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Pollutant Loadings Generated by Nonpoint Sources in the Santa Monica Bay Drainage Basin: A Case Study

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Abstract. The Santa Monica Bay provides a number of beneficial uses. To protect these, best management practices that control urban runoff should be utilized. In order to determine the types of best management practices to be used, an estimation of nonpoint source pollutant loads generated by the Santa Monica Drainage Basin is needed. Local land use, runoff, and chemical data were used to estimate pollutant loads from nonpoint source pollution and pollutant loads by land use in three subbasins of the Santa Monica Drainage Basin: namely, Ballona Creek, Malibu Creek, and Topanga Creek. The time period of available data was May 1988 to May 1990.
The study found that (1) nonpoint source pollutant loads may be derived from local data, (2) pollutant loads by land use could not be derived because of lack of data, (3) an evaluation of seasonal pollutant loads fails to show significant trends.
It is possible to evaluate pollutant loads that need control by best management practices in the Santa Monica Bay Drainage Basin by utilizing the pollutant load estimates of this study with pollutant impacts to beneficial uses.

Key words: Nonpoint source pollutants, BMPs, best management practices.

1. Introduction

1.1. LOCATION

The Santa Monica Drainage Basin covers approximately 1036 km^2. It is bordered on the north by the Santa Monica Mountains, on the east by Griffith Park, on the south by Point Fermin, and on the west by Ventura County. A drainage basin is "the area of land that drains water, sediment, and dissolved material to a common outlet" (Dunne, 1978). The common outlet for the Santa Monica Drainage Basin is the Santa Monica Bay. The Santa Monica Drainage Area is further divided into 28 subbasins. This study will focus on three of those subbasins (Ballona Creek, Malibu Creek, and Topanga Creek), which comprise 63% of the total basin area.

1.2. STATEMENT OF PROBLEM

The Santa Monica Bay provides access to 50 miles of coastline for nine million residents. The last 25 years has marked a growing concern for the Bay. In July 1988, the Bay became one of 17 waterbodies nationwide to be included in the National

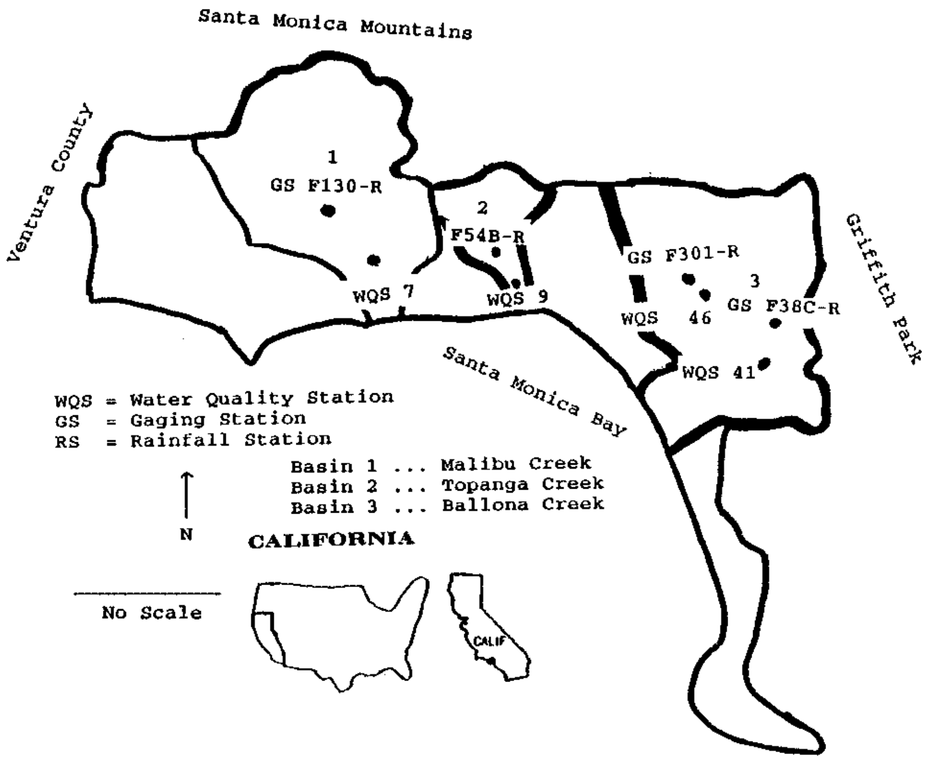

Fig. 1. Location map for the Santa Monica Drainage Basin. The study area is Malibu Creek, Topanga Creek, and Ballona Creek basin, map from Stenstrom (1992).

