DEMONSTRATION OF NON-POINT POLLUTION MANAGEMENT ON CASTRO VALLEY CREEK

FIRST ANNUAL REPORT

PREPARED FOR

ENVIRONMENTAL PROTECTION AGENCY
WATER PLANNING DIVISION
WASHINGTON, D.C. 20460

NOVEMBER 1979

BY

ALAMEDA COUNTY FLOOD CONTROL AND WATER CONSERVATION DISTRICT
HAYWARD, CALIFORNIA 94544

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ABSTRACT

This annual report presents the results and preliminary conclusions from the first year of study in the EPA-sponsored non-point pollution management project on Castro Valley Creek. As part of the San Francisco Bay Area's 208 Continuing Planning Program, this project is the first prototype project that is part of the EPA's National Urban Runoff Program. This is the first research project designed to correlate street cleaning and receiving water quality.

The study area is a 1,542-acre watershed that was divided into three test areas for street cleaning and sampling convenience and to develop information about topographical affects on accumulation rates of the pollutants associated with street dirt. To demonstrate the relationship between street cleaning and receiving water quality, the project is designed to measure the following: (1) street cleaning effectiveness to identify the quantity of pollutants removed and the initial and residual loadings before and after cleaning; (2) weekly street surface pollutant loadings to identify the loading on the streets at any time, and (3) receiving water quality to know the quantity of pollutants washed off the watershed for various types of rainstorms. Curve fitting analysis was used to correlate street surface pollutant loadings before rain events with changes in receiving water pollutant mass yields.

Although only a small quantity of receiving water data was obtained during the first year, it was determined that street cleaning could significantly affect the quality of receiving waters. Forty percent of the total solids, lead, and zinc in urban runoff could be removed by changing from monthly to weekly street cleaning schedules. The conclusions drawn from the first year of study are based on limited data and conclusions in the final report may be significantly different based on a larger sample population. The final results will identify the role that street cleaning should pursue to meet the goals of the 1972 Clean Water Act.

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SECTION 1

CONCLUSIONS

Research funded by the Environmental Protection Agency (EPA) is being conducted to determine whether street cleaning activities can significantly affect non-point source water pollution.

With the limited receiving water data obtained in the first year of this study, the following conclusions have been reached.

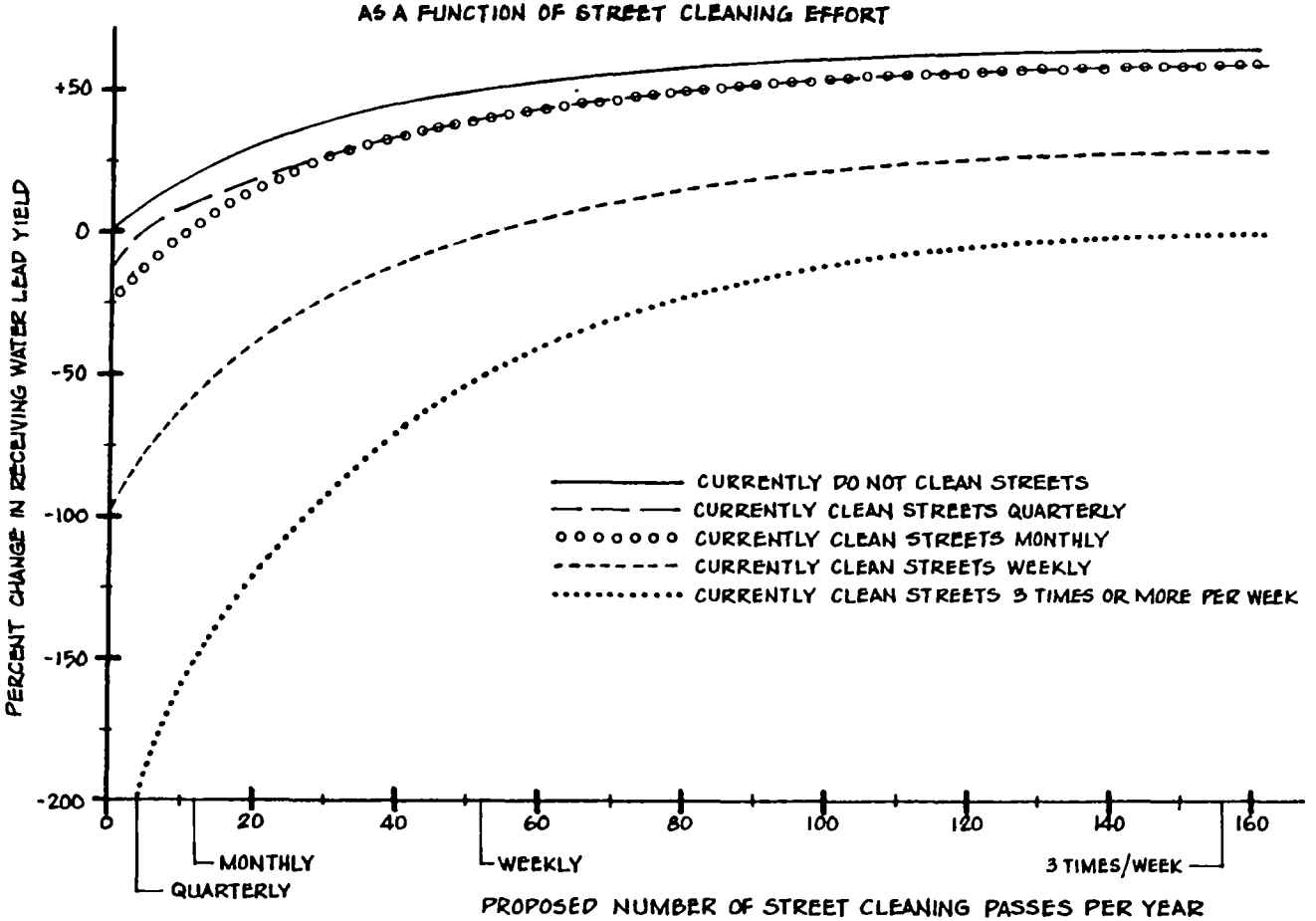
1. Street cleaning can significantly affect the quality of receiving water. The amounts of lead, total solids, and zinc in storm mass yields can be reduced 40 percent by changing from monthly to weekly street cleaning schedules (see Figure 1). If street cleaning was increased from a "no effort" to a "maximum effort" of three times per week, these pollutants could be reduced by as much as 65 percent.

2. Street cleaning could be an important factor in affecting the quality of receiving water for rain events that normally occur in the fall. These rain events are characterized by long accumulation intervals between rains and small rainfall quantities.

3. If an area is cleaned weekly it would be effective to maintain that schedule and start weekly cleaning in other areas that are cleaned monthly or less frequently (e.g., industrial areas). Similarly, if an area is cleaned more than three times per week then the cleaning effort should be reduced to either twice or once per week (See Figure 1) and other areas should be cleaned using the new resources. In these cases, street cleaning would be better applied to other areas because after a certain effort additional cleaning is wasted. It is much more efficient in terms of reduced annual loadings to receiving waters to apply additional street cleaning effort to areas that have high street surface loading values rather than areas with low loading values.

FIGURE 1

CHANGES IN RECEIVING WATER LEAD YIELD
AS A FUNCTION OF STREET CLEANING EFFORT



4. In the California coastal climate category, the first significant rain of the year usually occurs in September or October and can account for almost one-half of the total annual pollutant runoff from street surfaces. That is, one-half of the total annual street surface pollutant load. In contrast, January and February runoff contains large amounts of erosion from areas adjacent to street surfaces and are not as sensitive to street surface contaminant loading. This conclusion illustrates the need for rescheduling of street cleaning programs. Concentrated street cleaning before the first significant rain and less during the winter could reduce the amount of annual urban runoff loading. This relationship between street surface loading and street cleaning schedules could be optimized to protect receiving waters.

5. Under certain storm conditions, pollutant deposition in the storm sewerage system (i.e., inlets and laterals) may be an important component in the total urban runoff mass balance equation. Another important component which remains to be quantified for this mass balance equation is the loading from adjacent land areas.

SECTION 2

INTRODUCTION

In order for the reader to better understand the relationships between street surface pollutant loading, street cleaning and receiving water quality, a simplified conceptual model is offered. This urban runoff mass balance model consists of the following two equations:

1. Receiving water quality is defined as the pollution load in the receiving water. Therefore, receiving water quality when it is not influenced by "point sources" is a function of the pollution load from stream baseflow plus surface runoff plus aerial fallout.

2. Surface runoff quality is a function of the pollution load from street surfaces plus adjacent land areas plus storm sewerage.

The purpose of this project is to determine whether removing the pollution load from the street by street cleaning has an affect on surface runoff quality from street surfaces and consequently an affect on receiving water quality. Throughout the project, data will be collected to compare the monitored mass pollutant flows of the storms with the total pollutant removal of street cleaning programs. A valid data set for this analysis consists of a data point for a monitored runoff event that occurs between adjacent street surface monitoring data points. During the first year of this study, eight valid data sets were collected.

Data will also be collected during the second year to develop adequate street cleaning programs, determine street loading values, and monitor rain events. A large number of these data points could demonstrate that street cleaning significantly changes receiving water concentrations as well as storm mass yields.

Demonstrating that a reduction in the quantity of street surface contaminants improves the quality of receiving waters may have strong policy implications. Most cities have street cleaning programs and the financial resources devoted to those programs are significant portions of local public works departments operating expenses. As local decision-makers balance priorities with revenues, street cleaning for aesthetic purposes is usually relegated a low priority. Street cleaning was a candidate 208 control measure in the San Francisco Bay Area Environmental Management Plan, and local decision-makers are looking forward to the results of this project. If it can be demonstrated that street cleaning has a positive affect on water quality, then decision-makers may have more reason to give their street cleaning budgets higher priority. A rescheduling of cleaning effort within the existing budgets in order to maximize water quality benefits may be in order. The water quality benefits of street cleaning must be proven in these times of serious fiscal constraints.

In 1971, the Castro Valley Watershed was selected by the U.S. Geological Survey (USGS) and the Corps of Engineers (CORPS) (Hydrologic Engineering Center) for urban runoff monitoring. This watershed was selected because it was considered to be typical of residential basins in the San Francisco Bay-Delta region (Sylvester and Brown, 1978). The main purposes of this early federal effort were to (1) determine relationships between land use and land surface characteristics and the quantity and quality of urban runoff, and (2) determine whether control of urban runoff is necessary to meet regional water quality objectives.

Castro Valley Creek has few beneficial uses (as defined in the San Francisco Bay Basin Plan) and none have been officially established by the state. However, the Castro Valley Basin probably has more data about urban runoff than any other basin in California.

Many agencies have continued to monitor urban runoff since 1971. To date, portions of about 45 storms have been monitored. Two continuous recording stream gages and two automatic ISCO water samplers have been installed by the USGS and the Alameda County Flood Control and Water Conservation District (ACFC&WCD) in Castro Valley Creek. The upper station (USGS No. 11181004) is located at Seaview Street and measures the contributions from the relatively undeveloped portions of the study area. The lower station (USGS No. 11181006) is located at Knox Street and in addition to the upper undeveloped portions of the study area, measures the contributions from the urban areas. The CORPS has been monitoring another station at the confluence of Chabot and Castro Valley Creek.

San Lorenzo Creek, downstream from the confluence of Castro Valley and Chabot creeks, is a large watercourse with contiguous urban development. This creek carries the flow to its discharge point in San Francisco Bay.

The ACFC&WCD is the lead agency in this project and the Association of Bay Area Governments (ABAG) is the project sponsor. The USGS , the CORPS, and the State Regional Water Quality Control Board (RWQCB) are responsible for technical review assistance. The Project Manager, Gary Shawley, is a research scientist and private consultant under contract to the ACFC&WCD, and the Principal Investigator, Robert Pitt, is an environmental engineer and private consultant to Woodward-Clyde Consultants.

SECTION 3

DESCRIPTION OF STUDY AREA

The Castro Valley Watershed covers approximately 5.6 square miles and is located within the San Francisco Bay Area (Figure 2). An aerial view of the watershed is presented in Figure 3. The Castro Valley Creek branch of the Castro Valley Watershed was selected as the study area to reduce the study area to a more manageable size (from 5.6 square miles to 2.4 square miles).

The study area is predominantly residential. The majority of the residential land use consists of single family housing with lot sizes varying from 5,000 square feet to 10,000 square feet. The estimated residential population density is about 20 people per acre. Residential land use occupies 2,464 acres (70 percent), commercial land use occupies about 246 acres (7 percent), and the remaining land is open space (809 acres or 23 percent). Development along the stream banks in Castro Valley is intense and houses are frequently constructed directly over the existing streambed. Some light commercial areas, more than a dozen schools, and a short portion of Interstate Highway 580 are also in the area. Photographs of typical Castro Valley land uses are shown in Figure 4 A, B, and C.

Topography within the drainage basin is highly variable, and the land slopes range from 10 percent to 70 percent in the upper end of the basin to slopes as low as 1 percent in the valley portion near San Lorenzo Creek. The Castro Valley Creek streambed in the lower portions of the drainage basin range from 20 feet to 50 feet in width and 8 feet to 10 feet in depth. The streambed is often strewn with litter and debris.

The study area was divided into four sub-areas (Figure 5). These horizontal divisions across the watershed (based on topography and street patterns) increased the amount of useful data obtained from the street surface monitoring activities.

There are many similarities in the three lower urban sub-areas (see Table 1). The most important of these similarities are the types of gutters and the condition of the street surfaces. Seventy-five percent of the gutters are concrete and 25 percent are asphalt. The shapes of the curbs (straight or rolled) influence the amounts of street surface contaminants that remain on the streets (and are available to street cleaners), and the amounts that are transported to the shoulder of the road (and are not available for pickup in normal street cleaning operations). The condition of street surfaces determines the nature of contaminants and the performance of street cleaning equipment. In the study area, 91 percent of street surfaces in the lower three urban test areas are in fair condition, with little variability in condition or width (95 percent of the streets in these sub-areas are 20 feet to 40 feet wide).

The variable that may significantly influence the quantity of nutrients removed by street cleaning operations is the amount of leaf material on the streets. In the study area, the largest accumulation of leaves on streets is in the upper urban sub-area, but the difference among the three areas is not large.

