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LAND USE CONSIDERATIONS IN REDUCING OIL AND GREASE IN URBAN STORMWATER RUNOFF

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ABSTRACT

This article describes the input of oil and grease (hydrocarbons) to San Francisco Bay from the local drainage areas. Results of two earlier experimentally based studies were used to develop the parameters for a material balance model for the entire San Francisco Bay local drainage area. Land use data and growth scenarios were determined from census data and local government projections. Total oil and grease emissions are estimated for several scenarios, including growth until the year 2000. Present emissions from urban runoff appear to be slightly less than point source emissions. For the anticipated growth occurring over the next fifteen years, the model predicts an 8 to 15 percent increase in oil and grease emissions depending on the rainfall conditions. Mitigation techniques are discussed.

Stormwater runoff from urban areas has been shown to carry substantial pollutant loads. Yet, controlling the quality of runoff has received relatively little attention. Difficulties in assessing major sources of pollution, determining responsible parties, and developing effective control measures are all contributing reasons for this low level of activity. However, as the relative contribution of pollution from runoff grows, so does the need for control. Examination of the

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distribution pattern of oil and grease within watersheds reveals a potential for substantial pollutant removal through mitigation measures directed at relatively small land areas.

Past research indicates that stormwater runoff carries substantial quantities of oil and grease. The National Academy of Science reported that about 31 percent of the total oil and grease input to the oceans is from runoff [1]. A number of recent studies indicate particularly significant loading of oil and grease in runoff from urban areas [2-8]. A few researchers have quantified input from local stormwater with respect to other sources. Connel reported that urban runoff was the predominant source of oil and grease loading to the Hudson Rarity Estuary (New York) [9]. An average of about 37,000 kg of oil and grease flowed into the estuary daily from urban runoff (about 40% of the total oil and grease load), with sewage discharges being the next highest input source at 35,000 kg/day. Similarly, Whipple and Hunter reported that urban runoff is anticipated to carry about 40 percent of the total oil and grease load into the Delaware Estuary [12] (although in 1975 it carried only 16% to 18% of the total load due to high releases from petroleum refineries). Eganhouse and Kaplan's work on extractable hydrocarbons in runoff and municipal wastewaters in the Los Angeles area showed that in a drier area, municipal discharge may carry a relatively larger fraction of the total pollutant load [11, 12].

While it is clear that substantial quantities of oil and grease are discharged with urban stormwater, little is known about its environmental effects on the receiving water. For example, in the San Francisco Bay area (Bay Area), aromatic hydrocarbons have regularly been found in Bay water, and fish and shellfish tissue [13-15]. Other investigators report that hydrocarbons, particularly the aromatic fractions, may be contributing to the current decline of the striped bass (moreone *saxatiles*) and other fisheries [16]. Yet causal relationships have not been established, so hydrocarbons only can be implicated as a contributing factor to chronic environmental problems in the Bay.

Furthermore, the relative impact of oil and grease to receiving water cannot be assessed simply on the basis of the magnitude of loading, complicating efforts to assess the impact of urban stormwater runoff. In comparison to discharge of wastewater, oil and grease in urban stormwater runoff tends to vary considerably in chemical characteristics and temporal and spatial discharge patterns [12]. In a relatively dry climate, such as in the Bay Area, most of the total runoff (and total pollutant loading) from local drainages occurs over a few days during and immediately following storms. While loading is concentrated over a few days, this loading takes place through discharge from a large number of sources. In comparison, point source discharges are relatively few in number and maintain fairly consistent flow and quality.

Similarly, the inherent toxicity of oil and grease from nonpoint sources is difficult to quantify, or compare to point sources. Eganhouse and Kaplan showed in the Los Angeles, California area that hydrocarbons comprised about

51 percent of the extractable material in urban stormwater runoff while comprising only about 21 percent of the total extractable material in sewage [11, 12]. Coincident with these differences in chemical make-up are differences in toxicity. The variety of compounds characteristic of oil and grease in stormwater runoff, and the extreme toxicity of some of these compounds [10, 17, 18], makes it extremely difficult to make reliable estimates of either acute or chronic toxicity to the receiving water.