data to estimate nonpoint source pollutant loads generated from the study area and to estimate pollutant loads for land use types. Seasonal fluctuations for one station 41/F38C-R in Ballona Creek were evaluated. Results of the study were compared with two other studies (Stenstrom, 1992 and SCAG, 1988) in order to discern similarities and differences between the studies and note any significant trends.

2. Methods of Data Collection and Analysis

A detailed account of the data used to estimate pollutant loads is summarized below.

2.1. RUNOFF DATA

There are four runoff gaging stations located within the Santa Monica Drainage Basin (Figure 1). Data from the gaging stations are maintained by the Los Angeles County Department of Public Works, Hydraulic and Water Conservation Division. Data were collected for the time period of May 1988 to May 1990. The above time period was selected because the dates correspond to a consistent amount of data for concentration values of pollutant constituents, and also because it contains an

Topanga Creek is open while Ballona Creek subbasin is a mixture of urbanized land uses.

2.4. CHEMICAL METHODS

The water quality monitoring stations were chosen from an IBM compatible PC-based program known as SMBURD (Santa Monica Bay Urban Runoff Database) (Stenstrom, 1992). These particular monitoring stations were chosen because of their land use characteristics and consistency of data available (consistent meaning that the data were obtained from one source). A dependable amount of monitoring took place between May 1988 and May 1990 (dependable meaning that measurements were taken once a month, at each of the four stations). All samples are grab samples in that they are a result of sampling at a specific point in time.

The following constituents were analyzed: total zinc, total copper, total lead, oil and grease, total phosphate, nitrate, nitrite, fecal coliform, and total coliform. These constituents were chosen because, (1) the four stations contain a consistent amount of data for the above time period, (2) the NPDES stormwater permit requires that the above constituents be monitored (excluding coliform bacteria), (3) coliform levels have been a constituent of particular concern due to closures of local beaches because of elevated levels.

Concentration values were obtained from SMBURD. The original source of the database for the concentration values for this study are a result of monitoring by the Los Angeles Department of Public Works.

Concentration values were available once a month in the time period of May 1988 to May 1990. It was necessary to extrapolate values for each day during this time period. Two methods were used to estimate these daily values. Method 1, using a Linear Basis, consisted of estimating daily values by linear interpolation. Each day that monitoring took place is considered a separate point of a continuous pieceursi linear interpolation function. The specified time period had 29 points. Every two points were considered as a separate line. The slope and intercept, for each pieceursi segment, is determined using the following formulas for each line

$$m = \sum(x_i - \bar{x})(y_i - \bar{y}) / \sum(x_i - \bar{x})^2 \,, \tag{1}$$

where

m = slope,

$\bar{x}$ = average value of x,

x_i = x value,

$\bar{y}$ = average value of y,

y_i = y value;

and

$$b = \bar{y} - m(\bar{x}) \,, \tag{2}$$

TABLE I. Water quality monitoring stations with corresponding gaging stations and basin identification

Water quality station	Gaging station	Basin identification
7	F130–R	Malibu Creek
9	F54B–R	Topanga Creek
41	F38C–R	Ballona Creek
46	F301–R	Ballona Creek

TABLE II. Linkage of SCAG and NURP land use designations (Stenstrom, 1992)

SCAG	NURP
Single-family	Residential sites
Multi-family	Mixed sites
Other urban	Mixed sites
Unknown	Mixed sites
Commercial	Commercial sites
Public	Commercial sites
Light industrial	Commercial sites
Open	Open sites

or $K = 0.086$.