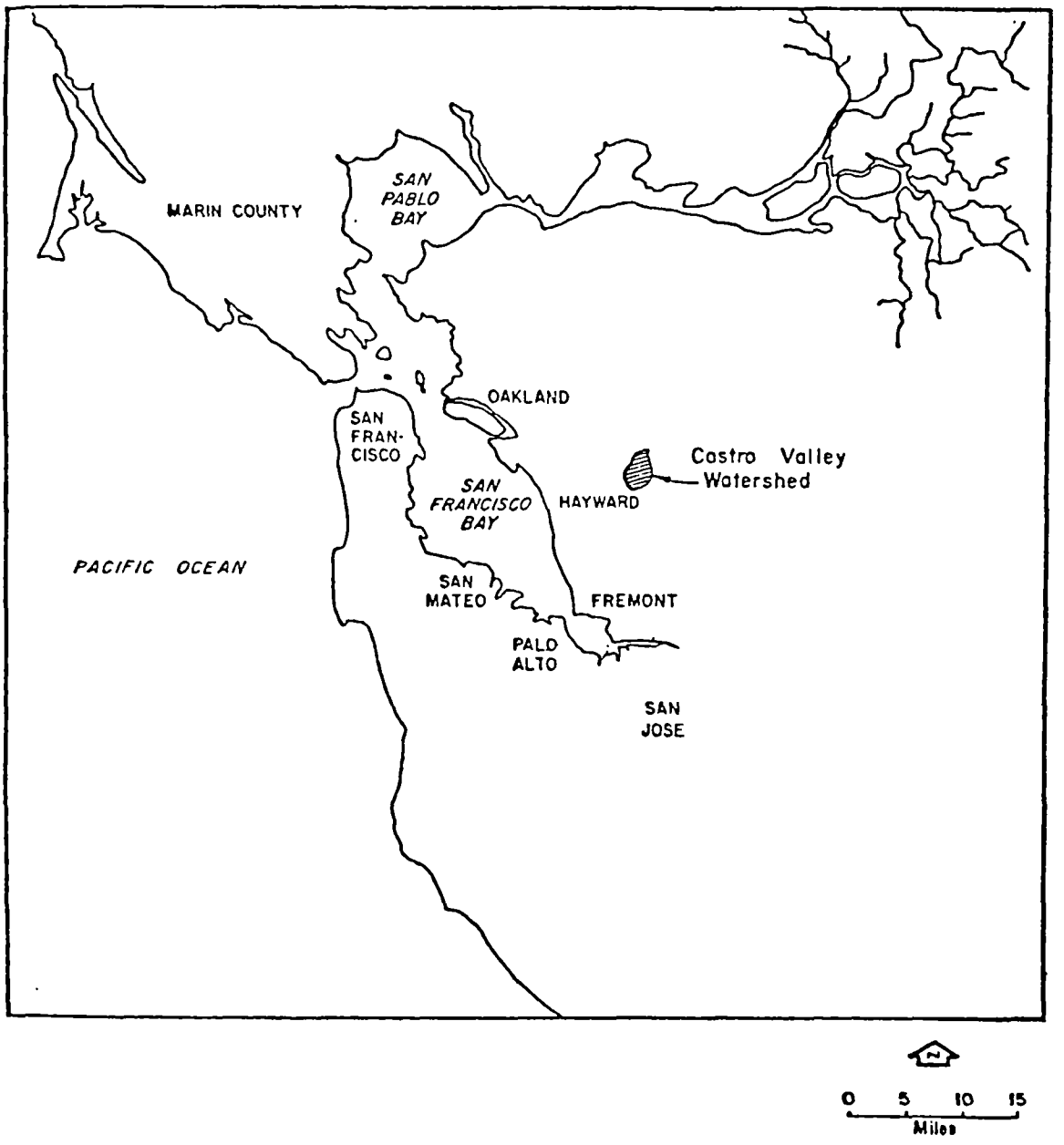


FIGURE 2. SAN FRANCISCO BAY AREA SHOWING THE GENERAL LOCATION OF THE CASTRO VALLEY WATERSHED

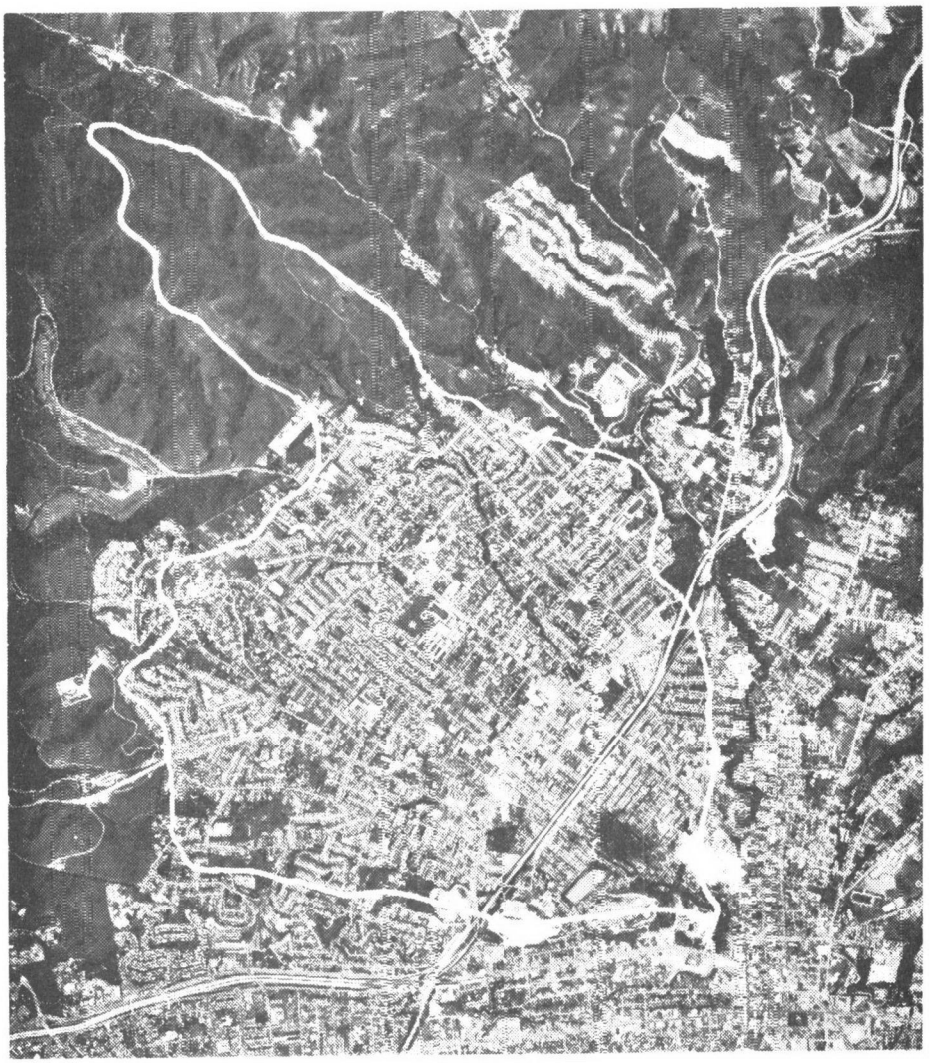


Figure 3
Aerial View of Castro Va ley

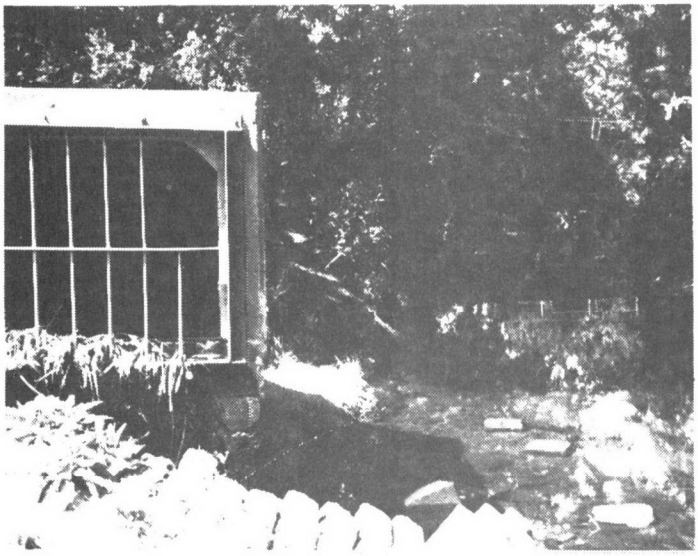
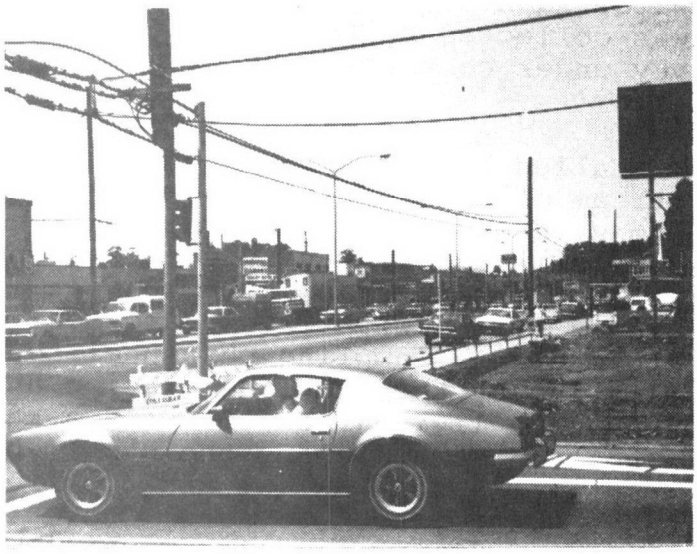
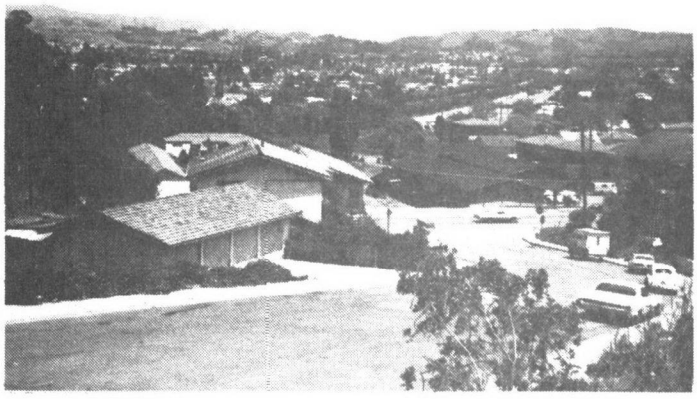


FIGURE 4
a. Castro Valley Creek
and Storm Sewer Outfall.

b. Commercial Land Use
Castro Valley, Cal.





c. Residential Land Use
and Topography
Castro Valley, Cal.

FIGURE 5. STUDY AREA DIVISIONS (CASTRO VALLEY CREEK-
DRAINAGE AREA = 2.41 SQ. MI.)

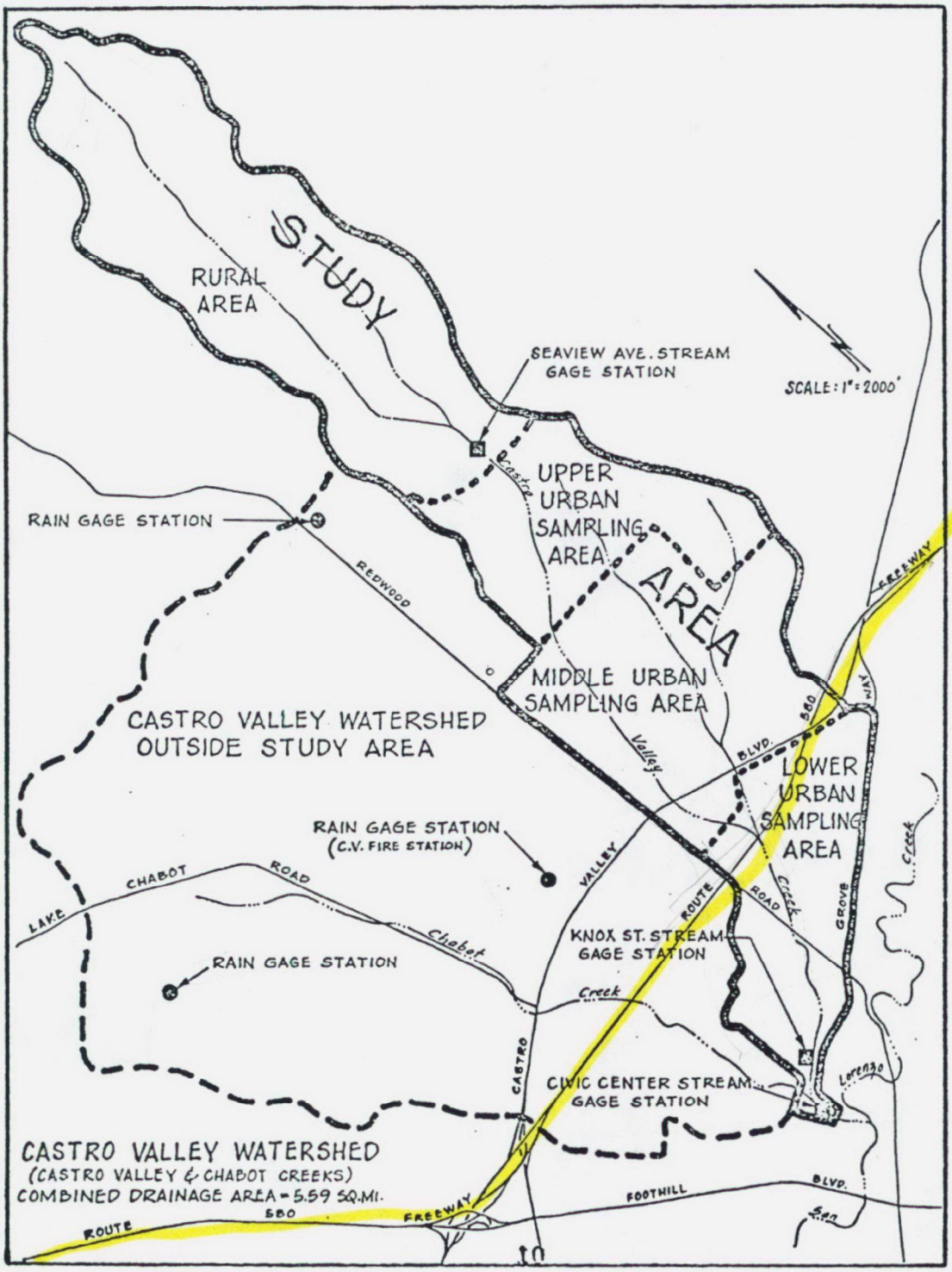


TABLE 1. TEST AREA CHARACTERISTICS (PERCENT, UNLESS OTHERWISE NOTED)
DRAINAGE AREA =2.4 SQUARE MILES

	LOWER	MIDDLE	UPPER	TOTAL
Number of Gutters				
0	0	6	0	2
1	0	0	11	4
2	100	89	89	92
4	9	5	0	2
Gutter Type				
Concrete	93	62	78	76
Asphalt	7	38	17	22
Mixed	0	0	5	2
Gutter Shape				
Straight	0	0	5	2
Rolled	41	52	69	55
Mixed	59	48	26	43
Median Strip				
Yes	0	5	0	2
No	100	95	100	98
Street Condition				
Poor	0	0	3	1
Fair	74	97	97	91
Good	26	3	0	8
Street Width				
20 to 40 feet	93	95	100	96
40 feet	7	5	0	4
Landscaping Type				
Deciduous	78	74	46	65
Evergreen	11	5	0	5
Mixed	11	21	54	30
Landscaping Quantity				
None	11	0	0	3
Some	85	89	91	89
Much	4	11	9	8
Leaves on Street				
Few	81	74	43	65
Some	15	21	45	28
Much	4	5	12	7
Parking Density				
None	4	2	0	2
Light	55	50	89	65
Moderate	37	42	11	30
Heavy	4	6	0	3