Lack of definitive knowledge of the link between a suspected pollutant and implementation of control measures has not been sufficient reason to delay implementing control strategies in other environmental areas. An obvious example is the implementation of the National Pollution Discharge Elimination System (NPDES) permit program; point sources of pollution are required to control discharge in anticipation of environmental threats. Clearly, pollutants from nonpoint sources entering receiving water in urban stormwater runoff present a similar environmental threat and present a similar need for control.

This article builds upon our previous work in the San Francisco Bay Area which demonstrated substantial quantities of oil and grease in local stormwater runoff. Monitoring data from a single mixed-used watershed (in Richmond, California) [7], and from fifteen watersheds around the Bay [19], were used to explore the implications of local runoff as a source of oil and grease. Using a simulation model, loading to the Bay is predicted, and the potential impact of mitigation techniques is explored.

MODEL DEVELOPMENT

Oil and grease concentrations in stormwater runoff from a number of watersheds draining into San Francisco Bay were examined with respect to land use. Details of the field monitoring program and quantification techniques were reported elsewhere [7, 19]. The sampling results were used with a simple simulation model to assess the extent of hydrocarbon loading from local drainages to San Francisco Bay, and to predict the impact of growth and remedial measures.

The Association of Bay Area Governments "Macroscopic" Planning Model (ABMAC) was used for oil and grease modeling [20, 21]. ABMAC is a simulation model based on simplified concepts of hydrology and water quality. The four input parameters required to use ABMAC are rainfall, land area, rational runoff coefficients, and pollutant concentration coefficients. Rational runoff coefficients are defined as the fraction of the precipitation resulting in surface water runoff for a given area.

Runoff is calculated using the rational method:

$$R = kAr$$

where,

R = runoff volume
A = land area
r = rainfall depth
k = rational runoff coefficient.

The pollutant load is calculated as the product of runoff and pollutant concentration:

$$M = CR$$

where

M = pollutant mass
C = pollutant concentration.

ABMAC is appropriate only for use as a planning model. Simplifying assumptions result in inaccuracies for predicting pollutant loading from individual storms. For example, the runoff coefficient is not constant; dry land absorbs more water than saturated land so the rational/runoff coefficient will vary during a storm and from season to season. No time lag, percolation rate or other hydrologic phenomenon are considered. Proper model use is for uniform application throughout a region over an extended time period to generate comparative data for individual land uses and loadings.

Use of a more complex model generating better estimates of loading for individual storm events would be only marginally more useful for planning purposes and would require substantially more data (and financial resources). Uncertainties regarding the relationship between oil and grease levels, chemical make-up, discharge patterns, and toxicity to receiving water limit use of the model results more than imprecision inherent in the model. Thus, the most appropriate use of the model is to predict the relative impact of growth and other changes in a watershed, rather than to provide accurate estimates of pollutant load and its effects.

Richmond Watershed

The model was calibrated initially using data from a single, mixed-use watershed in Richmond, California, draining into San Francisco Bay (Figure 1). Oil and grease levels were monitored during seven storms at five sampling stations during the winter of 1980/1981 [7]. The sampling stations were selected to provide a mix of land uses within the watershed; a description of these stations is summarized in Table 1.

The land use distribution of the entire watershed (needed for modeling the watershed mouth) was determined by examination of aerial photographs and planimetry. Land use characteristics for the four sub-watersheds upstream of the other sampling stations were determined through examination of the aerial photographs and direct observation, followed by planimetry. Six land uses were

