APPENDIX C - Technical Memorandum

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San Diego County Hydromodification Management Plan (HMP)

Subject: Summary of HSPF Modeling Reports in Southern California

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Hydromodification Technical Advisory Committee (TAC)

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This Technical Memorandum provides a summary of HSPF modeling reports in the Southern California region. As required in standards set forth by Regional Water Quality Control Board Order R9-2007-0001 Provision D.1.g, the analysis of hydromodification flow control facilities must use continuous simulation hydrologic models covering the full rainfall record. The HSPF software package is the industry standard for continuous simulation hydrologic modeling, though HEC-HMS and SWMM also provide public domain continuous modeling alternatives.

In preparing computer models to assess storm water controls and meet Interim Hydromodification Criteria, rainfall loss parameters describing soil characteristics, land cover descriptions, and slope should be validated to prove consistency with the local environment and climatic conditions. The goal, with regard to the San Diego HMP, is to develop a set of appropriate parameter ranges to account for variations of these key parameters.

This memo describes our key observations regarding each of the reviewed reports (Table 1) and describes a set of follow-on steps to utilize the results of this review into the development of HSPF models for the San Diego Hydromodification Management Plan (HMP). In conducting this review, particular interest was focused in determining how local and regional HSPF models simulate the pervious land surface (characterized by PERLND/PWATER parameters in HSPF) for various combinations of soils and land use types, because this component of hydrologic modeling is typically the most variable and difficult to describe.

In addition to the reports listed below, other TMDL reports from San Diego County and elsewhere in Southern California were reviewed. However, only those reports with a substantial description of modeling activities were summarized in the table.

TABLE 1 - Summary of HSPF Modeling Reports for Southern California

No.	Title	Authors	Date	Summary/Comments
1	TMDL to Reduce Bacterial Indicator Densities at Santa Monica Bay Beaches During Wet Weather (Preliminary Draft)	LA Regional Water Quality Control Board / Tetra Tech	June 21, 2002	• Combination of hydrologic and water quality modeling to estimate bacterial loadings to Santa Monica Bay • HSPF/Loading Simulation Program in C++ (LSPC) model was calibrated and validated using stream flow data collected on Malibu Creek and Ballona Creek. (LSPC is a recoded C++ version of HSPF) • No HSPF model parameters included in report
2	Technical Report – TMDLs for Indicator Bacteria in Baby Beach and Shelter Island Shoreline Park	San Diego Regional Water Quality Control Board / Tetra Tech	June 11, 2008	• Combination of hydrologic and water quality modeling • HSPF/LSPC model was calibrated to flow data collected in Aliso Creek and Rose Creek. • Calibrated infiltration rates were reported for Natural Resources Conservation Survey (NRCS) Group A, B, C, and D soils (in Appendix F). However, it is unclear if these rates correspond to specific HSPF model parameters. • This issue of how to apply the calibrated infiltration rates should be addressed through correspondence with study authors.
3	Evaluating HSPF in an Arid, Urbanized Watershed (in Journal of the American Water Resources Association, 2005, p477-486	Drew Ackerman, Kenneth Schiff, Stephen Weisburg (SCCWRP)	February 2005	• HSPF was used to simulate hydrologic processes in arid region, e.g., precipitation on dry soils, effect of irrigation. • Model was calibrated to gauge data collected in lower reaches of Malibu Creek. The calibration set aggregated the soil and land cover variations in the watershed (i.e., spatially “lumped” parameters). • Pervious land surface (PWATER) parameters were included in the paper (see Appendix A).

No.	Title	Authors	Date	Summary/Comments
4	TMDL for Indicator Bacteria Project I – Beaches and Creeks in the San Diego Region	San Diego Regional Water Quality Control Board / Tetra Tech	December 12, 2007	• HSPF/LSPC model parameters were selected from regional calibration. Calibration efforts used daily average stream flows as the baseline calibration condition. • Appendices describe the regional calibration process. The modeling files have been provided by the San Diego Regional Water Quality Control Board.
5	Lake Elsinore and Canyon Lake Nutrient Source Assessment (Final Report) for Santa Ana Watershed Authority	Tetra Tech, Inc.	January 2003	• HSPF/LSPC model was calibrated and validated using USGS gauging site data in the San Jacinto watershed • Model simulated pollutant loading to Lake Elsinore and Canyon Lake • Pervious land surface (PWATER) parameters were not published in the report.