TABLE 1. TEST AREA CHARACTERISTICS (PERCENT, UNLESS OTHERWISE NOTED)
DRAINAGE AREA ≈2.4 SQUARE MILES (CONCLUDED)

	LOWER	MIDDLE	UPPER	TOTAL
Traffic Density				
Light	79	63	77	72
Moderate	7	26	23	20
Heavy	14	11	0	8
Traffic Speed				
25 MPH	52	39	40	43
25 - 40 MPH	48	58	60	56
40 MPH	0	3	0	1
Topography				
Flat	66	39	3	34
Slight	30	34	3	22
Moderate	4	11	37	18
Moderate/Steep	0	3	11	5
Steep	0	13	46	21
Adjacent Land Use				
Low Income, Old, Single Family	28	13	0	12
Medium Income, Old, Single Family	57	66	98	75
Commercial	7	13	0	7
Multiple Family	4	2	0	2
Vacant	0	2	0	1
School	4	4	2	3
Street Surface Particulate Loadings				
Mean (lbs/curb-mile)	369	675	563	552
Median (lbs/curb-mile)	321	536	467	432
Standard Deviation (lbs/curb-mile)	219	540	363	425
Standard Deviation/Mean (ratio)	0.59	0.80	0.64	0.77
Minimum(lbs/curb-mile)	48	100	82	48
Maximum(lbs/curb-mile)	821	2970	1260	2970
Number of Valid Data Points	27	37	34	98

SECTION 4

TESTS OF CASTRO VALLEY STREET CLEANING EQUIPMENT

The objectives of the street cleaning equipment performance in Castro Valley were:

- To determine the accumulation rates of street surface contaminants.
- To determine the characteristics of street contaminants in relation to particle sizes.
- To investigate various street cleaning practices under actual field conditions (including various street surface conditions, residual particulate loadings, traffic densities, parked cars, and climatic conditions) to determine the range of possible cleaning performances.

RESULTS OF YEAR ONE EXPERIMENTAL DESIGN

Street surface samples were collected from narrow strips that were the width of the street. The analytical procedure used to determine the number of sub-samples needed involved weighing individual sub-samples in the study area to calculate the standard deviations (σ) and the means ($\bar{x}$) of street surface loading values.

From these two values, the number of sub-samples necessary (N), depending on the allowable error (L), were determined. An allowable error value of about 25 percent, or less, was used.

The formula used (Cochran 1963) was:

$$N = 4\sigma^2/L^2 .$$

With a 95 percent confidence limit, this formula determines the number of samples needed to determine the true value for loading within a range of $\pm$ L. Initially, individual samples were taken at 100 locations in the three study areas to determine the loading variability. Loading varied within the study area but the median values in the three test areas were fairly close. The overall minimum loading was about 50 lbs/curb-mile, the overall maximum value was about 3,000 lbs/curb-mile, and the overall median value was about 400 lbs/curb-mile. The median values in the three areas were about 320, 540, and 470 lbs/curb-mile.

Preliminary statistical analyses (using Student "t" tests) have shown little loading variations between candidate sub-division groups. The topographical grouping was made for sampling convenience, as it was difficult to sample the complete study area twice in a single day (as required for the street cleaning tests). The relative variations of particulate loadings within the three test areas did vary.

STREET CLEANING TESTS

Several street cleaning programs using various levels-of-effort were evaluated during the first year of study. The street cleaning program for the first year is presented in Table 2. The first year of the testing program was divided into five segments and different street cleaning programs were conducted in each of the three urban test areas. The values in Table 2 for each week refer to the number of street cleaning equipment passes conducted in each area during that week. An initial cleaning was conducted during the first project week. The next week of the study involved monitoring a typical leaf removal operation which consisted of continuous front-end-loader and dump truck activity, 5 days a week. The street cleaning program studies in following weeks varied from one to five passes every week. From 6 to 15 weeks passed before the regular street cleaning tests began so that street surface contaminants could accumulate. This street cleaning schedule permitted street surface loading conditions to be evaluated under a wide range of cleaning practices.

This information was used to evaluate the street surface particulate accumulation rates and street cleaner performance. This information is compared to Castro Valley Creek pollutant flows during storm events in the next section of this report.

Street cleaning equipment performance is very sensitive to operator skill and equipment maintenance. The equipment must be adjusted adequately, and maintained and operated in a manner to optimize debris removal and minimize cost. The operators and maintenance personnel used during these tests were supplied by the Public Works Department of Alameda County. They were all well trained, skilled and operated the test equipment in an optimum and recommended manner.

Long-term and frequent street surface sampling in the test areas made it possible to directly measure accumulation rates of street surface contaminants. Street surface samples were collected within a few hours before and after street cleaning by the procedures described in the First Year Work Plan. The idealized loading pattern resulting from sampling at these intervals, a sawtooth pattern depicting the deposition and removal of street surface particulates is illustrated in Figure 6. The pattern observed during year one generlly agreed with Figure 6 (First Technical Progress Report on Castro Valley). Accumulation rates for the various contaminants can be determined by calculating the angle of the slope between adjacent sampling periods.

FIGURE 6

SAWTOOTH PATTERN ASSOCIATED WITH DEPOSITION AND REMOVAL OF PARTICULATES

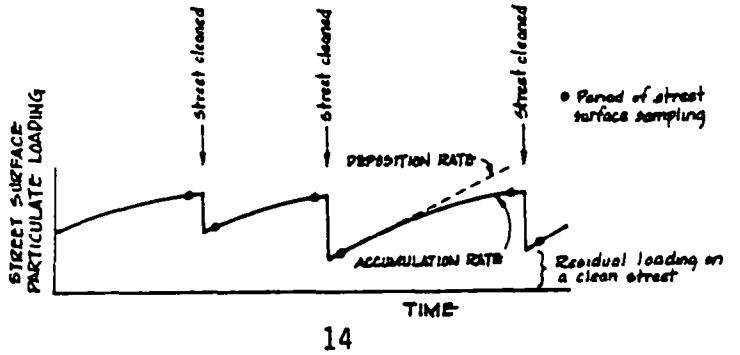


TABLE 2. STREET CLEANING SCHEDULE [1]

5-Day Work-Weeks		Upper Urban Area	Middle Urban Area	Lower Urban Area
11/20	11/24/78	1(2)	1(2)	1(2)
11/27	12/1	4L(3)	4L(3)	4L(3)
12/4	12/8	0	0	0
12/11	12/15	0	0	0
12/18	12/22	0	0	0
12/25	12/29	0	0	0
1/1	1/5/79	0	0	0
1/8	1/12	0	0	0
1/15	1/19	0	1	0
1/22	1/26	0	1	0
1/29	2/2	0	1	0
2/5	2/9	0	1	0
2/12	2/16	0	0	0
2/19	2/23	0	0	0
2/26	3/2	3	0	0
3/5	3/9	0	0	0
3/12	3/16	0	5	0
3/19	3/23	0	0	1
3/26	3/30	0	0	1
4/2	4/6	0	0	1
4/9	4/13	0	0	1
4/16	4/20	0	0	1
4/23	4/27	0	0	1
4/30	5/4	1	0	0
5/7	5/11	1	0	0
5/14	5/18	1	0	0
5/21	5/25	1	0	0
5/28	6/1	1	0	0

1 Number of street cleaning tests per week are shown - all performed w/Mobil (brand name of equipment)

2 Not monitored; a starting date

3 Leaf removal tests.

The data collected in these test areas were used to identify the range of performance that can be expected from the available street cleaning equipment. Differences in removal values (lbs/curb-mile removed) instead of percentage removals (percentage of the initial loadings removed) for the test conditions are used as a more meaningful measure of equipment performance. The lbs/curb-mile measure is more realistic because it provides the specific amount of material removed.

The following elements summarize this program:

- All samples ("accumulation" and "before and after street cleaning test") were sieved for particle size analyses with a 0.25 wire screen (6370 microns), Tyler Screens No. 10 (2000 microns), No. 20 (850 microns), No. 30 (600 microns), No. 40 (250 microns), No. 60 (106 microns) and No. 325 (45 microns); and a pan. The pan collected the material which passed through the finest screens.

- The loading values expressed in lbs/curb-mile for each particle size and the percentage of sample in each particle size was calculated for each sample.

- The samples for each size, each test area and test phase were combined to analyze the amounts of lead, zinc, volatile solids, chemical oxygen demand, phosphorous, orthophosphates, arsenic, copper, chromium, sulphur and Kjeldahl nitrogen.

SOURCES OF URBAN RUNOFF POLLUTANTS

One of the major problem areas yet to be sufficiently addressed concerning urban runoff is the quantification of the relative contributions from pollutant sources in the adjacent land areas of the watershed to the outfall yield. This adjacent land area contribution is one of the factors discussed in the urban runoff mass balance conceptual model described in the introduction section. The contribution from these non-street adjacent land areas will be quantified in the final report. That is why this discussion of sources of urban runoff pollutants is included here. The following discusses the specific pollutants deposited in the major urban source areas and the quantity that actually reaches the storm outfalls.

Usually sources that are farther from storm drainage systems require overland flow and have a very low yield when compared with parking lots or street surfaces which are impervious and located adjacent to the drainage system. Table 3 presents the preliminary results from the second phase of the Coyote Creek project (Pitt and Bozeman 1979), which examined potential sources of urban runoff pollutants. In the second phase, runoff samples were collected during rainstorms from different areas within the South San Francisco Bay Area. These areas were all small and included runoff from different types of building roofs, parking lots, and gutter flows. Rainfall and outfall samples were also collected for chemical analyses. In most cases, rain had the lowest pollutant concentrations. Puddles in cities had the highest concentrations of total solids, specific conductance, and nitrates.

TABLE 3 URBAN RUNOFF POLLUTANT CONCENTRATIONS FROM MAJOR AREAS
(mg/l, unless otherwise noted)

Parameter	Outfall	Gutter Flow	Parking Lot	Commercial Park Puddles	Residential Tar and Gravel Roof	Composition Shingle Roof	Rain
pH, pH Units	7.8	7.5	7.0	7.3	7.5	6.5	6.4
Specific Conductance, (umhos/cm)	185	130	45	2400	155	11.2	10.4
Turbidity, NTU	29	100	26	21	1	<1	<1
Total Solids	162	235	340	2140	186	18	30
BOD5	8	13	22	3	7	3	3
COD	97	172	176	69	131	19	12
P-PO4	0.23	0.12	0.47	0.32	0.02	0.08	0.03
Total PO4	0.34	0.31	0.49	0.42	0.07	0.10	0.03
Kjeldahl N	1.52	2.41	1.47	1.32	4.37	0.71	0.64
NH3	0.25	0.42	0.35	1.223	1.06	0.50	0.36
NO3	0.74	0.42	0.13	285	0.22	0.09	0.09
S	4	2	<1	15	5	<1	<1
SO4	13	7	<1	38	21	<1	<1
As	<0.01	<0.01	0.02	0.10	<0.01	0.01	<0.01
Zn	0.06	0.14	0.23	0.01	0.08	0.18	0.04
Pb	0.08	0.67	1.09	0.035	0.019	0.017	<0.01
Cr	0.009	0.049	0.071	0.010	<0.005	<0.005	<0.005
Cu	0.013	0.029	0.046	0.031	0.11	<0.005	0.010
Total Coliform Bacteria (MPN/100ml)	>2400	>2400	540	49	170	<2	8
Fecal Coliform Bacteria (MPN/100ml)	>2400	920	350	49	9	<2	2
Fecal Strep. Bacteria (MPN/100ml)	>2400	>2400	>2400	920	17	920	<2
Fecal Coliform/Fecal Strep. Ratio	-	<0.4	<0.2	0.5	0.5	<0.002	>1

Source: Pitt and Bozeman 1979

Table 4 is a generalization of urban runoff pollutant sources for common pollutants in the South Bay Area. No one source area is expected to contribute significant quantities of the pollutants, but some of the areas are expected to be quite important. Street surfaces are expected to contribute significant amounts of heavy metals. Oxygen demanding materials and nutrients are thought to originate mostly from landscaped and vacant areas. Table 5 is also a generalization of urban runoff pollutant sources and attempts to show the major contributors affecting the major areas and the approximate delivery yields from each of the source areas to the outfall yield. Vacant lots and landscaped areas are the most pervious surfaces in urban areas and are located farthest from the urban drainage system; therefore, they contribute little flow. Landscaped and vacant areas sometimes constitute almost half of the total area in residential communities. However, only 5 percent of the rainfall in these areas is expected to contribute to the outfall flow. Similarly, very little of the potential pollutant yield from these areas is expected to affect the outfall. Rooftops, which can constitute about 15-20 percent of residential communities, are also located a relatively long distance away from the storm sewerage system. Rooftops are impervious; however, a large part of the roof drainage systems in Castro Valley are not directly connected to the storm sewerage system and require considerable overland flow. Therefore, the outfall runoff yield from rooftops is expected to be about 30 percent. Sidewalks, generally constitute about 5 percent of residential communities, and are located closer to the storm drainage systems. However, some of their drainage flow is directed towards adjacent landscaped or other pervious areas. Consequently, only about half of the runoff yield from sidewalks enters the receiving water flow. Parking lots can make up about 7 percent of an area and in the Castro Valley area are usually paved and impervious. Again, some of the runoff from the parking lots (especially near homes and apartments) is directed towards adjacent impervious areas, and only about half of the parking lot runoff is expected to reach the receiving waters. Street surfaces, however, are located close to the storm drainage systems and are mostly impervious. In Castro Valley, street surfaces and parking lots constitute about 26 percent of the watershed (Ellefsen and Raburn 1978). Most of the runoff originating from impervious areas is expected to reach the outfall. However, some of the street surface flow does not reach the outfall because of infiltration and evaporation or streets in poor condition. Dust fall and precipitation affect all of the components. However, dust fall, is not a major pollutant source, instead it mostly transports pollutants. Most of the dust fall monitored in urban areas is resuspended particulate matter from street surfaces or wind erosion products from vacant areas. Some point source air pollutant emissions also contribute todust fall pollution. The bulk of the dust fall, however, is contributed by other major pollutant sources.