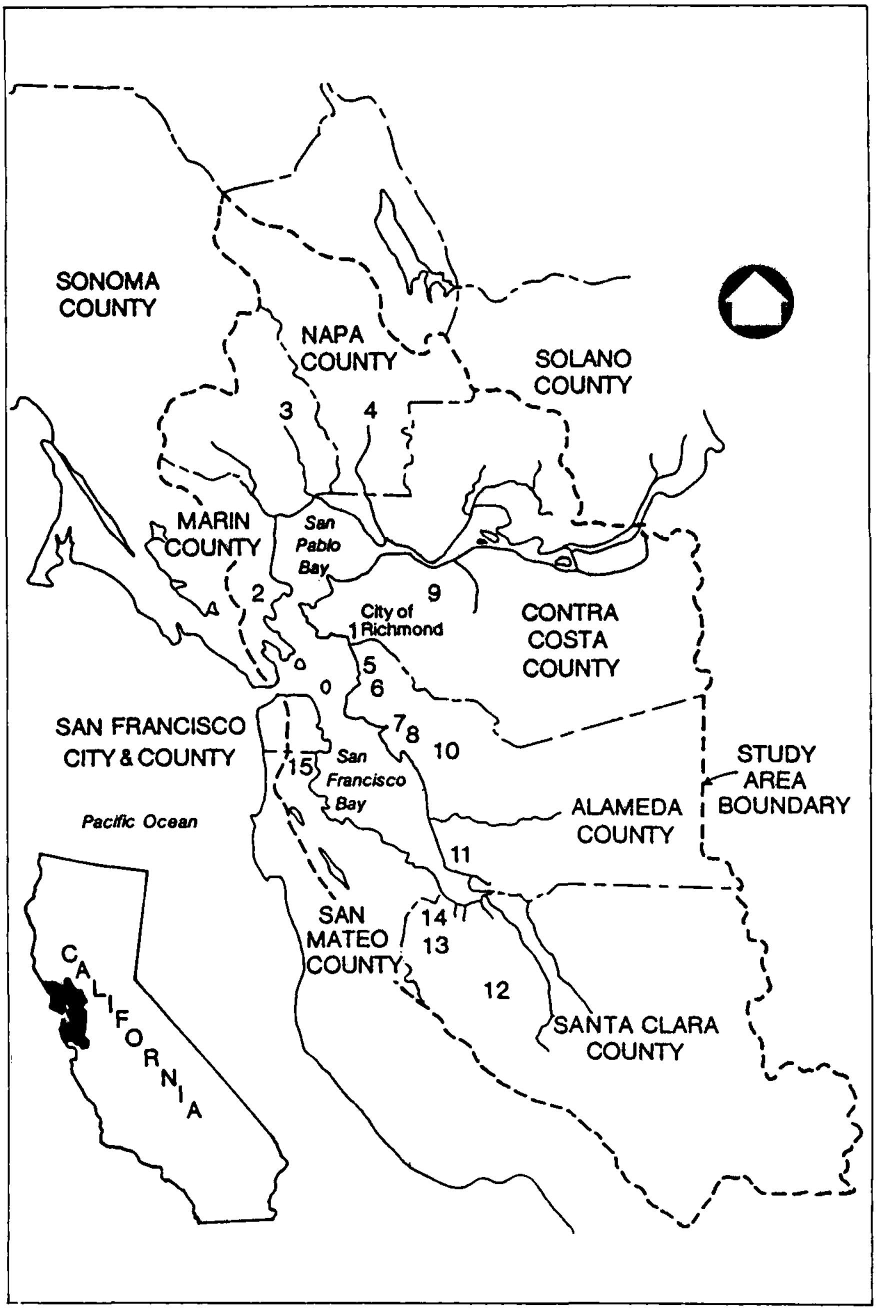

Figure 1. Sampling locations (see Table 1 for index to station number).

Table 1. Land Use Characteristics of Richmond Sampling Stations

	Station Number and Description				
Land Use (1)	*–1– Watershed Mouth Center (2)*	*–2– Supermarket Distribution Area (3)*	*–3– Parking Lot Commercial Street (4)*	*–4– Main Commercial (5)*	*–5– Residential (6)*
Fraction Undeveloped	0.052	0	0	0	0.05
Fraction Residential	0.751	0	0	0.70	0.95
Fraction Industrial	0.043	1.00	0	0	0
Fraction Commercial	0.058	0	0	0.30	0
Fraction Parking	0.060	0	1.00	0	0
Fraction Streets & Highways	0.036	0	0	0	0
Total (Km^2)	6.59	0.110	0.0028	0.081	0.530

specified: undeveloped, residential, industrial, commercial, parking lots, and freeways and railroads.

