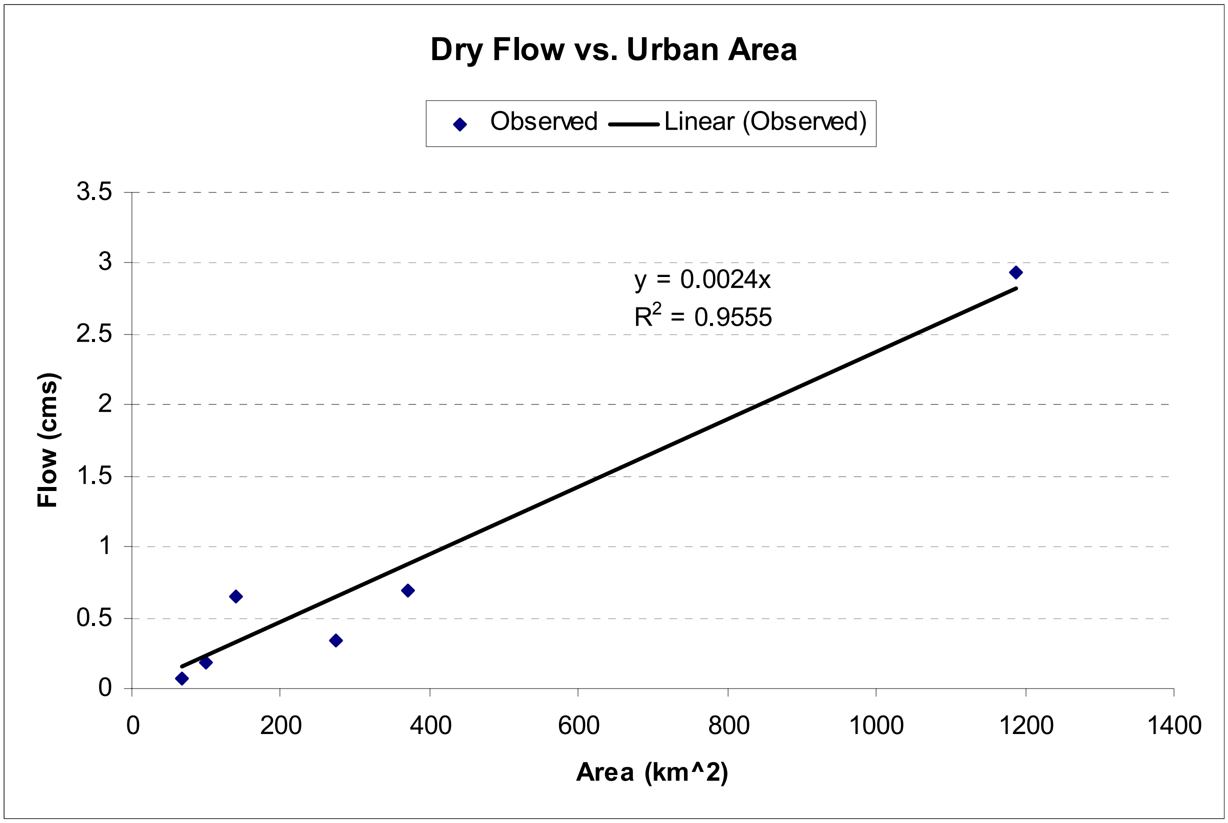

Figure 13. Regression Analysis of Dry-Weather Flows Verses Urban Area

Metals

Average dry-weather in-stream and stormdrain concentrations of metals in LAR and SGR, based on dry-weather monitoring organized by SCCWRP, are reported by Ackerman et al. (2003), Ackerman et al. (2005b), and Stein and Ackerman (in press). These results were used to estimate existing conditions for dry-weather loadings in LAR and SGR to support development of metals TMDLs for the rivers (LARWQCB, 2005c; draft San Gabriel River TMDL currently under development). For the current study, similar assumptions for metals concentrations can be made for flows to estuaries from LA River and San Gabriel River. Specifically, dry-weather metals concentrations will be based on an average or measurements performed by SCCWRP (Ackerman et al., 2003; Ackerman et al., 2005b) and LADPW mass emissions data located near the mouths of the respective watersheds.