Automobile tire wear is a substantial source of zinc in urban runoff and is deposited mostly on street surfaces and adjacent areas. About half of the particulates from tire wear settle on the street and the remaining material settles within about 20 feet of the roadway. Auto exhaust particulates are also significant pollutant contributors of heavy metals, particularly lead, and mostly affect street surfaces and adjacent areas. Other

TABLE 4. POTENTIAL SIGNIFICANT URBAN RUNOFF POLLUTANT SOURCES

	Potential Significant Polluant Sources						
Common Urban Runoff Pollutants	Rooftops	Street Surfaces	Parking Lots	Landscaped Areas	Vacant Land	Construction Sites	Other (Industrial and Solid Waste Runoff)
Sediment		X			X	X	
Oxygen Demanding Matter				X			
Nutrients				X	X		
Salts							
Bacteria					X		
Heavy Metals		X	X				
Pesticides/ Herbicides				X			
Oils and Grease	X	X	X			X	
Floating Matter				X			
Other Toxic Materials	X	X					X

Source: Pitt and Bozeman 1979

TABLE 5 MAJOR URBAN AREAS AND DELIVERY YIELDS TO OUTFALL (Percent)

Pollutant Contributors	Lawn and Landscaped Areas 5%	Vacant Lots 5%	Rooftops 30%	Sidewalks 45%	Parking Lots 50%	Street Surface 75%
Dustfall	X	X	X	X	X	X
Precipitation	X	X	X	X	X	X
Tire Wear	X (Adjacent)			X	X	X
Auto Exhaust Particulates	X (Adjacent)			X	X	X
Other Auto Use (Fluid Drips, Wear Prod.)				X	X	X
Vegetation Litter	X	X		X	X	X
Construction Erosion		X				
Other Litter		X		X	X	X
Bird Feces	X	X	X	X		
Dog Feces	X	X				X
Cat Feces	X	X				
Fertilizer Use	X					
Pesticide Use	X					

Source: Pitt and Bozeman 1979

heavy metals and asbestos are important pollutants associated with these other automobile losses. Most of these pollutants directly affect parking lots and street surfaces and some material is transported to adjacent areas by wind.

Vegetation is usually a significant source of pollutants in most source areas. In Castro Valley the fall months are an important source of leaf litter. While animal feces contributes quantities of important nutrients and bacteria to urban areas, only vacant and landscaped areas are usually affected. Fertilizer and pesticide use is mostly associated with landscaped areas, but large amounts of pesticides can be used to control plant growth on impervious surfaces and fertilizers can be used in road maintenance operations.

Table 6, based on preliminary results from the current Coyote Creek project (Pitt and Bozeman 1979), estimates the percentage contribution of the various pollutants from the different source areas studied. In most cases, rooftops contribute the least amount of pollutants, while pervious areas are the major source of solids, oxygen demanding materials, and some nutrients. Parking lots, street surfaces, and sidewalks are expected to be a major source of heavy metals, bacteria, and some nutrients of the total outfall runoff yield.

Most of the street surface dust and dirt materials (by weight) are local soil erosion products, some of which are deposited by motor vehicle emissions and tire wear. Minor contributions are made by wear of those smooth street surfaces in good repair. The specific makeup of street surface contaminants is a function of many site conditions and varies widely. Many pollutant sources are specific to particular areas and activities. For example, iron oxides are associated with welding operations and strontium, used in the production of flares, would probably be found on streets in greater quantities during holiday times or at the scenes of traffic accidents.

Relative deposition values for pollutants from source areas are summarized in Table 7. These deposition values are percentages of the total pollutants deposited in urban areas and are much larger than the pollutant yields to the outfall. In comparison, Table 8 shows the relative yields from these source areas to the total outfall runoff yield. The deposition rates for some pollutants are relatively high for some of the impervious areas, but these source yields are substantially reduced when infiltration is considered. Automobile activity is responsible for most of the heavy metal yield in the runoff and up to half of the total solids yield. Vegetation sources contribute most of the oxygen demand materials, and domesticated animal feces and fertilizers contribute most of the nitrogen in urban runoff.

In conclusion, if the total solids pollutant depositions in an urban area were summed, only about one-third would reach the outfall. Only about 10 percent of the nutrients and oxygen demanding materials deposited would affect the quality of receiving waters, but most of the heavy metals deposited in the area would affect water quality. Those pollutants that

Table 6. ESTIMATED CONTRIBUTION FROM VARIOUS AREAS TO OUTFALL RUNOFF YIELDS (Percent)

Sources	Total Solids	COD	BOD5	Ortho PO_4	Total PO_4	Total Kjeldahl N	NH_3	NO_3	Total S
Rooftops	2	5	2	10	5	15	20	2	5
Landscaped Areas and Vacant Lots	50	50	50	20	15	25	20	5	50
Parking Lots	10	15	20	30	20	10	10	1	1
Street Surfaces and Sidewalks	40	25	25	45	65	50	50	20	45

	SO_4	As	Zn	Pb	Cr	Cu	Total Coliform Bacteria	Fecal Coliform Bacteria	Fecal Strep Bacteria
Rooftops	5	10	20	1	1	10	1	1	30
Landscaped Areas and Vacant Lots	40	70	1	1	2	10	1	1	3
Parking Lots	1	15	20	20	20	20	5	3	10
Street Surfaces and Sidewalks	50	1	60	80	80	60	95	95	60

Source: Pitt and Bozeman 1979

TABLE 7. RELATIVE SOURCE ANNUAL DEPOSITIONS (Percent)

Source	Total Solids	BOD_5	TKN	Pb	Zn	Cr	Cu
Precipitation	10	3	5	1	15	1	10
Tire Wear	5	1		10	80	10	5
Auto and Street Use	20	1	1	90	1	70	50
Vegetation	40	95	15				
Construction Erosion	20		1	1	2	10	2
Bird Feces	2	1	1	1	1		
Dog Feces			40				
Cat Feces			1				
Fertilizer Use			40				
Other	3	1				10	30

Source: Pitt and Bozeman 1979

TABLE 8. RELATIVE RUNOFF YIELD CONTRIBUTIONS (Percent)

Source	Total Solids	BOD_5	TKN	Pb	Zn	Cr	Cu
Precipitation	10	10	20	1	20	1	5
Tire Wear	5	1		1	80	3	2
Auto and Street Use	50	10	10	100		90	80
Vegetation	30	70	10				
Construction Erosion	5		1	1	1	1	1
Bird Feces	5	1	1	1	1		
Dog Feces			30				
Cat Feces			1				
Fertilizer Use			30				
Other	3	5				5	15

Source: Pitt and Bozeman 1979

are washed off the source areas and do not reach the outfall would be accumulated in other areas of the urban environment. The most significant pollutant "sinks" in the urban area are expected to be soils and plants. For example, many studies have shown significant concentrations of heavy metals in roadside soil and vegetation (Farmer and Lyon 1977; McMullen and Faoro 1977; Olson and Skogerboe 1975; Pitt and Amy 1973). As noted earlier, much of this material (about 15 percent of the total deposition) can be associated with dust fall. However, most of this dust fall is resuspended particulates from streets and vacant areas and is not an actual source of urban runoff pollutants, excepting point source air pollution emissions that settle out.

STREET SURFACE CONTAMINANT ACCUMULATION RATES

The objective of this portion of the study was to determine specific accumulation rates in the test areas. This information must be obtained before an effective street cleaning program can be designed. In addition, this information was necessary to evaluate the Castro Valley Creek pollutant flows. The rainfall patterns during this study were examined and those periods in which rains removed significant amounts of street surface contaminants were eliminated from the accumulation rate calculation. To determine accumulation rates of different pollutants, the samples were analyzed by particle size (as previously described). This procedure is essential because different particle sizes have different concentrations of pollutants. Equipment performance also varies with particle size and this affects the overall amount of pollutants that can be removed by street cleaning.

Approximately 58 days had measurable rain during the 1978-1979 portion of this project. Twenty-three of these days had what was considered to be significant rainfall. A significant rain is one that removes as much of the street surface contaminants as possible. However, these rains can also add material to the street surface through erosion of adjacent areas. A significant rain is defined as having a total rainfall of about 0.2 inches, or more, within about 1-day (irrespective of traffic conditions); rain with a peak instantaneous intensity (5-minute duration) of 0.5 inches per hour (irrespective of traffic conditions); a rain with an average intensity of 0.1 inches per hour, or greater, with moderate to heavy traffic. Rains and traffic conditions which meet one of these criteria are capable of imparting enough energy to the street surface to loosen contaminants and suppling enough water to flush them along the street surface and gutters to the storm sewerage inlets. If sufficient amounts of water are not available to carry the particulates through the storm sewerage to the outfall, material will be deposited in the sewerage system. Rainfall intensities and removal effectiveness relationships were studied by Sartor and Boyd (1972) and discussed by others (including Pitt and Field 1977).

Periodic and unexplained decreases in loadings were observed. These data resemble the sawtooth pattern similar to that shown in Figure 6. These decreases in loadings may be caused by high winds. Winds greater than about 13 miles per hour have been shown to be capable of removing particulates from the street surface in the absence of traffic (McMullen 1977). In some

cases, significant rains cause decreases in street surface loadings while they cause an increase in others. Increases are thought to be caused by erosion. As described previously, all of the test and accumulation samples were separated by particle size. Samples of each particle size category for each test area were then analyzed for the various pollutants.

Figures 7, 8, and 9 show estimated curves for total solids accumulation and deposition rates. The loading values and associated time periods since last cleaned were grouped by test area and season to identify the best fitting curves. Loading values that were affected by rains were eliminated from this analysis. These figures are highly influenced by residual loading values. In general, loading values are the cleanest the streets can be and are the values immediately after street cleaning or certain rains.

The resulting loading, deposition, and accumulation rates were quite different for each test area. Loadings did not level off although the accumulation rates decreased with time. Table 9 presents calculated average accumulation rates for the three test areas for various times after street cleaning or a significant rain. The lower test area had appreciably greater accumulation rates and loading values than the other two test areas. The middle area had intermediate rates and values, while the upper area had the lowest loading values and accumulation rates. The deposition rates are assumed to be equal to first day accumulation rates (70, 60 and 30 lbs/curb mile-day for the lower, middle, and upper areas, respectively). The two factors which affect the accumulation rate are the deposition rate and the removal rate. The accumulation rate equals the deposition rate minus the removal rate. The deposition rate is a function of the characteristics of the area, such as climate, land use, traffic, and street surface conditions. Removal of pollutants can be accomplished either by street cleaning or naturally by winds or rains. The difference between the accumulation and deposition rates (at any time) is assumed to be loss from the street surface by wind or traffic-induced turbulence. This material can become suspended in the air, but most of the material settles about 10 feet off the roadway (Pitt 1979).

The average street surface total solids loadings immediately after street cleaning are also shown in Table 10. These values are also greatest for the lower test area and the least for the upper test area. Significant rains can produce cleaner street surfaces in the lower and middle test areas when compared to street cleaning, but in the upper test area, street cleaning can result in cleaner streets more than significant rains.

CASTRO VALLEY STREET CLEANING DEMONSTRATION STUDY RESULTS

The design of an effective street cleaning program requires not only a determination of accumulation rates but also an assessment of the specific street cleaning equipment performance for the actual conditions encountered. Service goals, which consider effects on water quality, air quality, public safety, aesthetics, and public relations are the driving force in establishing a street cleaning program. The major objective of this part of the study was to determine the effectivenesses of street cleaning equipment for various levels-of-effort for comparison with pollutant flow information.