For coliform measurements, L was in units of MPN (Most Probable Number) per day. The K value is equal to 2.44×10^9. To determine the pollutant load in kg/yr the pollutant loads for each day were summed for the monitoring period. The formula to determine L in kg/yr is

$$L(\mathrm{kg/yr}) = \sum_{i=1}^{365} L\,. \tag{6}$$

Table I summarizes how gaging stations and water quality monitoring stations were paired to determine loadings for their respective subbasins. The load (kg/yr) was determined for both interpolations of Method 1 and Method 2. A time period was chosen that would reflect an equal number of wet and dry seasons. This time period was May 1988–May 1990, which also maximizes available water quality and runoff data.

2.6. ESTIMATING POLLUTANT LOADS BY LAND USE

Pollutant loads by land use were calculated by solving three simultaneous linear equations. Equation (7) was used for each of the three study areas.

$$L = \mathrm{ALU1\,(R1)} + \mathrm{ALU2\,(R2)} + \mathrm{ALU3\,(R3)}\,, \tag{7}$$

TABLE IV. Median EMC (μg/L) by land use (EPA, 1983)

Pollutant	Median EMC (μg/L) by land use				
	Residential	Mixed	Commercial	Open	% RPD[a]
Zinc	135	154	226	195	13
Lead	144	114	104	30	9
Copper	33	27	29	–	7
Oil and grease[b]	3	22	22	22	0
Nitrate + nitrite	736	558	572	543	2
Phosphorus	383	263	201	121	27

[a] RPD (relative percent deviation) between two closest values, this is mixed and commercial for each pollutant except zinc which is between residential and mixed.
[b] Stenstrom (1992).

and water quality stations. The load contributions from this point source were calculated using:

$$\mathrm{Lpt} = (A)\,(B)\,(C)\,(D)\,, \tag{8}$$

where
Lpt = contribution of point source in kg/month,
A = average creek discharge for the month in, m^3/sec,
B = average pollutant concentration for the month in mg/l,
C = constant value of 86.0 to convert to kg/month, and
D = number of days in the month.

This formula was used for each month of the study time period. To calculate kg/yr, the loads for the specified months of the years were summed. This point source contribution was substracted from results obtained from Equation (6) using runoff and concentration data from water quality station 7 and gaging station F130-R. The resultant value is the nonpoint source contribution to Malibu Creek. This total load was used in Equation (7).

3. Results and Discussion of Results

Loads for each year are represented by an average of the two methods (Table V). The 1988 to 1989 period is represented by May 1988 to April 1989 and 1989 to 1990 is represented by May 1989 to April 1990. There is no basis to prefer one method to the other. A way to evaluate the relationship between loadings with respect to pollutant and location is by use of a ranking system. A ranking of 1 in the location category corresponds to the highest value of total pollutant loads based on an average of Methods 1 and 2 between the four locations. A ranking of 4 corresponds to the lowest value of total pollutant loads based on an average of Methods 1 and 2 between the four locations. A ranking of 1 in the pollutant category means the highest value of total pollutant loads based on an average of

TABLE VI. Ranking by location for time periods 1988–1989 and 1989–1990

Pollutant	Station 41/F38C-R		Station 46/F301-R		Station 7/F130-R		Station 9/F54B-R	
	88–89	89–90	88–89	89–90	88–89	89–90	88–89	89–90
Zinc	1	1	2	2	3	3	4	4
Lead	1	2	2	1	3	3	4	4
Copper	1	1	3	2	2	3	4	4
Oil and grease	1	1	2	2	3	3	4	4
Nitrate	2	2	3	3	1	1	4	4
Nitrite	1	1	2	2	3	3	4	4
Phosphate	2	2	3	3	1	1	4	4
Fecal coliform	1	1	2	2	3	3	4	4
Total coliform	1	1	2	2	3	3	4	4