Rainfall was determined by using data obtained from the Civic Center rain gauge in downtown Richmond. Differences among rainfall at actual sites within the watershed were ignored, as they should impose relatively minor error to the model.

Runoff and oil and grease coefficients characteristic of each land use were determined from analysis of the measured flows and pollutant concentrations. Runoff coefficients were estimated for each station by dividing the measured flow volume by the total volume of rain falling in the watershed, with characteristic coefficients taken to be the average of values for the six measured storms. Rational runoff coefficients for each land use were estimated by solving Equation (3) for k_j:

$$k_i = \sum_{j=1}^{m} k_j A_{ij} / A_i \tag{3}$$

where

k_i = rational runoff coefficient for station i
A_i = total area for station i
k_j = rational runoff coefficient for land-use j
A_{ij} = area of land use j within station i
m = total number of stations.

Runoff coefficients for each land use type based on the mean runoff coefficient found at each sampling station were determined through solution of simultaneous equations following Equation (3). A coefficient of 0.02 was used for undeveloped land, based upon experience from the Los Angeles Flood Control District. Five equations with five unknowns were obtained. This procedure produced a set of parameters which estimated each storm discharge with ±50 percent, and produced mean zero residual.

A similar procedure was followed to estimate oil and grease coefficients for each land use by solving Equation (4) for C_j:

$$C_i = \sum_{j=1}^{m} C_j A_{ij} k_j / k_i A_i \qquad (4)$$

where

C_i = pollutant concentration at Station i
C_j = pollutant concentration of land use j.

A value for one coefficient had to be assumed because there were six unknowns and five equations; therefore the sixth coefficient was chosen to minimize the sum of squares error. C_j was assumed zero for undeveloped land. Near zero values for undeveloped land have been reported by others [5, 8]. Also, since undeveloped land has a low runoff coefficient, any small concentration in undeveloped land would result in minimal impact on overall watershed loading. Thus, errors in modeling resulting from assuming a coefficient of zero should be negligible.

The runoff and oil and grease coefficients estimated from this procedure and used in the model are shown on Table 2. Adjustments were made to two of the calculated runoff coefficients in order to obtain a better overall fit; the value for commercial property was slightly higher than 1, and so was set equal to 1, and the value for freeways and railroads was greater than 1 and estimated to be about

Table 2. Runoff and Oil and Grease Coefficients for Richmond Watershed

Land Use *(1)*	*Runoff Coefficient (k_j)* *(2)*	*Oil and Grease (C_j)* *(3)*
Undeveloped	0.02	0.00
Residential	0.19	3.89
Industrial	0.76	7.10
Commercial	1.00	13.13
Parking	0.94	12.81
Freeways and Railroads	0.90	7.04

0.90. Since the coefficient for freeways and railroads was the last coefficient calculated, it contained all of the error inherent in calculating the other runoff coefficients.

The model was verified by comparing measured and predicted loads for Station 1. The model both over and under estimated oil and grease mass discharge. Predicted results were within 50 percent of measured results for all seven storms.

Fifteen Bay Area Watersheds

We judged the coefficients from the Richmond study to be sufficiently accurate to examine the relative impact of controlling various land uses, and to produce a coarse estimate of annual oil and grease loading. However, we were interested in refining the coefficients and extending the study to cover the entire urban runoff load to San Francisco Bay from local development. Thus, another field study was considered in which measurements had been taken at fifteen sampling stations near the mouths of watersheds scattered around San Francisco Bay (Figure 1). These stations had been selected to include a variety of watersheds with different combinations of land uses, and with somewhat different climatic characteristics.

The watershed boundaries and areas for each of the fifteen sampling stations were determined using maps supplied by local water agencies and USGS topographical maps. Maps identifying watershed boundaries were generally available from South and Central Bay water agencies; USGS maps had to be used in the North Bay and boundaries determined from contours.