Summary and Recommended Follow-On Activities

The technical reports listed in Table 1 demonstrate that a variety of detailed HSPF modeling studies have occurred in the past 10 years in Southern California. However, adapting these modeling efforts for use on the San Diego HMP project will require additional work. This is because the reports listed above did not publish their HSPF parameter sets, with the exception of the Ackerman study (see No. 3 above), which published a set of generalized parameters that aggregate or “spatially lump” the contributions of different soil/land use combinations in the upper watershed.

The HSPF model described in the Ackerman paper simulates all soil and land use combinations using a single composite parameter set. In a follow-on conversation in May 2008, Drew Ackerman explained that the “Arid, Urbanized” HSPF model was calibrated only to gauge data in the lower Santa Monica Bay watershed, because the model’s purpose was to estimate pollutant loadings to area beaches and water bodies. His study was understandably less focused on characterizing the variation in runoff rates and volumes among the different land uses in the upper portions of the watershed. Additionally, the effect of upstream surface water impoundments would have made the development of an accurate, detailed calibration at the sub-catchment scale very difficult to achieve. Unfortunately, this “spatially lumped” parameter set is of limited usefulness for the purpose of the HMP project, given the need to develop parameter sets that describe a variety of common soil and land use combinations.

Continuous simulation modeling files associated with the report titled “Bacteria Project I – Beaches and Creeks in the San Diego Region” (February 2009) include infiltration parameter calibrations based upon 15-20 years of average daily flows. Per discussions with Tetra Tech in November 2008 and January 2009, ongoing work related to TMDL development for San Diego County lagoons may also prove to be beneficial to the future San Diego HMP model parameter estimation effort.

The consultant team will continue to review additional HSPF studies in preparation for development of a hydromodification flow control sizing tool for San Diego County. Recently, we have had discussions with Tony Donigian of Aquaterra, who has prepared numerous HSPF models and serves as an EPA-sponsored trainer for HSPF modeling.

Aquaterra's HSPF modeling efforts in Southern California have focused on Ventura County. Aquaterra has requested permission from Ventura County to allow the San Diego HMP consultant team to review modeling results and input data sets for the Ventura County HSPF modeling efforts.

To better utilize the existing HPSF models for use in the San Diego HMP project, we recommend conducting the following activities while the Regional Board reviews the Draft HMP submittal:

- Contact the authors of the studies listed in Table 1 (and others provided by Tetra Tech, Aquaterra and SCCWRP) to obtain copies of the HSPF pervious land surface (PERLND/PWATER) parameter sets. We have discussed this issue with SCCWRP, Tetra Tech, and Aquaterra and have planned future follow-up correspondence to clarify assumptions made in past studies.
- Relate the HSPF parameters to NRCS soil groups and common land use types. Develop a range of recommended HSPF input parameters that could be used to characterize the range of soil and land use types common to San Diego County.

The results could be presented to the Regional Board prior to April 24, 2009.

Appendix A: Example HSPF Pervious Land Surface Model Parameters

The following model parameters were published in the Drew Ackerman et al. paper described in Table 1. The specific values were selected by calibrating an HSPF model to flow monitoring data in the Santa Monica Bay watershed, specifically on Malibu Creek. The values represent a composite of the various upstream soils and land uses.

Table 2. Model parameters utilized for modeling of Santa Monica Bay.

Pervious Parameters		Value	Units
Fraction of Remaining E-T from Active Groundwater Storage	AGEWTP	0.05	None
Basic Groundwater Recession Rate	AGWRC	0.92	1/d
Fraction of Remaining E-T from Baseflow	BASETP	0.05	None
Interception Storage Capacity	CEPSC	0.25	cm
Fraction of Groundwater to Deep Aquifer	DEEPFR	0.40	None
Forest Fraction	FOREST	0.0	%
Infiltration Equation Exponent	INFEXP	2.0	None
Ratio between the Maximum and Mean Infiltration Capacities	INFILD	2.0	None
Infiltration Capacity	INFILT	0.10	cm/hr
Interflow Inflow Parameter	INTFW	1.50	None
Interflow Recession Parameter	IRC	0.70	1/d
Groundwater Recession Flow Coefficient	KVARY	7.6	1/cm
Overland Flow Length	LSUR	61	m
Lower Zone E-T Parameter	LZETP	0.70	None
Lower Zone Nominal Storage	LZSN	25	cm
Manning's n for Overland Flow	NSUR	0.20	Complex
Temperature Maximum for Evapotranspiration (E-T)	PETMAX	1.7	°C
Temperature that E-T is Zero	PETMIN	-1.1	°C
Overland Flow Slope	SLSUR	0.03	None
Upper Zone Nominal Storage	UZSN	3.0	cm

APPENDIX B: BASINS HSPF Parameter Information

Additional reference material can be located in the document titled, *"BASINS Technical Notice 6, Estimating Hydrology and Hydraulic Parameters for HSPF,"* prepared the U.S. Environmental Protection Agency and dated July 2000. This document provides details regarding pervious and impervious land hydrology parameters along with flow routing parameters. Parameter and value range summary tables are included in the document.