Methods 1 and 2 between all pollutants within a particular monitoring station. A ranking of 9 in the pollutant category means the lowest value of total pollutant loads based on an average of Methods 1 and 2 between all pollutants within a particular monitoring station. All rankings assume each pollutant has equivalent value. The Malibu Creek area is the sum of point (Las Virgines Municipal Water District) and nonpoint sources which is the result of using loads calculated from station 7/F301-R. The point source was included to reflect total loads generated by that particular subbasin. Within the location category (Table VI) some general observations are as follows: station 41/F38C-R ranks as number 1 78% of the time for the time period 1988–1989 (this means if you look at station 41/F38C-R it has a ranking of 1 for seven out of the nine pollutants) and number one 67% of the time for the time period 1989–1990; station 46/F301-R ranks as number two 67% of the time for both time periods; station 7/F130-R ranks number three 67% and 78% respectively for the time periods 1988–1989 and 1989–1990; and station 9/F54B-R ranks number four 100% for both time periods. The two instances that station 7/F130-R does not rank number three in the location category is with respect to nitrate and phosphate, and it ranks as number 1. Broader categories define the effect certain pollutants have on the environment. For example, fecal and total coliform belong to the biological category; nitrate, phosphate, and nitrite belong to the nutrient category; lead, zinc, and copper are associated with heavy metals; and oil and grease is in its own category (Driscoll, 1987). Nitrite is considered a nutrient but its loads differ from phosphate and nitrate values. This is probably due to the degradation of nitrite to nitrate in the nitrogen cycle. For the purpose of this study it will be considered as a single category. In an attempt to identify certain trends pollutants will be grouped by these broader categories. The ranking system will again be used. The following observations about the various categories were made for the time period of 1988–1989: biological ranks as number 1 and 2 100% of the time; nutrients rank 3 and 4 100% of the time; oil and grease ranks 5 for 75% of the time; heavy metals rank 6, 7, and 8 for 92% of the time; nitrite

TABLE VII. Calculated loads for mixed/commercial and open land use categories in the study area

Pollutant	Mixed/ commercial 88–89	Mixed/ commercial 89–90	% RPD	Open 88–89	Open 89–90	% RPD
Zinc (kg/ha year)[a]	0.15	0.16	7	–0.010	–0.007	–
Lead (kg/ha year)	0.45	0.020	128	0.009	–0.003	–
Copper (kg/ha year)	0.12	0.027	183	0.022	–0.002	–
Oil and grease (kg/ha year)	0.71	9.5	172	–0.090	0.078	–
Nitrate (kg/ha year)	12	–	–	0.063	–	–
Phosphate (kg/ha year)	3.2	2.1	42	0.12	0.17	–
Fecal coliform (MPN/ha year)	4.00E+05	4.40E+15	200	–5.9E+14	–6.4E+14	–
Total coliform (MPN/ha year)	7.71E+13	6.40E+12	169	–1.1E+13	–1.64E+11	–

[a] Zinc land use is commercial.

TABLE VIII. Calculated loads for residential land use categories in the study area

Pollutant	Residential 88–89	Residential 89–90	% RPD
Zinc (kg/ha year)[a]	0.078	0.056	33
Lead (kg/ha year)	–0.17	0.022	–
Copper (kg/ha year)	–0.066	0.022	–
Oil and grease (kg/ha year)	0.76	–0.22	–
Nitrate (kg/ha year)	–4.66	–	–
Phosphate (kg/ha year)	–0.55	–1.3	–
Fecal coliform (MPN/ha year)	4.52E+15	4.97E+15	9
Total coliform (MPN/ha year)	4.72E+18	1.29E+17	189

[a] Zinc land use is mixed/residential.

being a majority, of time: biological > nutrients > heavy metals. Oil and grease is only available at Ballona Creek for 1984; no comparisons was made for it. It is seen that similar trends exist between pollutants for the study model and State of the Bay results. The same discrepancy, no majority ranking being assigned, also exists for nitrite. Ranking by location indicates no dominant station in 1983. In 1984, Ballona Creek is ranked the same as the study model, i.e. Ballona Creek ranked as number 1 in all categories except nitrate and phosphate.