Land use within each watershed was determined primarily on the basis of 1980 census tract data [22], with area identified as residential, commercial/industrial, or undeveloped. The land use data for those portions of a watershed that contained discrete census tracts were obtained by compiling land uses for these tracts. When only a portion of a tract was within a watershed, the size of that portion was determined by planimetry. Some areas were obviously appropriate to designate as undeveloped. For developed and partially developed areas, a judgment was made whether the land use was uniform within the entire census tract based on local zoning ordinance maps, street maps, topographical maps, and on-site inspections. If the land use was uniform, the land use distribution within the entire census tract was used to proportion that portion of the tract within the watershed into land use classifications. If land use was not uniform, an estimate was made from available land use maps and on-site inspection of appropriate land use designations for that portion of the census tract within the sampled watershed. A description of those stations is summarized in Table 3.

Oil and grease were monitored at these stations during 1984 and 1985. A total of thirty-four samples were taken at these sites during periods of active rainfall, or immediately following rainfall when discharge levels were still high.

Table 3. Land Use Characteristics of Fifteen Bay Area Watersheds

	Percent Land Use			
Creek Sampled (1)	*Residential (2)*	*Commercial/ Industrial (3)*	*Undevelpped (4)*	*Total Area (km^2) (5)*
1. Richmond	73	22	5	6.6
2. Sleepy Hollow	26	0	74	8.0
3. Sonoma	2	0	98	160.0
4. Napa	10	3	87	44.0
5. Temescal	53	13	34	15.0
6. Glen Echo	51	14	35	2.2
7. Arroyo Viejo	40	12	48	16.3
8. Elmhurst	58	34	8	7.8
9. Pine-Galindo	23	5	72	68.0
10. Castro Valley	56	12	32	12.0
11. Crandall	44	15	41	3.1
12. Guadalupe	22	4	74	160.0
13. Calabazas	56	14	30	38.0
14. Matadero	5	2	93	7.5
15. Colma	38	21	41	25.0

The field monitoring program and quantification techniques were described in depth elsewhere [19].

The model was recalibrated based on the results of these measurements. Thirty-four equations were developed based on Equation (4), one for each sample. Runoff coefficients were not re-determined, since flow measurements were not taken in the second experimental study. Only three unknowns appear in these equations: oil and grease coefficients characteristic of residential, industrial/commercial, and undeveloped land use. Oil and grease concentrations associated with each land use were determined by regression.

Using land use as independent variables, and oil and grease concentration as the dependent variable for each of the thirty-four samples, resulted in a negative oil and grease coefficient for undeveloped areas. Since a negative coefficient is meaningless, it was set equal to zero, as done in modeling the Richmond watersheds. A relatively high coefficient of 21.64 characterized commercial/industrial land uses (see Table 4). This relatively high figure was heavily influenced by just a few points, with only six of the thirty-four samples having oil and grease concentration greater than 20 mg/L. Rather than ignore these high readings as outliers, they were included in the analysis as they indicate the sporadic nature of hydrocarbon loading. The coefficient for residential areas

Table 4. Oil and Grease Coefficients Determined Through Regression of Fifteen Station Sampling Data

Land Use (1)	*Coefficient* (2)	*Prob > F* (3)
Commercial/Industrial	21.05	0.0017
Residential	4.15	0.5572
Undeveloped	-3.28	0.6438
Commercial/Industrial[a]	21.64	0.0009
Residential[a]	2.73	0.6632

[a] After setting undeveloped = 0.

Table 5. Statistical Test for Variance: Oil and Grease as a Function of Land Use

		Independent Variable—Land Use		
Dependent Variable (1)	*Statistic* (2)	*Commercial/ Industrial* (3)	*Residential* (4)	*Undeveloped* (5)
Oil and Grease	r^2	0.38	0.39	0.37
	F	3.19	2.76	2.77
	Probability > F	0.0006	0.0018	0.0021

did not appear to be a reliable function of oil and grease concentration ($F <$ 0.6632), in part reflecting the overwhelming importance of the contribution from commercial/industrial areas.