Pervious Land Hydrology (PWATER) Parameters

The HSPF hydrology parameters of PWATER are divided into four sections, titled PARM1-4. PARM1 is a series of checks to outline any monthly variability versus constant parameter values within the simulated algorithm; whereas, PARM2 and 3 are a series of climate, geology, topography, and vegetation parameters that require numerical values to be inputted.

PARM2 involves the basic geometry of the overland flow, the impact of groundwater recession, potential snow impact due to forest cover and the expected infiltration and soil moisture storage. The main parameters of groundwater recession are KVARY and AGWRC. The infiltration and soil moisture storage parameters are INFILT and LZSN.

PARM3 involves the impact of climate temperature during active snow conditions, a wide range of evaporation parameters due to the variability of the onsite soil and existing vegetation and subsurface losses due to groundwater recharge or the existing geology. The main evaporation parameters are INFEXP, INFILD, BASETP and AGWETP. The parameter for subsurface loss is DEEPFR which accounts for one of only three major losses from the PWATER water balance (i.e. in addition to evaporation, and lateral and stream outflows).

PARM4 involves the flow and hydrograph characteristics, the expectation of rain interception due to the inherent moisture storage capacity from existing vegetation, land use and/or near surface soil conditions and evaporation due to the root zone of the soil profile. The main interception parameters are CEPSC and UZSN. The parameter for evaporation as a primary function of vegetation is LZETP.

PARM2

KVARY - Groundwater recession flow parameter used to describe non-linear groundwater recession rate *(/inches) (initialize with reported values, then calibrate as needed*).

KVARY is usually one of the last PWATER parameters to be adjusted; it is used when the observed groundwater recession demonstrates a seasonal variability with a faster recession (i.e. higher slope and lower AGWRC values) during wet periods, and the opposite during dry periods. Value ranges are shown in the Summary Table. Users should start with a value of 0.0 for KVARY, and then adjust (i.e. increase) if seasonal variations are evident. Plotting daily flows with a logarithmic scale helps to elucidate the slope of the flow recession.

AGWRC **-** Groundwater recession rate, or ratio of current groundwater discharge to that from 24 hours earlier (when KVARY is zero) *(/day) (estimate, then calibrate)*.

The overall watershed recession rate is a complex function of watershed conditions, including climate, topography, soils, and land use. Hydrograph separation techniques can be used to estimate the recession rate from observed daily flow data (such as plotting on a logarithmic scale). Value ranges are shown in the Summary Table.

INFILT **-** Index to mean soil infiltration rate *(in/hr); (estimate, then calibrate).*

In HSPF, INFILT is the parameter that effectively controls the overall division of the available moisture from precipitation (after interception) into surface runoff. Since INFILT is not a maximum rate nor an infiltration capacity term, it's values are normally much less than published infiltration rates, percolation rates (from soil percolation tests), or permeability rates from the literature. In any case, initial values are adjusted in the calibration process.

INFILT is primarily a function of soil characteristics, and value ranges have been related to SCS hydrologic soil groups (Donigian and Davis, 1978, p.61, variable INFIL) as follows:

SCS Hydrologic Soil Group	INFILT Estimate		Runoff Potential
	(in/hr)	(mm/hr)	
A	0.4 - 1.0	10.0 - 25.0	Low
B	0.1 - 0.4	2.5 - 10.0	Moderate
C	0.05 - 0.1	1.25 - 2.5	Moderate to High
D	0.01 - 0.05	0.25 - 1.25	High

An alternate estimation method that has not been validated is derived from the premise that the combination of infiltration and interflow in HSPF represents the infiltration commonly modeled in the literature (e.g. Viessman et al, 1989, Chapter 4). With this assumption, the value of 2.0*INFILT*INTFW should approximate the average measured soil infiltration rate at saturation, or mean permeability.