FIGURE 7

DEPOSITION & ACCUMULATION RATES
FOR LOWER TEST AREA

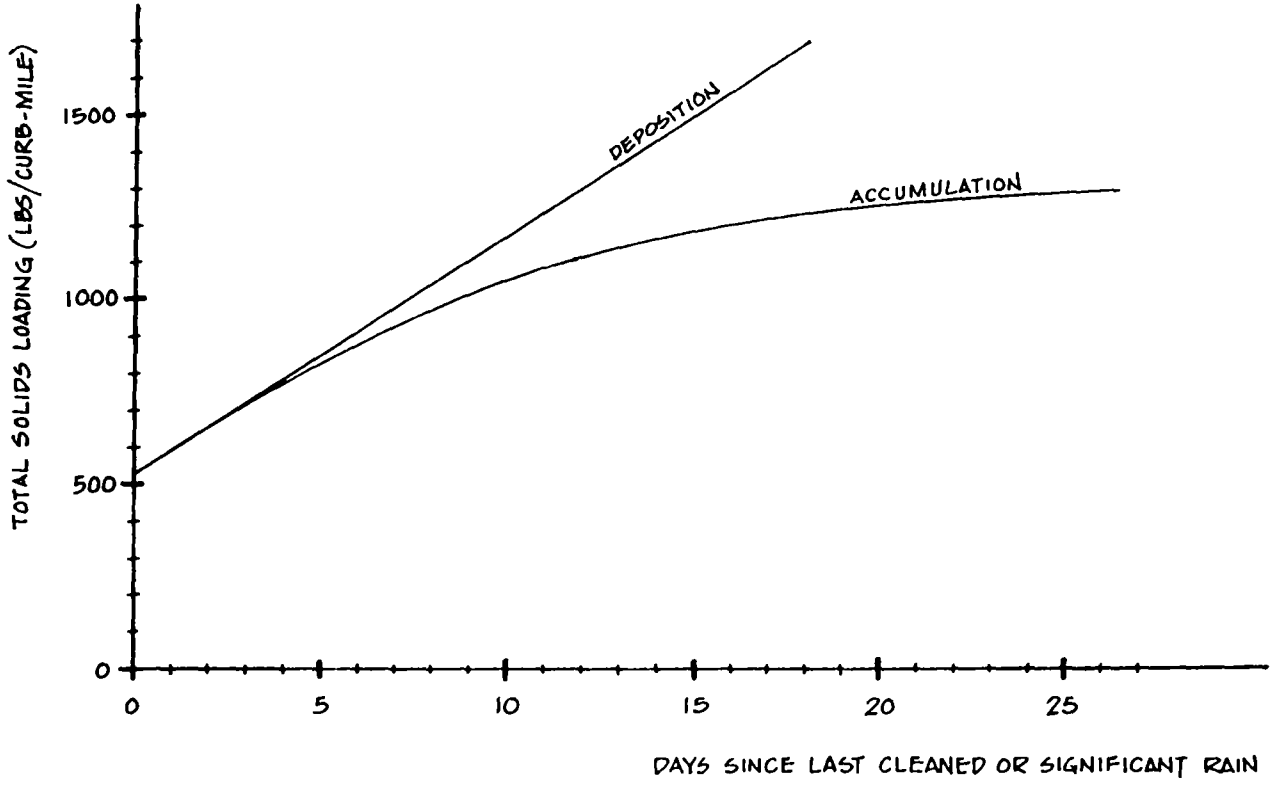


FIGURE 8

DEPOSITION & ACCUMULATION RATES
FOR MIDDLE TEST AREA

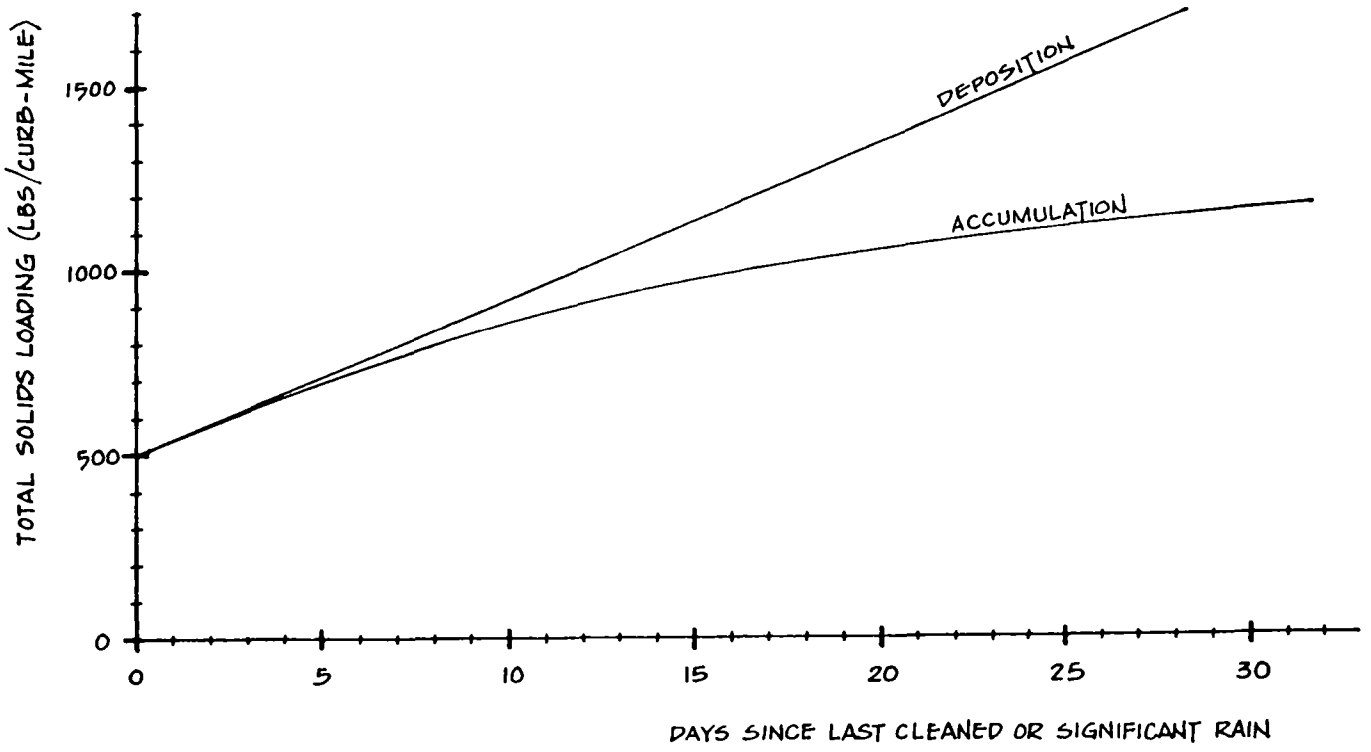


FIGURE 9

DEPOSITION & ACCUMULATION RATES
FOR UPPER TEST AREA

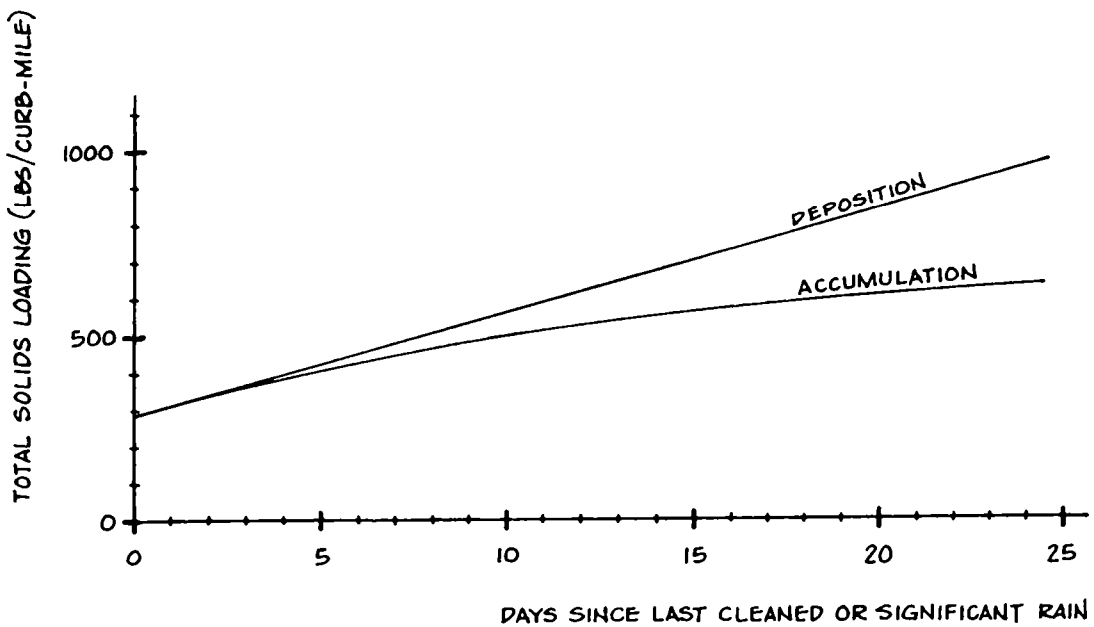


TABLE 9. CASTRO VALLEY TOTAL SOLIDS ACCUMULATION RATES

Days After Street Cleaning or Significant Rain	Lbs./Curb Mile Lower Area Loading Value	Lower Area Accum. Rate	Middle Area Loading Value	Middle Area Accum. Rate	Upper Area Loading Value	Upper Area Accum. Rate
0	530	--	500	--	285	--
1	600	70	560	60	315	30
3	725	63	630	35	365	25
5	840	58	700	35	405	20
7	930	45	760	30	440	18
10	1,050	40	850	30	490	17
15	1,180	26	960	22	560	11
20	1,240	12	1,050	18	605	9
25	--	--	1,100	12	--	--
30	--	--	1,160	10	--	--
35	--	--	1,200	8	--	--
Average first day loading values after:						
Street Cleaning:	620		590		280	
Significant Rains:	490		420		350	

TABLE 10. STREET CLEANING EFFECTIVENESS

Test Area	Date	lbs./Curb-Mile Before Loading	After Loading	Removal lbs.	Removal %	Days since Last cleaning	Days since Last rain	Significant Rain Interference
Lower	3/23	1,385	1,182	203	15	121	8	Yes
	3/30	564	557	7	1	7	3	Yes
	4/5	955	727	228	24	6	9	
	4/12	535	365	170	32	7	16	
	4/18	1,131	1,371	-240	-21	6	22	
	5/14	1,012	664	348	34	26	18	Yes
	5/15	807	732	75	9	0.8	19	
	5/16	758	470	288	38	1.0	20	
	5/17	679	668	11	2	1.0	21	
	5/18	568	535	33	6	1.0	22	
Middle								
	1/19	454	381	73	16	58	1.4	Yes
	1/25	703	473	230	33	6	8	
	2/1	462	455	7	2	7	15	
	2/7	674	429	245	36	6	21	
	3/12	1,070	729	341	32	33	12	Yes
	3/13	629	623	6	1	1	13	
	3/14	756	824	-68	-9	1	14	
Upper								
	2/27	488	199	289	59	97	3	Yes
	2/28	332	202	130	39	0.9	4	
	3/2	236	249	-13	-6	1.9	1.5	Yes
	3/5	298	193	105	35	3	4	
	4/25	420	344	76	18	51	29	Yes
	5/3	400	424	-24	-6	9	8	
	5/9	209	182	27	13	6	14	
	5/23	551	340	211	38	14	28	
	5/31	575	357	218	38	8	36	

Average Removal = 115 lbs./curb-mile
Average Removal percentage = 18.4%

Street cleaning performance depends on many conditions including the character of the street surface, street surface initial loading characteristics (total loading value and particle size distribution), and other environmental factors. Street cleaning variables that most affect street cleaning performance include the number of passes the equipment makes and the intervals in street cleaning. The most important measure of street cleaning effectiveness is lbs/curb-mile removed for a specific program condition. This removal value, in conjunction with unit curb-mile costs, allows the cost for removing a pound of pollutant for a specific street cleaning program to be calculated. The "percentage-of-the-before-loading-removed" has often been used as a measure of street cleaning equipment performance. It is very misleading, however, because it is not a measure of the magnitude of the amount of material removed. A street cleaning program may have a very low percentage removal value but a high total amount removed if the initial loading value is high.

The loading and removal rates for all pollutants combined in each test area for all street cleaning programs combined are summarized in Table 10. The percentage removal values for the total solids are similar to other pollutants monitored; however, the removal rates expressed on a lbs/curb-mile removed basis vary greatly. The lbs/curb-mile removed values can be used to estimate the quantity of pollutants that are removed over both a large area and long time period.

Figures 10, 11, and 12 are production functions developed from the first year information for the three test areas. Figure 10 presents the average for all three test areas for the amount of street dirt removed as a function of the street cleaning effort. For example, monthly street cleaning may result in removals of about 2,500 lbs/curb-mile each year. Weekly street cleaning, at four times the cost, may remove about 8,000 lbs/curb-mile each year, and daily street cleaning may remove a total of about 25,000 lbs/curb-mile each year. Unit costs increase as the street cleaning effort increases. Therefore, it is important that a minimum level-of-effort be used to meet the program objectives. Additional street cleaning operations conducted in an area are usually less efficient than if part of the street cleaning effort is redirected to other areas.

Figure 11 is a graph showing the initial total solids loading values. These values are the total solids particulates values on the street before cleaning with different levels-of-effort. These values are the dirtiest that the streets are likely to be for the various street cleaning programs and test areas. Again, there is a decrease in unit effectivness as the number of cleaning passes increased in a year. After about two passes per week, very little additional cleanliness can be obtained in the test areas. However, the lower area may be about four times as dirty as the upper area at this mimimum value.

Figure 12 presents the residual street surface total solids loading values. These residual values are the cleanest that the streets are likely to be with these various street cleaning programs. Again, the upper area can be made noticably cleaner than the other two areas. There is not a significant improvement in these residual loadings after about two or three passes per week. There can be major changes in going from monthly to weekly street cleaning.