The ABMAC model requires a single coefficient for oil and grease characteristic of each land use type. The difference in the oil and grease coefficients calculated using data from the two studies demonstrates that factors other than land use play an important role in determining oil and grease concentration. Results of a regression of oil and grease concentration versus land use, considering water quality measurements taken during low flow conditions in addition to during storm conditions, reveals that land use accounts for only a little more than one-third of overall variation (Table 5). However, this regression also demonstrates that oil and grease concentration varies significantly as a function of land use.

We used the ABMAC model with coefficients determined for both the Richmond watershed and the fifteen watersheds sampled throughout the region. In consideration of the extremely sporadic nature of oil and grease input and the over simplifying assumption of a single coefficient being representative of a particular land use type, interpretation of model results must be limited to predicting long term trends as opposed to single events.

MODEL APPLICATION

The local drainage to San Francisco Bay is considered to encompass about 14,500 km^2 (Figure 1). About 4 percent of the total flow into the Bay is from the local drainage, with the majority of the flow coming from the Sacramento and San Joaquin Rivers through the Delta [23]. For use with ABMAC, the local drainage has been divided into 110 modeling units, with each unit characterized by rainfall and land use. Nine precipitation gauge stations reporting to the National Oceanic and Atmospheric Administration (NOAA) provide rainfall data for these modeling units, with precipitation multiplied by correction factors to account for typical differences between rainfall in these units and at the gauges [20].

Current and projected land use data (based on the 1980 census) for each of the 110 modeling units were obtained from the census center at the Association of Bay Area Governments [22]. A correspondence table was developed by overlaying census tract maps with modeling unit maps. Where census tracts were not entirely contained within a single modeling unit, the tracts were divided on the basis of whether one-quarter, one-half, or three-quarters of a tract should be assigned to a particular unit. The land use distribution within a fraction of a unit was assumed to be identical to the distribution for the unit as a whole. The land area devoted to each use within each modeling unit was compiled as the composite of the areas from the contained census tracts.

While this procedure was fairly crude in assigning census tracts to appropriate watersheds, the significance of errors was minimized by two factors. First, large census tracts, in which area designation only to the nearest one-quarter of the tract could result in relatively large errors in assigning land to appropriate watersheds, were largely undeveloped. Since undeveloped areas contribute little oil and grease to a watershed (and for modeling purposes had been assigned an oil and grease coefficient of zero), assignment of area to a neighboring watershed will result in no difference to overall calculations of oil and grease loading. Second, assignment of land to a neighboring watershed will impact calculated values of oil and grease loading only as a function of the difference in rainfall between the two watersheds. Since neighboring watersheds usually have similar rainfall, inaccuracies caused by imprecise assignment of census tract will result in little difference to calculation of oil and grease loading.

Using this land use data for the entire Bay region, the ABMAC model was run considering average, high, and low rainfall conditions. Rainfall records from the National Oceanographic and Atmospheric Administration (NOAA) were the source of precipitation data. Average rainfall for four of the precipitation stations was determined from the monthly departure from normal rainfall data considering the period 1951-1980 given in NOAA's Climatological Data Annual

Summary. For the other five stations where similar data were not available, average rainfall was calculated as the mean of rainfall during the years 1975-1983.

High rainfall was determined by using the rainfall record from calendar year 1982, the year with the highest rainfall in the Bay area during the period 1975-1983 (and representing one of the heaviest recorded precipitation years). Similarly, 1976 was used to represent a low rainfall year, since it had the least amount of precipitation in the Bay Area during the 1975-1983 period (and one of the lowest recorded precipitation years). On occasion, rainfall data were missing for a given month. Missing rainfall data were estimated by calculating the ratio of precipitation from the current and following years at a neighboring station and using this as a factor to calculate rainfall for the missing month using data from the following year.

RESULTS

Results of running the model for the years 1985 and 2000 are shown in Table 6. Estimates of current annual oil and grease loading to the Bay based on coefficients determined by sampling fifteen watersheds are almost twice the estimates obtained by using the Richmond watershed coefficients in an average rainfall year, about 4470 metric tons/year compared to 2410 metric tons/year. The model projects that oil and grease discharge from runoff will increase in the next fifteen years by 8 to 15 percent. This level of discharge appears slightly less than that from point source dischargers, which was estimated as 5200 metric tons/year from all major local sources in 1982 [24].