LZSN **-** Lower zone nominal soil moisture storage *(inches), (estimate, then calibrate).*

LZSN is related to both precipitation patterns and soil characteristics in the region. Viessman, et al, 1989, provide initial estimates for LZSN in the Stanford Watershed Model (SWM-IV, predecessor model to HSPF) as one-quarter of the mean annual rainfall plus four inches for arid and semiarid regions, or one-eighth annual mean rainfall plus 4 inches for coastal, humid, or subhumid climates. These formulae tend to give values somewhat higher than are typically seen as final calibrated values; since LZSN will be adjusted through calibration, initial estimates obtained through these formulae may be reasonable starting values.

PARM3

INFEXP **-** Exponent that determines how much a deviation from nominal lower zone storage affects the infiltration rate (HSPF Manual, p. 60) *(initialize with reported values, then calibrate).*

Variations of the Stanford approach have used a POWER variable for this parameter; various values of POWER are included in Donigian and Davis (1978, p. 58). However, the vast majority of HSPF applications have used the default value of 2.0 for this exponent. Use the default value of 2.0, and adjust only if supported by local data and conditions.

INFILD **-** Ratio of maximum and mean soil infiltration capacities *(initialize with reported value).*

In the Stanford approach, this parameter has always been set to 2.0, so that the maximum infiltration rate is twice the mean (i.e. input) value; when HSPF was developed, the INFILD parameter was included to allow investigation of this assumption. However, there has been very little research to support using a value other than 2.0. Use the default value of 2.0, and adjust only if supported by local data and conditions.

DEEPFR **-** The fraction of infiltrating water which is lost to deep aquifers (i.e. inactive groundwater), with the remaining fraction (i.e. 1-DEEPFR) assigned to active groundwater storage that contributes baseflow to the stream *(estimate, then calibrate).*

It is also used to represent any other losses that may not be measured at the flow gage used for calibration, such as flow around or under the gage site. Watershed areas at high elevations, or in the upland portion of the watershed, are likely to lose more water to deep groundwater (i.e. groundwater that does not discharge within the area of the watershed), than areas at lower elevations or closer to the gage. DEEPFR should be set to 0.0 initially or estimated based on groundwater studies, and then calibrated, in conjunction with adjustments to ET parameters.

BASETP **-** ET by riparian vegetation as active groundwater enters streambed; specified as a fraction of potential ET, which is fulfilled only as outflow exists *(estimate, then calibrate).*

Typical and possible value ranges are shown in the Summary Table. If significant riparian vegetation is present in the watershed then non-zero values of BASETP should be used. If riparian vegetation is significant, start with a BASETP value of 0.03 and adjust to obtain a reasonable low-flow simulation in conjunction with a satisfactory annual water balance.

AGWETP **-** Fraction of model segment (i.e. pervious land segment) that is subject to direct evaporation from groundwater storage, e.g. wetlands or marsh areas, where the groundwater surface is at or near the land surface, or in areas with phreatophytic vegetation drawing directly from groundwater. This is represented in the model as the fraction of remaining potential ET (i.e. after base ET, interception ET, and upper zone ET are satisfied), that can be met from active groundwater storage *(estimate, then calibrate).*

If wetlands are represented as a separate PLS (pervious land segment), then AGWETP should be 0.0 for all other land uses, and a high value (0.3 to 0.7) should be used for the wetlands PLS. If wetlands are not separated out as a PLS, identify the fraction of the model segment that meets the conditions of wetlands/marshes or phreatophytic vegetation and use that fraction for an initial value of AGWETP. Like BASETP, adjustments to AGWETP will be visible in changes in the low-flow simulation, and will effect the annual water balance. Follow above guidance for an initial value of AGWETP, and then adjust to obtain a reasonable low-flow simulation in conjunction with a satisfactory annual water balance.

<u>PARM4</u>

CEPSC **-** Amount of rainfall, in inches, which is retained by vegetation, never reaches the land surface, and is eventually evaporated (*estimate, then calibrate*). Typical guidance for CEPSC for selected land surfaces is provided in Donigian and Davis (1978, p. 54, variable EPXM) as follows:

Land Cover	Maximum Interception (in)
Grassland	0.10

Cropland	0.10 – 0.25
Forest Cover, light	0.15
Forest Cover, heavy	0.20

LZETP **-** Index to lower zone evapotranspiration (unitless) (*estimate, then calibrate*).