Differences between the model and State of the Bay may be due to the method of calculating pollutant loads. State of the Bay assumes average concentrations and average runoff values for the entire year. The model uses an average concentration and runoff value for each day. The model's estimations should minimize the error

TABLE X. Comparison of model versus Stenstrom

Location	Pollutant	Model[a] 1988	Model[a] 1989	Stenstrom[b]	%RPD[e]	%RPD[f]
Malibu Creek[c]	Zinc (kg)	62	78	7294	292	196
Topanga Creek	Zinc (kg)	192	207	1199	189	141
Ballona Creek[d]	Zinc (kg)	2219	1863	18525	216	163
Malibu	Lead (kg)	781	14	3677	194	198
Topanga Creek	Lead (kg)	789	21	614	37	187
Ballona Creek	Lead (kg)	2568	439	13966	201	188
Malibu	Copper (kg)	205	8	1156	209	197
Topanga Creek	Copper (kg)	224	44	200	15	127
Ballona Creek	Copper (kg)	527	594	3688	197	145
Malibu	Phosphate (kg)	5.35E+03	3.58E+03	1.44E+04	117	120
Topanga Creek	Phosphate (kg)	2.70E+04	2.46E+04	1.84E+03	141	172
Ballona Creek	Phosphate (kg)	2.79E+04	5.62E+03	2.74E+04	2	132
Malibu	Nitrate + Nitrite (kg)	1.87E+04	0.00	2.46E+04	41	200
Topanga Creek	Nitrate + Nitrite (kg)	8.39E+04	2.49E+04	4.63E+03	210	137
Ballona Creek	Nitrate + Nitrite (kg)	7.35E+04	5.71E+04	5.85E+04	24	2
Malibu	Oil and grease (kg)	2.59E+02	1.20E+04	7.53E+04	257	145
Topanga Creek	Oil and grease (kg)	2.59E+02	1.20E+04	2.93E+03	53	121
Ballona Creek	Oil and grease (kg)	1.73E+04	9.84E+04	5.53E+05	240	140

[a] Average value of interpolation Methods 1 and 2.
[b] Modified NURP model.
[c] Point source contribution is subtracted in Model because Stenstrom (1992) did not include point sources.
[d] Stenstrom load estimates for Ballona Creek correspond to the summation of Model values at station 41/F38C-R and 46/F301-R.
[e] RPD between Model 1988–1989 and Stenstrom (1992).
[f] RPD between Model 1989–1990 and Stenstrom (1992).

Differences in the Strenstrom (1992) and the model could be due to the following: (1) Stenstrom (1992) does not include dry weather data nor storms under 0.254 cm of rain, (2) 90th percentile EMC values were used in Stenstrom (1992) which were based on limited data from the Santa Monica Bay area, (3) flow data were based on a typical percent value of imperviousness Stenstrom (1992).

Quantitative comparisons of State of the Bay and Stenstrom (1992) to the study model showed large differences in relative percent deviations. Quantitative comparisons between Stenstrom (1992) and State of the Bay also show a large relative percent deviation between the two studies. Quantitatively, each of the three models are not comparable, but qualitatively they indicate similar trends for both pollutant ranking and location rankings. Pollutant trends are as follows: biological > nutrients > heavy metals. Oil and grease and nitrite rankings are unresolved because of placement of these two categories in different ranking for three studies. Location trends are as follows: Ballona Creek > Malibu Creek > Topanga Creek.

To control the amount of nonpoint source pollution entering the Santa Monica Bay, it is recommended that (1) results of this study be used as an estimation of locations and pollutants that need control by best management practices, (2) that a local monitoring program be established that can identify pollutant loads over a significant amount of time and help evaluate the results of best management practices, (3) further research of land use and associated pollutant loads for the local area be conducted. A discussion of what best management practices are appropriate for the study area is beyond the scope of this study. References that discuss best management practices that are suitable for California may be found in the publications of State of California (1992). References that discuss controlling nonpoint source pollution are Lawrence (1987), Corder (1988), and Goyen (1987).

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