Most of the projected increase in oil and grease loading over the next fifteen years is attributed to increases in commercial/industrial areas. Of the approximately 12,000 km^2 considered as local Bay watershed, about 4.0 percent additional land will be developed, of which about 87.5 percent will be residential

Table 6. Annual Oil and Grease Loading to San Francisco Bay from Local Runoff

		Oil and Grease Load (Metric Tons) *Source of Model Coefficients*	
Rainfall Condition (1)	*Year (2)*	*Richmond Watershed (3)*	*15 Bay Area Watersheds (4)*
Low	1985	1170	2190
Average	1985	2410	4470
High	1985	3650	6810
Low	2000	1290	2390
Average	2000	2770	5060
High	2000	4130	7560

and 12.5 percent will be commercial/industrial. In an average rainfall year, between 86 and 95 percent of the projected increase in oil and grease will come from the new commercial/industrial development (Table 7). Thus, imposing development controls on about 60 km^2 could eliminate almost all of the projected increase in oil and grease loading to the Bay from local runoff.

Since commercial/industrial areas have a disproportionate impact on oil and grease loading in a watershed, concentrating mitigation activities on this land use may provide an efficient means of control. Examination of a scattergram of oil and grease concentration versus commercial/industrial land development derived from the region wide sampling data reveals that high concentrations appeared sporadically, and that heavily developed areas were sometimes associated with relatively low oil and grease concentrations (Figure 2). A reasonable explanation for the sporadic nature of input is that high concentrations are due to discrete events resulting in a short lived flushing of oil and grease, and that the likelihood of event occurrence increases as a function of watershed development.

The model was run again using coefficients derived from the regional sampling data, but ignoring the two samples with highest oil and grease concentration. This was done to simulate an effective control program that minimized episodic loading to the watershed. Total loading into the Bay was predicted to decrease by approximately 30 percent; eliminating relatively few oil and grease sources (perhaps discharging only intermittently) has the potential to result in substantial water quality improvements.

DISCUSSION AND CONCLUSION

It is apparent that the majority of the oil and grease in Bay Area stormwater runoff emanates from a relatively small part of the watershed, and that this discharge is sporadic. Taking advantage of the particular land use characteristics

Table 7. Impact of Land Use Changes in Years 1985-2000 on Annual Oil and Grease Loading to San Francisco Bay from Local Runoff

Source of Additional Oil and Grease Load (1)	*Additional Oil and Grease Load (Metric Tons) Source of Model Coefficients*	
	Richmond Watershed (2)	*15 Bay Area Watersheds (3)*
Commercial/Industrial Development (58 km^2)	310	550
Residential Development (305 km^2)	50	30
Total (363 km^2)	360	580