The LADPW mass emission data (LADPW, 2006) was assumed to be most representative of the LA Region since it incorporates runoff from various land uses and were therefore used to estimate average representative metals concentrations for the nearshore subwatersheds. To determine average dry-weather metals concentrations, the mass emissions data across all monitoring stations in the region were averaged. An analysis was performed to compare different methodologies to address the non-detected values in these data. Specifically, the average metals concentrations were calculated while replacing non-detects with zero, one-half the detection limit, and the detection limit. The average concentrations associated with these three options are presented in Table 6. This table also presents the associated loads for the Forest subwatershed, which were calculated by multiplying the various concentrations by the constant dry-weather flow (0.014 cfs). This methodology will be applied to the dry-weather flows for all other nearshore model subwatersheds.

Table 6. Dry-Weather Metals Concentrations and Loads Included in Loading Analyses[a] (LADPW, 2006)

Metals Values	Value for Non-Detected Samples		
	0	1/2 Detection Limit	Detection Limit
Region-wide Concentrations			
Average Copper Concentration (ug/L)	19.92	20.33	20.74
Average Lead Concentration (ug/L)	1.92	3.31	4.70
Average Zinc Concentration (ug/L)	85.50	95.66	105.83
Forest Subwatershed Loads			
Average Copper Load (g/day)	0.66	0.67	0.68
Average Lead Load (g/day)	0.06	0.11	0.16
Average Zinc Load (g/day)	2.82	3.15	3.49

a. Concentrations and loads are based on an average of LADPW Mass Emissions data.

PAHs, DDT, Chlordane, and PCBs

No detectable levels of organic pollutants are typically observed during dry weather based on LADPW mass emissions stations in the region (LADPW, 2006). In the absence of local detectable levels, assumptions may be based on values from studies performed outside of the LA Region. However, organic pollutant concentrations are assumed to be zero for dry-weather runoff since evidence suggests that sources are not prevalent during these conditions.

REFERENCES

Ackerman, D., and K. Schiff. 2003. Modeling Stormwater Mass Emissions to the Southern California Bight. Southern California Coastal Water Research Project Annual Report 2001-2002. Westminster, CA.

Ackerman, D., K. Schiff, H. Trim, and M. Mullin. 2003. Characterization of Water Quality in the Los Angeles River. *Bulletin of the Southern California Academy of Sciences*, 102:1-17.

Ackerman, D., K. Schiff, and S. Weisberg. 2005a. Evaluating HSPF in an Arid, Urban Watershed. *Journal of the American Water Resources Association*, 41(2):477-486.

Ackerman, D., E. Stein, and K. Schiff. 2005b. Dry-season Water Quality in the San Gabriel River Watershed. Southern California Coastal Water Research Project Annual Report 2003-2004. Westminster, CA.

Bicknell, B. R., J. C. Imhoff, J. John L. Kittle, T. H. Jobes and J. Anthony S. Donigian. 2001. Hydrological simulation program - FORTRAN, Version 12. AQUA TERRA Consultants. Mountain View, California. 873 pp.

Buffleben, M., K. Zayeed, D. Kimbrough, M. Stenstrom, and I. Suffet. 2002. Evaluation of Urban Non-point Source Runoff of Hazardous Metals Entering Santa Monica Bay, California. *Water Science and Technology*, Vol. 45, No. 9, pp 263-268.

CALTRANS. 2003. A Review of Contaminants and Toxicity Associated With Particles in Stormwater Runoff. California Department of Transportation, Sacramento, CA.

Hoffman, E., J. Latimer, G. Mills, and J. Quinn. 1982. Petroleum Hydrocarbons in Urban Runoff from a Commercial Land Use Area. *Journal WPCF*, Vol. 54, No. 11.

LADPW. 2006. Historic mass emissions data in Los Angeles County from 5/11/88 to 7/18/2005, provided by the Los Angeles County Department of Public Works, Alhambra, CA.

LARWQCB. 2005a. Total Maximum Daily Load for Metals in Ballona Creek. Los Angeles Regional Water Quality Control Board, Los Angeles, CA.