FIGURE 10

STREET DIRT REMOVED AS A FUNCTION OF THE STREET CLEANING EFFORT

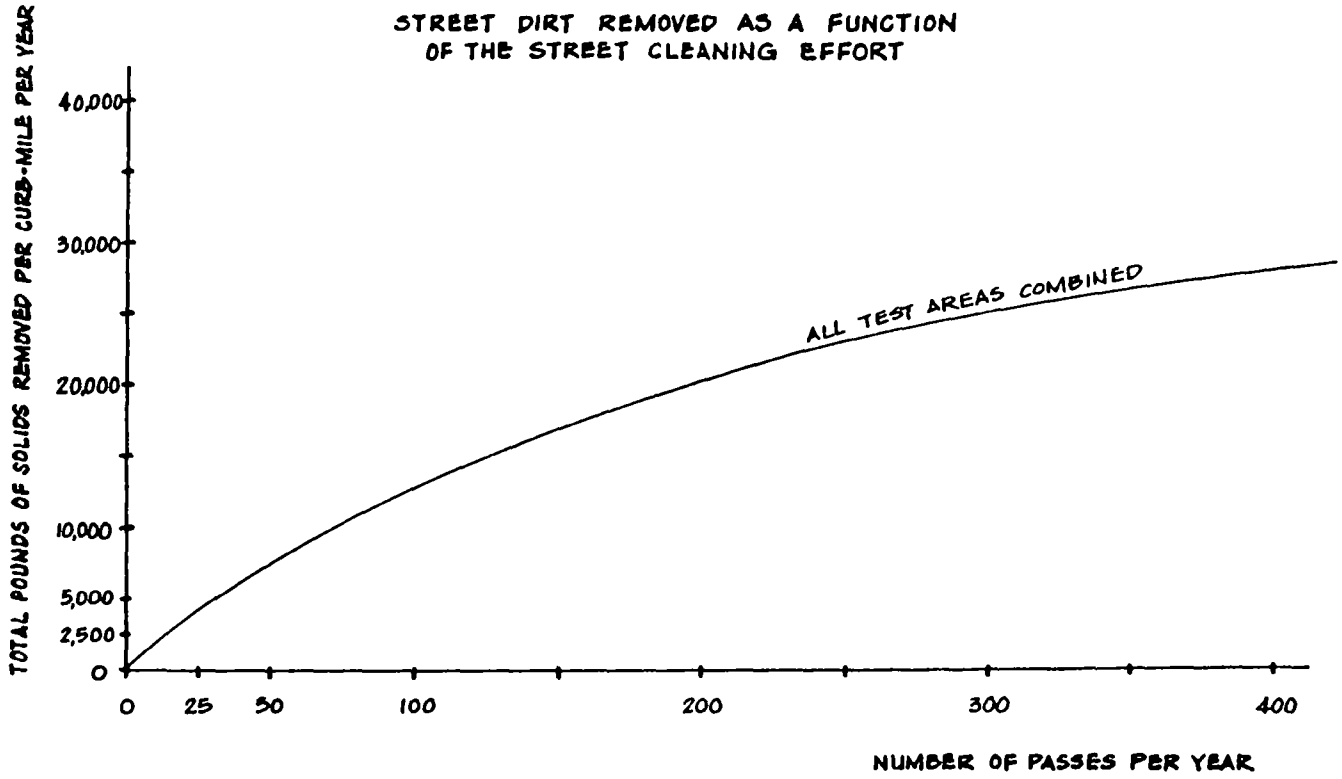


FIGURE 11

INITIAL STREET LOADING AS A FUNCTION OF THE CLEANING EFFORT

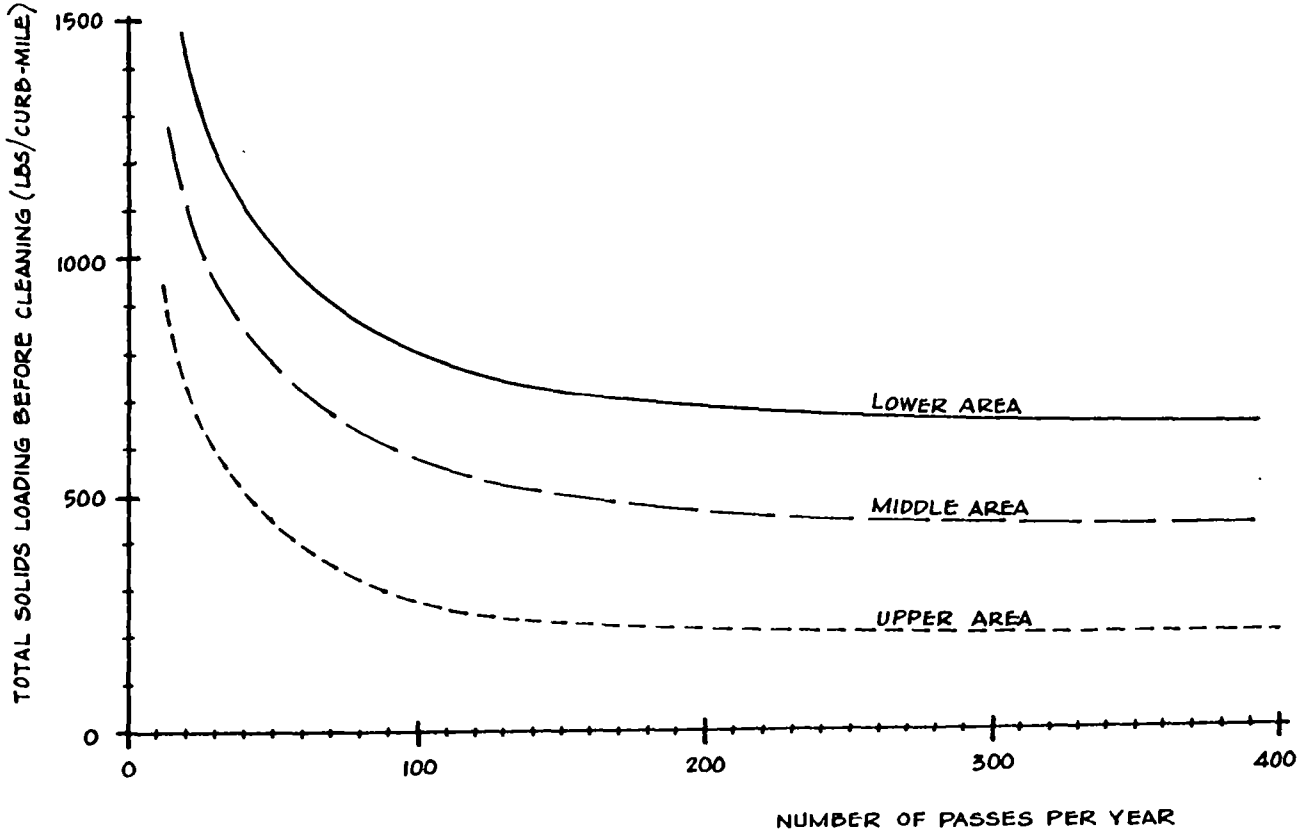
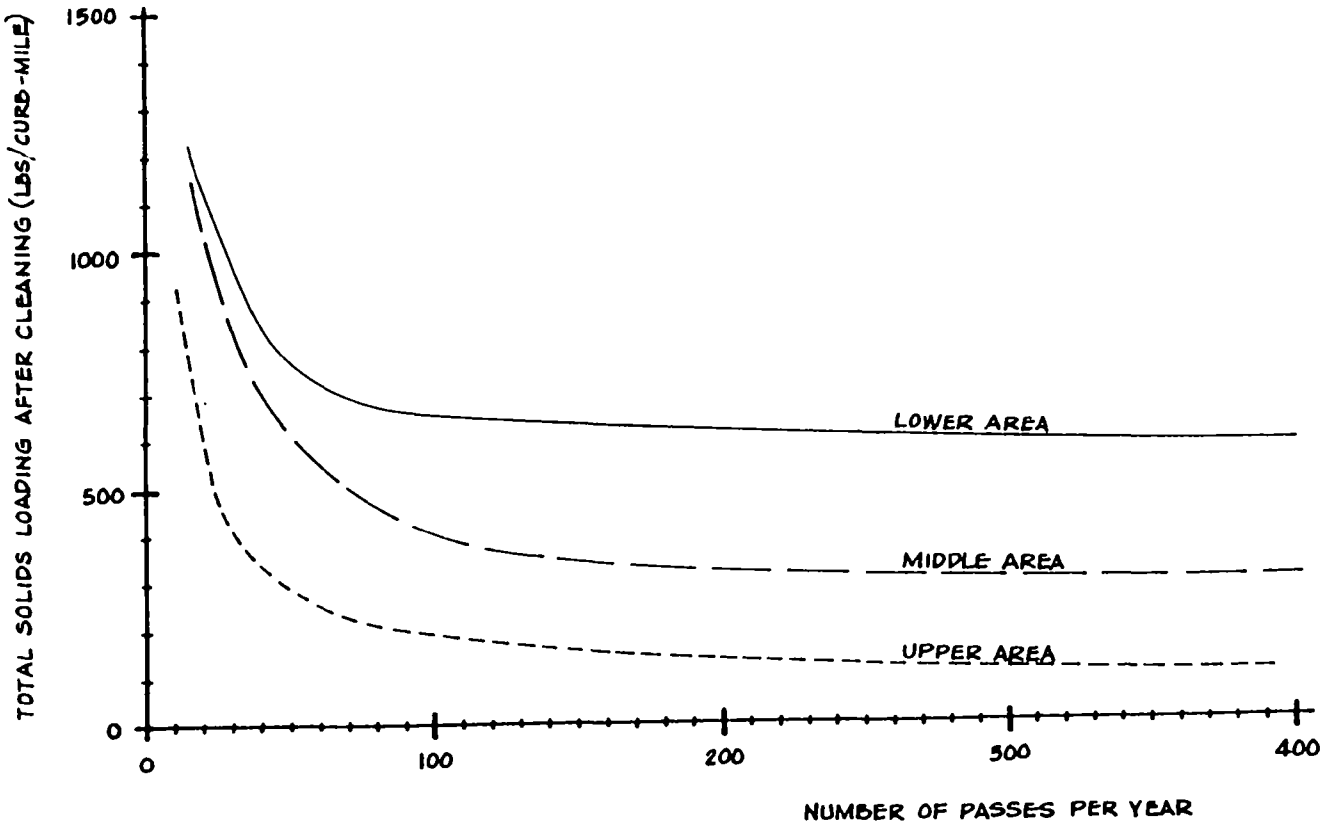


FIGURE 12

RESIDUAL STREET LOADING AS A FUNCTION OF THE CLEANING EFFORT



These figures are based on preliminary information and will change after data from the complete study is analyzed for the final, second year report. However, the figures do point out important aspects of street cleaning programs. The most important of these aspects is that additional cleaning after a certain level-of-effort is not productive and that street cleaning effort would be better applied to other areas. The information relating to street cleaning program effectiveness and accumulation rates is used to address the major objectives of this demonstration project. This major objective is relating different magnitudes of street cleaning effort to Castro Valley Creek pollutant flow information and is presented in Section 5 of this report.

SECTION 5

CASTRO VALLEY CREEK MONITORING

The objectives of the study of pollutant mass flow characteristics of Castro Valley Creek were:

- To estimate the beneficial effects of street cleaning on the quality of receiving waters.
- To investigate the quantity of pollutants removed from the watershed by the various types of rainstorms.

Runoff event monitoring began on December 5, 1978, after two receiving water monitoring stations were installed by the USGS at Seaview Avenue (USGS #11181004) and Knox Street (USGS #11181096). Some of the monitored flows at these two locations are shown in Figure 13.

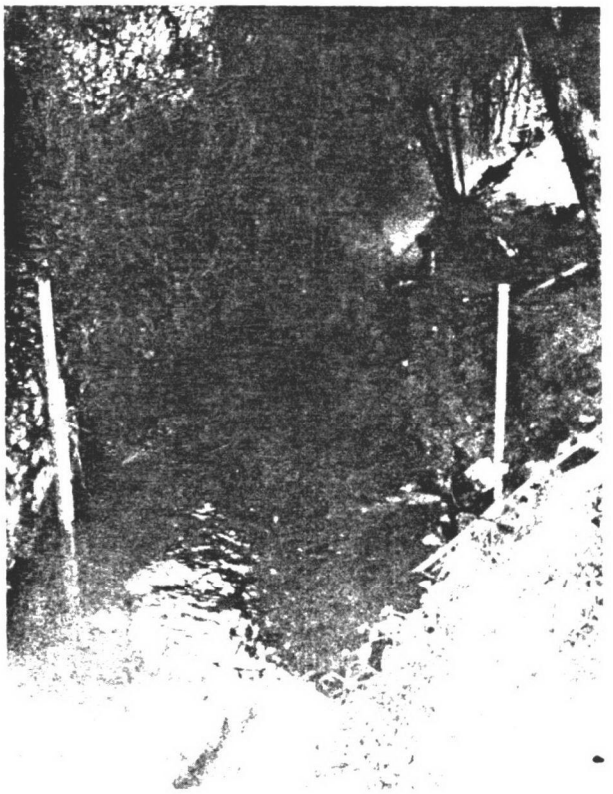
Nineteen individual storm-days have been monitored. However, for most data analysis purposes, a monitored storm cannot be used unless a street surface sample is collected from the entire study area before and after a storm. If an unmonitored storm occurs in a series of monitored storms between adjacent street surface sampling, the complete runoff yield for that storm series cannot be calculated or compared to the in street surface loadings. Consequently, from the 19 storm-days, eight valid data sets have been obtained for analysis.

Since the onset of the 1978-1979 wet season, measurable rain has occurred on 58 days (with 1-day of rain prior to initiation of field activities). These events are summarized on Table 11. In comparison to an annual average of 21.7 inches, the total amount of rain from September 1978 to April 17, 1979 was almost 17 inches. Individual rains have lasted from 15 minutes to 23 hours per day and the storm periods have ranged to a maximum of 7 days.

Table 12 summarizes the significant rains that occurred during the field activities of the first year of this study and compares rainfall conditions observed at the Proctor and Fire Station raingage locations. The rain total and intensity values observed at these two stations agree within reasonable limits. The times of the rains observed at the Proctor Station are also indicated on this table. The total rainfall during any one of these significant rain days ranged from 0.18 inches to 1.8 inches. Average intensity ranged from 0.01 inches to 0.21 inches per hour. Peak 5 minute intensities during these rains were substantially greater. Peak 1 hour intensities ranged from 0.4 inch per hour to 0.67 inches per hour.