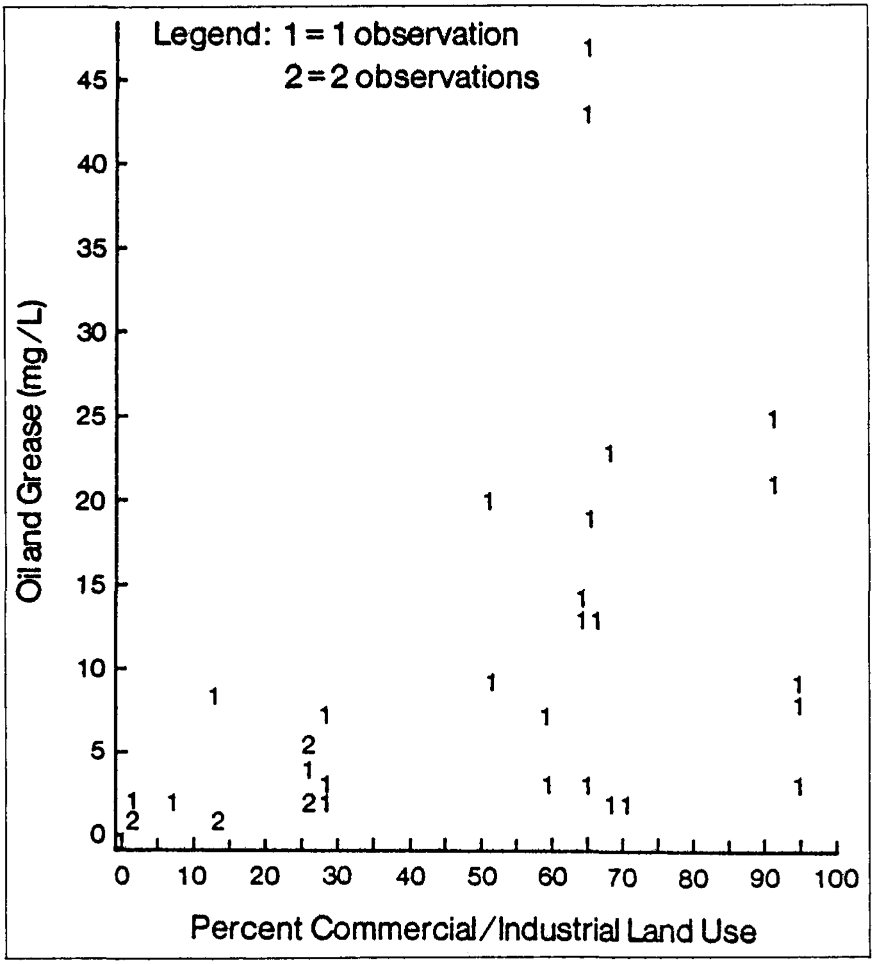

Figure 2. Scattergram of oil and grease concentration versus commercial/industrial land use.

of a watershed appears to offer the potential for providing a mechanism for practical nonpoint pollution control. This may be true in other settings as well. Wilkins and Jackson describe the significance of controlling farmlands bordering stream drainages on overall watershed phosphorous levels [25]. Hoffman et al. suggest that highway runoff can contribute over 50 percent of the annual polycyclic aromatic hydrocarbon load to a watershed [26]. Thus, those control strategies that are directed at the influence of particular land uses on specific pollutants appear to have the best potential for implementation.

Reducing sporadically high discharges to the watershed can result in major decreases in overall loading. Relatively large oil and grease releases are associated with both intentional dumping and poor housekeeping practices. Enforcement and educational programs that encourage the proper containment and disposal of oil and grease may have a substantial impact on stormwater quality. For example, publicizing the availability of oil recycling centers, coupled with vigorous prosecution of illegal dumpers and sources of major leaks, appears to have the potential to significantly reduce the amount of oil and grease load entering the local drainage.

Control of chronic nonpoint sources of oil and grease discharge into a watershed has not been achieved in any urban area. A review of potential control measures reveals that traditional techniques used to reduce oil and grease discharge from point sources have relatively little potential for widespread implementation [27]. Traditional control measures work best with uniform flow rates. To be effective in treating stormwater, flow would have to be equalized through the use of massive retention devices. Since stormwater flow is extremely variable, these retention devices would have to be very large. Thus, these measures would not be cost effective. Furthermore, traditional control devices have been designed to work with initial concentrations of oil and grease quite a bit higher than normally found in urban stormwater. System effectiveness would be problematic even if the expense was not prohibitive.

Innovative techniques designed to limit the release of oil and grease from commercial/industrial areas appear to offer more promise. As indicated by the modeling results, controls applied to commercial/industrial areas can result in major reductions in the total oil and grease load from a drainage. Designing parking and other areas receiving high vehicular use to allow runoff to infiltrate through a porous surface or other adsorbent media prior to discharge into storm drains offers the potential to capture (with subsequent biological and chemical degradation) a substantial portion of the oil and grease deposits. While a number of methods have been suggested, all are untested in this application [27].

The initial model selection was driven by the need to determine the magnitude of current and future discharge into the Bay from local runoff, and the relative distribution of major oil and grease sources. From this information, control strategies can be devised based on the relative effectiveness of controlling discrete land areas. While more precise information on the magnitude of oil and grease discharge is desirable, it is not currently needed for strategy formulation. A more pressing need is for performance data on specific control techniques designed to limit oil and grease discharge from urban drainages.

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