LARWQCB. 2005b. Total Maximum Daily Load for Toxic Pollutants in Ballona Creek Estuary. Los Angeles Regional Water Quality Control Board, Los Angeles, CA.

LARWQCB. 2005c. Total Maximum Daily Load for Metals – Los Angeles River and Tributaries. Los Angeles Regional Water Quality Control Board, Los Angeles, CA.

Lau, S., and M. Stenstrom. 2005. Metals and PAHs Adsorbed to Street Particles. *Water Research*, 39 (2005) 4083-4092.

Longanathan, B., K. Irvine, K. Kannan, V. Pragatheeswaran, and K. Sajwan. 1997. Distribution of Selected PCB Congeners in the Babcock Street Sewer District: A Multimedia Approach to Identify PCB Sources in the Combined Sewer Overflows (CSOs) Discharging to the Buffalo River, New York. *Archives of Environmental Contamination and Toxicology*, 33, 130-140.

McPherson, T., S. Burian, M. Stenstrom, H. Turin, M. Brown, and I. Suffet. 2005a. Trace Metal Pollutant Load in Urban Runoff from a Southern California Watershed. *Journal of Environmental Engineering*, July 2005.

McPherson, T., S. Burian, M. Stenstrom, H. Turin, M. Brown, and I. Suffet. 2005b. Dry and Wet Weather Flow Nutrient Loads from a Los Angeles Watershed. *Journal of the American Water Resources Association*, August 2005.

SCCWRP. 2004. Model Development for Trace Metals Loading in an Arid Urbanized Watershed. Prepared for USEPA Region 9 and the Los Angeles Regional Water Quality Control Board by the Southern California Coastal Water Research Project, Los Angeles, CA.

SARWQCB. 2000. Final Problem Statement for the Total Maximum Daily Load for Toxic Substances in Newport Bay and San Diego Creek. Santa Ana Regional Water Quality Control Board, Riverside, CA.

Shen, J., A. Parker, and J. Riverson. 2004. A New Approach for a Windows-based Watershed Modeling System Based on a Database-supporting Architecture. *Environmental Modelling and Software*, July 2004.

Stein. E., and D. Ackerman. In press. Dry Weather Water Quality Loadings in Arid, Urban Watersheds. *Journal of American Water Resources Association*.

Stein, E., D. Ackerman, and K. Schiff. 2003. Watershed-based Sources of Contaminants to San Pedro Bay and Marina del Rey: Patterns and Trends. Report prepared for the Los Angeles Contaminated Sediments Task Force by the Southern California Coastal Water Research Project, Westminster, CA.

Stein, E., and L. Tiefenthaler. 2005. Characterization and Source Identification of Dry-weather Metals and Bacteria in Ballona Creek. Southern California Coastal Water Research Project Annual Report 2003-2004. Westminster, CA.

Stein, E., L. Tiefenthaler, and K. Schiff. 2005. Watershed-based Sources of Polycyclic Aromatic Hydrocarbons in Urban Stormwater. *Environmental Toxicology and Chemistry*, Vol. 25, No. 2, pp 373-385.

Tetra Tech, Inc, 2004. Model Development for Simulation of Wet-Weather Metals Loading from the Los Angeles River Watershed. Report prepared for USEPA Region 9 and the Los Angeles Regional Water Quality Control Board by Tetra Tech, Inc, San Diego, CA.

Tetra Tech, Inc, 2005a. Model Development for Simulation of Wet-Weather Metals Loading from the San Gabriel River Watershed. Report prepared for USEPA Region 9 and the Los Angeles Regional Water Quality Control Board by Tetra Tech, Inc, San Diego, CA.

Tetra Tech, Inc, 2005b. Model Development for Simulation of Dry-Weather Metals Loading from the San Gabriel River Watershed. Report prepared for USEPA Region 9 and the Los Angeles Regional Water Quality Control Board by Tetra Tech, Inc, San Diego, CA.

Yunker, M., R. Macdonald, R. Vingarzan, R. Mitchell, D. Goyette, and S. Sylvestre. 2002. PAHs in the Frasier River Basin: A Critical Appraisal of PAH Ratios as Indicators of PAH Source and Composition. *Organic Geochemistry*, 33 (2002) 489-515.