LZETP is a coefficient to define the ET opportunity; it affects evapotranspiration from the lower zone which represents the primary soil moisture storage and root zone of the soil profile. LZETP behaves much like a 'crop coefficient' with values mostly in the range of 0.2 to 0.7; as such it is primarily a function of vegetation. Typical and possible value ranges are shown in the Summary Table, and the following ranges for different vegetation are expected for the 'maximum' value during the year:

Land Cover	Input Coefficient
Forest	0.6 - 0.8
Grassland	0.4 - 0.6
Row Crops	0.5 - 0.7
Barren	0.1 - 0.4
Wetlands	0.6 - 0.9

HSPF HYDROLOGY PARAMETERS AND VALUE RANGES

NAME	DEFINITION	UNITS	RANGE OF VALUES: TYPICAL MIN	TYPICAL MAX	POSSIBLE MIN	POSSIBLE MAX	FUNCTION OF ...	COMMENT
PWAT - PARM2								
FOREST	Fraction forest cover	none	0.0	0.50	0.0	0.95	Forest cover	Only impact when SNOW is active
LZSN	Lower Zone Nominal Soil Moisture Storage	inches	3.0	8.0	2.0	15.0	Soils, climate	**Calibration**
INFILT	Index to Infiltration Capacity	in/hr	0.01	0.25	0.001	0.50	Soils, land use	**Calibration**, divides surface and subsurface flow
LSUR	Length of overland flow	feet	200	500	100	700	Topography	Estimate from high resolution topo maps or GIS
SLSUR	Slope of overland flow plane	ft/ft	0.01	0.15	0.001	0.30	Topography	Estimate from high resolution topo maps or GIS
KVARY	Variable groundwater recession	1/inches	0.0	3.0	0.0	5.0	Baseflow recession variation	Used when recession rate varies with GW levels
AGWRC	Base groundwater recession	none	0.92	0.99	0.85	0.999	Baseflow recession	**Calibration**
PWAT - PARM3								
PETMAX	Temp below which ET is reduced	deg. F	35.0	45.0	32.0	48.0	Climate, vegetation	Reduces ET near freezing, when SNOW is active
PETMIN	Temp below which ET is set to zero	deg. F	30.0	35.0	30.0	40.0	Climate, vegetation	Reduces ET near freezing, when SNOW is active
INFEXP	Exponent in infiltration equation	none	2.0	2.0	1.0	3.0	Soils variability	Usually default to 2.0
INFILD	Ratio of max/mean infiltration capacities	none	2.0	2.0	1.0	3.0	Soils variability	Usually default to 2.0
DEEPFR	Fraction of GW inflow to deep recharge	none	0.0	0.20	0.0	0.50	Geology, GW recharge	Accounts for subsurface losses
BASETP	Fraction of remaining ET from baseflow	none	0.0	0.05	0.0	0.20	Riparian vegetation	Direct ET from riparian vegetation
AGWETP	Fraction of remaining ET from active GW	none	0.0	0.05	0.0	0.20	Marsh/wetlands extent	Direct ET from shallow GW
PWAT - PARM4								
CEPSC	Interception storage capacity	inches	0.03	0.20	0.01	0.40	Vegetation type/density, land use	Monthly values usually used
UZSN	Upper zone nominal soil moisture storage	inches	0.10	1.0	0.05	2.0	Surface soil conditions, land use	Accounts for near surface retention
NSUR	Manning's n (roughness) for overland flow	none	0.15	0.35	0.05	0.50	Surface conditions, residue, etc.	Monthly values often used for croplands
INTFW	Interflow inflow parameter	none	1.0	3.0	1.0	10.0	Soils, topography, land use	**Calibration,** based on hydrograph separation
IRC	Interflow recession parameter	none	0.5	0.7	0.3	0.85	Soils, topography, land use	Often start with a value of 0.7, and then adjust
LZETP	Lower zone ET parameter	none	0.2	0.7	0.1	0.9	Vegetation type/density, root depth	**Calibration**

APPENDIX C: Summary of Parameter Calibration Efforts by Tetra Tech (Beaches and Creeks TMDL Report for San Diego RWQCB – December 2007)

Model assumptions for stream reach infiltration rates were derived through calibration based on data collected within the reaches of Aliso Creek (11 stations) and Rose Creek (6 stations). In the model, infiltration rates vary by soil type. Stream infiltration was calibrated by adjusting a single infiltration value, which was varied for each soil type by factors established from literature ranges (USEPA, 2000) of infiltration rates specific to each soil type. The final resulting infiltration rates were 1.368 in/hr (Soil Group A), 0.698 in/hr (Soil Group B), 0.209 in/hr (Soil Group C) and 0.084 in/hr (Soil Group D). The infiltration rates for Soil Groups B, C and D are within the infiltration range given in literature (Wanielisata et al., 1997). The result for Soil Group A is below the range given in Wanielisata et al. (1997), however this result only represented one watershed in this TMDL study.