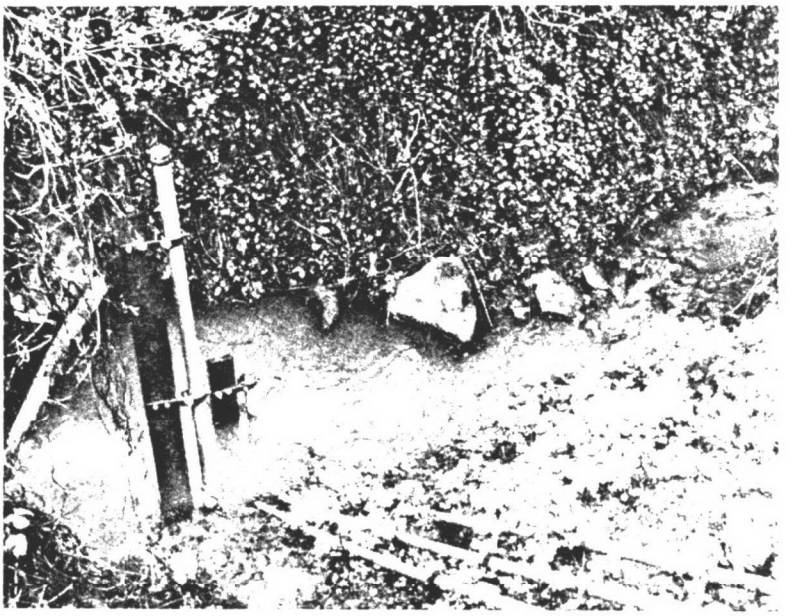
Table 13 summarizes the 1978-1979 monitored rain year. Almost seventeen inches of precipitation occurred during this rain year, which is about 77 percent of the normal annual rain. Rain occurred on a total of about 58 days, while 19 of these days were included in the Castro Valley Creek monitoring effort. Significant rains occurred on a total of about 23 days during this period of time. January and February accounted for most of the rain that occurred in this year while June, July, August, and October

FIGURE 13. RUNOFF FLOWS AT MONITORING STATION SITES



A. Discharge at Knox Street Station

B. Discharge at Seaview Avenue Station



C. Discharge and Staff Gage
at Seaview Avenue Station

TABLE 11 CASTRO VALLEY RAIN EVENTS DURING FIELD ACTIVITIES[1]

Date	Total (inches)	Duration (hours)	Average Intensity (inches/hour)	Peak Intensity (inches/hour)
Dec. 17, 1978*	.39	12.5	.03	.14
Dec. 18	.05	15.75	.003	.03
Dec. 19	.01	0.25	.01	.01
Jan. 3, 1979	.10	3.25	.03	.03
Jan. 4	.03	9.25	.003	.02
Jan. 5	.01	0.25	.01	.01
Jan. 7*	.34	14.75	.02	.05
Jan. 8*	1.24	6.0	.21	.40
Jan. 9	.18	8.25	.02	.04
Jan. 10*	.78	4.25	.18	.39
Jan. 11	1.80	20.75	.09	.27
Jan. 14*	1.43	20.75	.07	.33
Jan. 15	.28	12.75	.02	.09
Jan. 17	.24	5.75	.04	.11
Jan. 30	.01	.25	.01	.01
Feb. 3	.01	.25	.01	.01
Feb. 13*	1.11	13.25	.08	.25
Feb. 14	.09	9.25	.01	.01
Feb. 15	.01	.25	.01	.01
Feb. 16*	.49	11.75	.04	.21
Feb. 17	.01	.25	.01	.01
Feb. 18	.45	8.75	.05	.20
Feb. 19*	.06	1.25	.05	.05
Feb. 20*	.74	17.75	.04	.25
Feb. 21*	.41	11.0	.04	.17
Feb. 22*	.64	13.25	.05	.30
Feb. 23	.18	23.25	.01	.07
Feb. 25	.07	2.75	.03	.04
Feb. 26	.09	9.50	.01	.06
Feb. 28*	.58	6.25	.09	.17
Mar. 1	.01	.25	.04	.04
Mar. 3	.03	4.5	.01	.01
Mar. 15	.05	2.7	.02	.04
Mar. 16*	.69	17.3	.04	.15
Mar. 17	.01	.25	.04	.04
Mar. 26	.40	13.15	.03	.13
Mar. 27*	1.45	23.0	.06	.38
Mar. 28	.13	20.85	.01	.06
Apr. 6	.02	.25	.08	.08
Apr. 9	.01	.25	.04	.04
Apr. 16	.05	9.15	.01	.04
Apr. 17	.04	6.15	.01	.01
Apr. 22	.04	1.85	.02	.03
Apr. 23	.11	20.0	.01	.09
Apr. 25	.01	.25	.04	.04
Apr. 26*	.37	12.15	.03	.12
May 5	.02	.5	.04	.02
May 6	.05	23.5	.002	.03
May 7	.04	12.75	.003	.02
May 8	.03	2.0	.015	.02
May 15	.01	.25	.04	.04

Station discontinued for remainder of water year

1 Proctor School Rain Gage, USGS #71-1810.08

* Monitored Events

TABLE 12. SIGNIFICANT RAINS DURING FIELD ACTIVITIES OF FIRST YEAR

Date	Total Rain (in.) Proctor	Total Rain (in.) Fire Sta.	Average Intensity (in/hr) Proctor	Average Intensity (in/hr) Fire Sta.	Peak Intensity (in/hr) Proctor	Peak Intensity (in/hr) Fire Sta.	Time of Rain Proctor
Dec. 17,1978	0.39	0.44	0.03	0.02	0.14	0.1	0530 1800+
Jan. 7, 1979	0.34	0.38	0.02	0.02	0.05	0.05	0830 2315+
8	1.24	1.35	0.21	0.21	0.40	0.67	0945 1545+
9	0.18	0.12	0.02	-	0.04	-	0445 1300+
10	0.78	0.64	0.18	0.13	0.39	0.33	1925 2400+
11	1.80	1.57	0.09	0.01	0.27	0.23	0045 2130
14	1.43	0.58	0.07	0.09	0.33	0.15	0245 2330+
15	0.28	0.57	0.02	-	0.09	-	0130 1415
17	0.24	0.23	0.04	-	0.11	-	1630 2215
Feb. 13,1979	1.11	1.18	0.08	0.05	0.25	0.34	1020 2345+
16	0.49	0.48	0.04	0.04	0.21	0.28	0115 1300+
18	0.45	0.31	0.05	0.03	0.20	0.07	0830 1715+
20	0.74	0.84	0.04	0.04	0.25	0.21	0530 2315
21	0.41	0.57	0.04	0.05	0.17	0.27	0045 1145
22	0.64	0.90	0.05	0.08	0.30	0.43	0645 2000+
23	0.18	0.18	0.01	-	0.07	-	0045 2400+
28	0.58	0.58	0.09	0.08	0.17	0.19	1500 2115+
Mar. 16,1979	0.69	0.65	0.04	0.03	0.15	0.12	0230 1945+
26	0.40	0.45	0.03	0.03	0.13	0.13	0930 2245+
27	1.45	1.56	0.06	0.07	0.38	0.45	0100 2400+
Apr. 26,1979	0.37	0.35	0.03	0.08	0.12	0.19	0500 1715

of 1978 did not have any rain at all. Also shown on Table 13 is the average number of days between these rains. For the 23 significant storm days,the longest dry accumulation interval was about 150 days (this occurred before the September rain). In contrast, only about 4 dry accumulation days occurred between significant rains during January and February. Therefore, it can be expected that the first rain of the year, typically occurring in September or October, can account for almost one-half of the annual pollutant runoff from street surfaces. January and February rains are mostly influenced by erosion (non-street surface runoff) and are not significantly affected by street cleaning.

The collected runoff samples were analyzed individually and in selected composites. The more important parameters were investigated at different times during several initial rains to see how the concentrations changed as the rain progressed. Other parameters were analyzed only once during each monitored rain. These individual composite samples were based on a flow-weighted basis and represent the total quantity of pollutants flowing in Castro Valley Creek at the two stations.

Nineteen rain days were monitored during the first year of study (Table 13). The pollutant flow information from the Knox and Seaview monitoring stations was used to calculate the amounts of pollutant mass discharge that entered the creek.

ANALYTICAL PROGRAM

This project is concerned with total mass flows of pollutants and pollutant removals associated with various types of street cleaning programs and meteorological conditions. In order to maximize the number of monitored events, composite sampling and restricted analyses are necessary. Automatic water samplers directly connected to flow measuring devices are used at the two monitoring stations to enable flow-weighted composite samples to be obtained. Samples for any storm can be directely combined into a single flow-weighted composite sample representative of the total mass flows during the storm. Analyzing this single sample will enable calculation of the total mass flow that occurred during the runoff event.

The runoff measuring devices were not calibrated until several storms had occurred, so the first few storms necessitated collecting discrete samples throughout the period of the storm for individual analyses. These concentrations, representiative of different time periods in the storm, were later used to calculate mass flows. The first storm samples involved analyzing 10 discrete samples spread over the period of the runoff flow period. The next two runoff events were sampled utilizing an estimated stage-flow relationship, enabling a significant reduction in the amount of samples necessary and the associated costs. Additional storms were analyzed on a total storm flow-weighted composite basis during the first project year.

Table 15 lists the parameters included under three different sampling and analytical priorities. The first priority samples are the most important ones and are expected to be most sensitive to street surface loading conditions and associated street cleaning programs. The heavy metal storm yields--specifically lead and possibly zinc--are expected to be most sensitive to

TABLE 13. SUMMARY OF CASTRO VALLEY 1978-1979 MONITORED RAIN YEAR

1978-79 "Rain Year"	Total Rain (in)	Number of Rain-days Monitored	Number of Days with Rain >0.01 in.	Number of Insignif. Rain Days	Avg. No. of Days between Any Rain	Avg. No. of Rain between Signif. Rain
30 June,1978	0	0	0	0	30*	30*
31 July	0	0	0	0	31*	31*
31 August	0	0	0	0	31*	31*
30 September	0.35	0	1	1	30	30
31 October	0	0	0	0	31*	31*
30 November	0.84	0	5	1	6	30
31 December	0.81	1	4	1	8	31
31 January,1979	6.44	4	12	8	3	4
28 February	4.94	7	15	8	2	4
31 March	2.77	6	8	3	4	10
30 April	0.65	1	8	1	4	30
31 May	0.15	0	5	0	6	31*
TOTAL	16.95	19	58	23		

*Whole month; add to preceeding months value for total accumulation between storms:

Significant Storm Number for Year	Approximate Month	Approximate Accumulation Interval (days)
1	Sept.	149
2	Nov.	61
3	Dec.	31
4-11	Jan.	4
12-19	Feb.	4
20-22	March	10
23	April	30

TABLE 14. PARAMETER LIST FOR RECEIVING WATER ANALYSES

FIRST PRIORITY

Total Solids
Lead
Zinc
Specific Conductance
Turbidity
pH

SECOND PRIORITY

Total dissolved solids	Iron
Chemical oxygen demand	Chromium
Phosporous	Copper
Orthophosphate	Nickel
Kjeldahl nitrogen	Cadmium
Sulfate	Mercury
Arsenic	Ammonia
Suspended Solids	Nitrites
Volatile suspended solids	Potassium
Bicarbonate	Calcium
Carbonate	Magnesium
Chloride	Sodium

THIRD PRIORITY

Organic/pesticide-herbicide screen (by GC/MS)
Elemental screen (by SSMS)

street cleaning programs. The total solids analyses are important to relate relative concentrations (milligrams of pollutant per kilogram of total solids) of the runoff with the street surface samples. Specific conductance, turbidity, and pH measurements were taken on each individual sample throughout the project period as indicators of concentration variations during the storm period. The first priority list was analyzed on about five discrete samples during the two storms utilizing an assumed stage-flow relationship program in the sampling equipment. The second priority list is a comprehensive list of parameters generally analyzed for urban runoff samples reflecting the important parameter groups of solids, organics, nutrients, heavy metals, and major ions. A single time composited sample was analyzed from the next three storms for this list as a general indication of the runoff and receiving water characterization. The third priority list includes two types of screening procedures basically designed to identify other parameters not included in the normal monitoring program that may be present in important concentrations.

The total watershed yeilds were measured at the lower monitoring station (located at Knox Avenue) and the non-urban portion of the watershed was measured at the upper monitoring station. Street cleaning activities were only conducted in the lower urbanized sections of the watershed, so the mass yields were corrected and most of the analyses reflects the urbanized area only.

POLLUTANT REMOVAL CAPABILITIES OF MONITORED STORMS

Table 16 presents the total solids and various pollutant loading conditions observed on the street surfaces immediately before each of eight monitored rain periods. Table 16 also shows the urban runoff entering Castro Valley Creek between the two monitoring stations. Calculations were made to determine changes in the street surface contaminant loadings and the runoff yields. These calculations include factors to reflect expected street surface loading conditions immediately before and after the rain events. These loading corrections are based on the previously described street surface pollutant accumulation rates. Values smaller than one in the ratios between the street surface washoff and the observed creek yields possibly signify that more of the pollutants originated from non-street surface areas. Values greater than one possibly indicate that most of the material that originated from the street surfaces accumulated in the storm sewerage. These ratios appear to vary for the different pollutants as a function of the rain storm characteristics (magnitude of the rain quantity and accumulation interval between rains). The storms of greater intensity and lower street surface loading conditions appear to result in more material originating from surrounding areas and carried onto the street surfaces during the storms through erosion. Storms of relatively small intensities and long accumulation intervals, however, showed almost complete removals of street surface contaminants with little additional erosion yield for some of the pollutants. On some of these smaller rains, the flows in the sewerage were not capable of preventing the material from depositing in the sewerage. The small number of data points available for this analyses prevents a detailed model from being developed. However, the eight data points observed were used to develop

Table 15 OBSERVED STREET AND CREEK YIELDS

Storm Date	Total Rainfall (In.)	Days Since Last Signif. Rain	Avg. Days Since Cleaned	Total Initial Load (Lbs.)	Solids Storm Yield (Lbs.)	Lead Load	Lead Yield	Zinc Load	Zinc Yield	COD Load	COD Yield
Jan 8	1.24	1	47	66,300	112,000	245	--	33	70	10,600	20,000
Jan.10-11, 14	4.01	1	49	15,400	65,600	33	--	4.9	41	1,750	--
Feb.13-14	1.20	27	57	37,200	8,000	63	19	9.8	9.6	3,070	7,200
Feb. 15-16 18,19,20, 21 & 22	2.80	2	59	27,100	119,000	39	80	7.0	54	2,160	22,600
Feb. 28-Mar. 1	0.58	5	40	29,200	12,300	50	9.6	8.1	9.9	2,370	3,710
Mar.15-17	0.75	15	39	43,800	6,990	69	6.7	12	4.5	3,740	2,490
Mar.26-28	1.98	10	12	45,000	26,500	65	21	12	14	3,930	7,400
Apr. 26	0.37	31	17	33,500	4,970	47	8.2	8.5	4.1	2,850	2,020

Storm Date	Total P Load	Total P Yield	O-PO4 Load	O-PO4 Yield	Arsenic Load	Arsenic Yield	Copper Load	Copper Yield	Chromium Load	Chromium Yield	Sulphur Load	Sulphur Yield	Kjeldahl Nitrogen Load	Kjeldahl Nitrogen Yield	Volatile Solids Load	Volatile Solids Yield
Jan. 8	0.66	130	0.51	--	2.7	--	10.6	--	30.0	--	140	--	77	470	12	--
Jan. 10-11, 14	0.11	--	0.085	--	0.44	--	1.7	--	4.9	--	22	--	12	--	2.1	--
Feb. 13-14	0.19	23	0.14	29	0.73	0.30	3.3	2.3	8.7	0.55	43	--	23	83	1.9	--
Feb. 15-16, 18,19,20, 21 & 22	0.13	130	0.10	260	0.54	1.8	2.3	13	6.2	5.7	29	--	16	470	1.3	--
Feb. 28-Mar. 1	0.15	13	0.12	8.9	0.62	0.27	2.5	2.2	6.9	0.86	33	--	18	97	1.5	--
Mar. 15-17	18	6.7	1.9	2.9	0.43	0.10	3.1	1.2	12	0.63	35	--	17	18	3.1	--
Mar. 26-28	18	38	2.0	15	0.45	0.50	2.9	2.9	13	1.9	36	--	18	135	3.2	--
Apr. 26	14	5.8	1.6	0.93	0.34	0.042	2.1	0.71	9.5	0.25	27	--	13	41	2.8	--

rough approximations between street cleaning effectiveness and improving the creek runoff yields. The additional monitoring effort during the second year of the demonstration program will yield much more information for this analytical procedure.

EFFECTIVENESS OF STREET CLEANING IN IMPROVING RECEIVING WATER QUALITY IN CASTRO VALLEY

Street cleaning can be effective in reducing the quantity of some pollutants in urban runoff and therefore the effects of urban runoff on receiving waters. Most of the materials removed by a street cleaner on smooth streets would wash off during a rain and contribute to the pollution of a receiving water. Figures 14 through 18 relate street surface pollutant loadings before the storm to the change in creek pollutant yield between the two monitoring stations.

In almost all cases, two specific groupings of data were observed. One grouping was associated with short accumulation intervals before the monitored storm (one or two days) with storm quantities of values greater than 1-inch (up to 4-inches). These storms showed (for almost all the pollutants) that other sources besides the street surface are more important in urban runoff pollutant yields. Street cleaning therefore has little effect in reducing the pollutant loads from these storms. These storms have sufficient energy to remove the small amounts of street surface pollutants on the street before these storms and to erode significant quantities of pollutants from other known pollutant sources (such as roof tops, parking lots, vacant lots, landscaped areas, and other areas.

The other group of storms observed had relatively long accumulation intervals between storms (5 to 31 days) and had relatively small amounts of rainfall (0.37 to 1.98-inches of total rain). The ratios of number of days since last significant rain to total rain, in inches, for this category was always greater than about 5 (a maximum ratio of 84 was observed). In contrast, the ratio between the accumulation interval, in days, and total rainfall, in inches, for the other group of rain conditions observed were always less than one. These lighter rains were capable of removing as much of the street surface contaminants as possible, with little additional contributions for additional pollutant source areas. Street cleaning activities could be very important in affecting the runoff water quality and receiving water conditions for these storms.

Figures 14 and 15 show the street surface loading and runoff yield relationships for total solids and chemical oxygen demand (COD). For the lighter rains, with dirtier streets, (Figure 14) much of the street dirt accumulated in the sewerage or in the creek or was not completely washed off the street surface. Rains having heavier intensities and shorter accumulation intervals (Figure 15) showed that other sources of total solids were much more important than street dirt. These heavier rains were much more capable of creating significant erosion which would quickly dominate the urban runoff when compared to the street dirt yields.

FIGURE 14

TOTAL SOLIDS AND COD CREEK YIELDS FOR
STORMS OF RELATIVELY SMALL RAINFALL QUANTITIES AND LONG DRY ACCUMULATION PERIODS

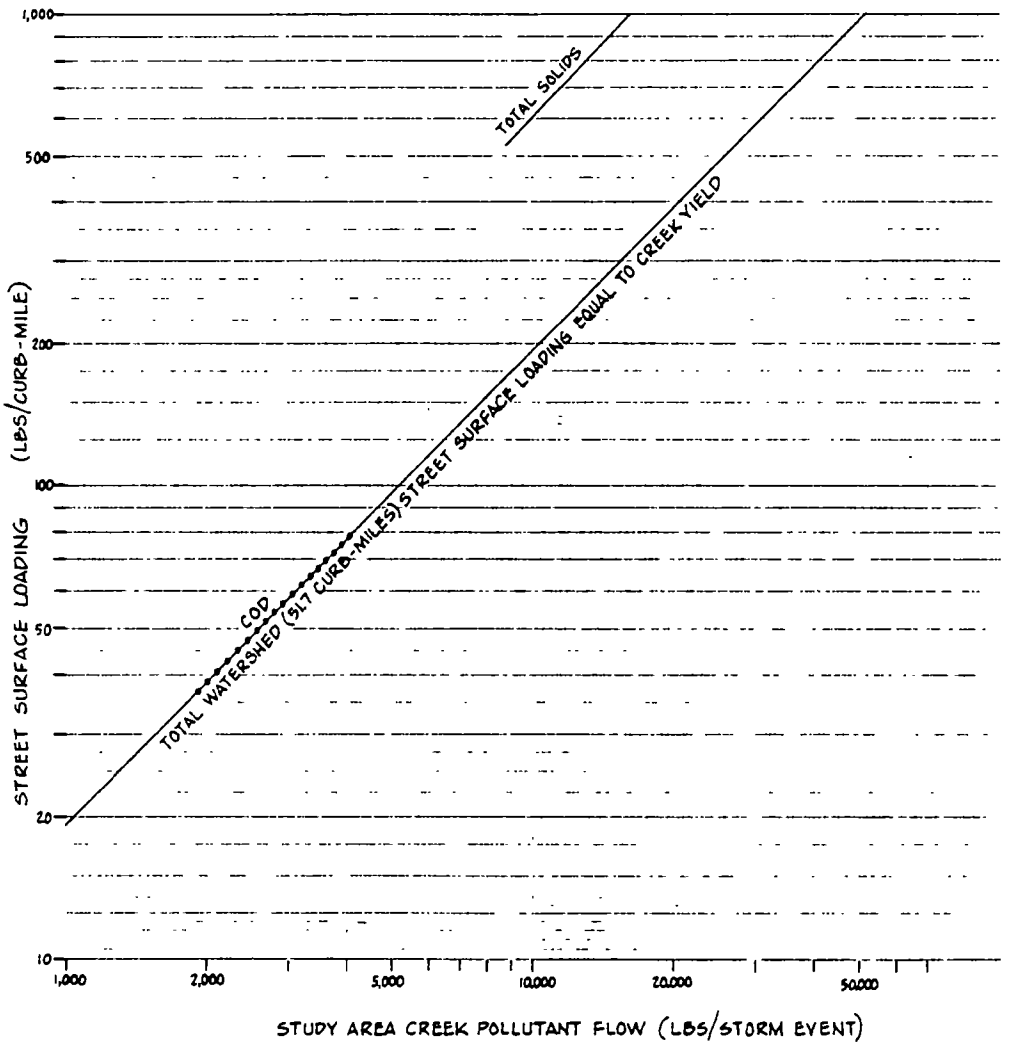
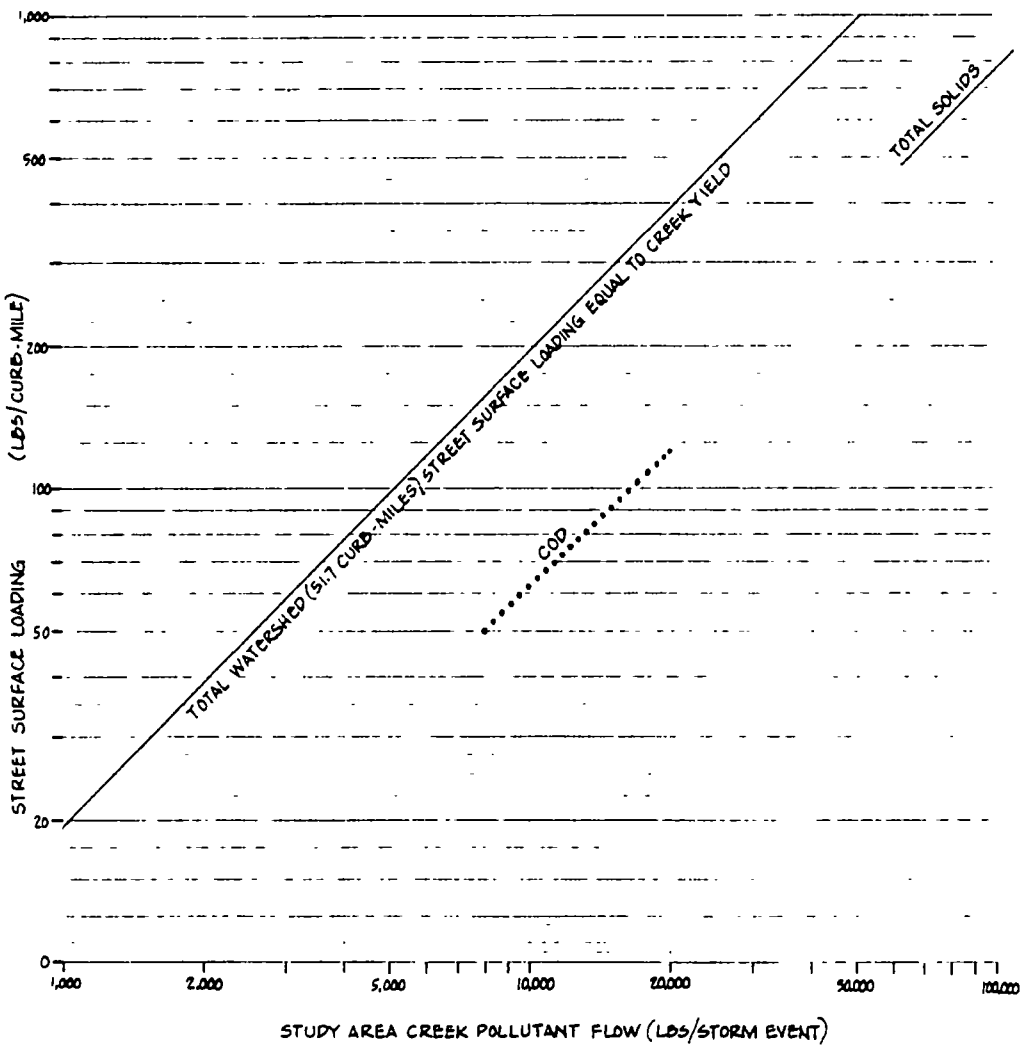


FIGURE 15

TOTAL SOLIDS AND COD CREEK YIELDS FOR
STORMS OF RELATIVELY LARGE RAINFALL QUANTITIES AND SHORT DRY ACCUMULATION PERIODS



A similar relationship was observed for lead (Figures 16 and 17) either not all the lead was removed from the streets or it was deposited in the sewerage or the creek before the Knox monitoring Station for the lighter rains. For the heavier rains with shorter accumulation intervals, more lead was observed in the creek flow than was on the street before the rain occurred. Other sources of lead (besides the street surfaces) were probably the storm sewerage and adjacent areas where lead was blown by winds or traffic induced turbulence off the street surfaces or parking lots and driveways could also have contributed lead under these conditions.

The zinc and COD relationships were slightly different. The heavier rains showed that much of the zinc and COD occurred in erosion material and not street surfaces. However, the lighter rains with the dirtier streets showed that almost all of the zinc or COD observed in the creek flow was due to the street surface loadings.

The nutrients Kjeldahl nitrogen, total phosphorous, and orthophoshate showed that almost all of the nutrients were associated with non-street surface sources, except during the lightest rains when the rains would not be capable of removing much of the non-street surface materials. Analysis of arsenic, copper, and chromium levels indicated that more of these metals were on street surfaces before the storms than in the creek flows. There was no pattern of runoff yield compared with rain magnitude or accumulation period for these metals. More variability in the runoff yields were observed than in the street loadings for these metals. Copper and chromium results showed that larger rains produced greater erosion yields.

Clearly, street cleaning can significantly affect the quality of receiving waters. The preliminary relationships between street cleaning programs and the quality of receiving waters are presented in Figure 1. The more common street cleaning program changes are summarized in Table 16. The receiving water conditions in this table are related to mass flow values between the two monitoring stations. The effects would not be as large if "base flow," especially if polluted by upstream construction or agricultural practices, was considered. Therefore, the effects relate only to receiving waters that are totally urban runoff. These values, however, are quite large. Lead, total solids, and zinc mass flows could be reduced 65 percent, if street cleaning programs were increased from "no effort" to a "maximum" effort of three times a week. These pollutants could even be reduced 40 percent by changing street cleaning programs from a monthly to weekly schedules. Changing from none to quarterly, quarterly to monthly, or weekly to several times per week would not be nearly as cost effective for the conditions monitored. If an area is currently cleaned weekly, it would be much better to leave that schedule alone and start weekly cleaning in other areas that currently receive monthly, or less cleaning (such as industrial areas). Similarly, if an area is being cleaned several times a week, that cleaning effort should be reduced to weekly cleaning and other areas should be cleaned using the newly available resources.

FIGURE 16

LEAD, ZINC, CHROMIUM, ORTHOPHOSPHATE AND TOTAL PHOSPHORUS CREEK YIELDS FOR STORMS OF RELATIVELY SMALL RAINFALL QUANTITIES AND LONG DRY ACCUMULATION PERIODS

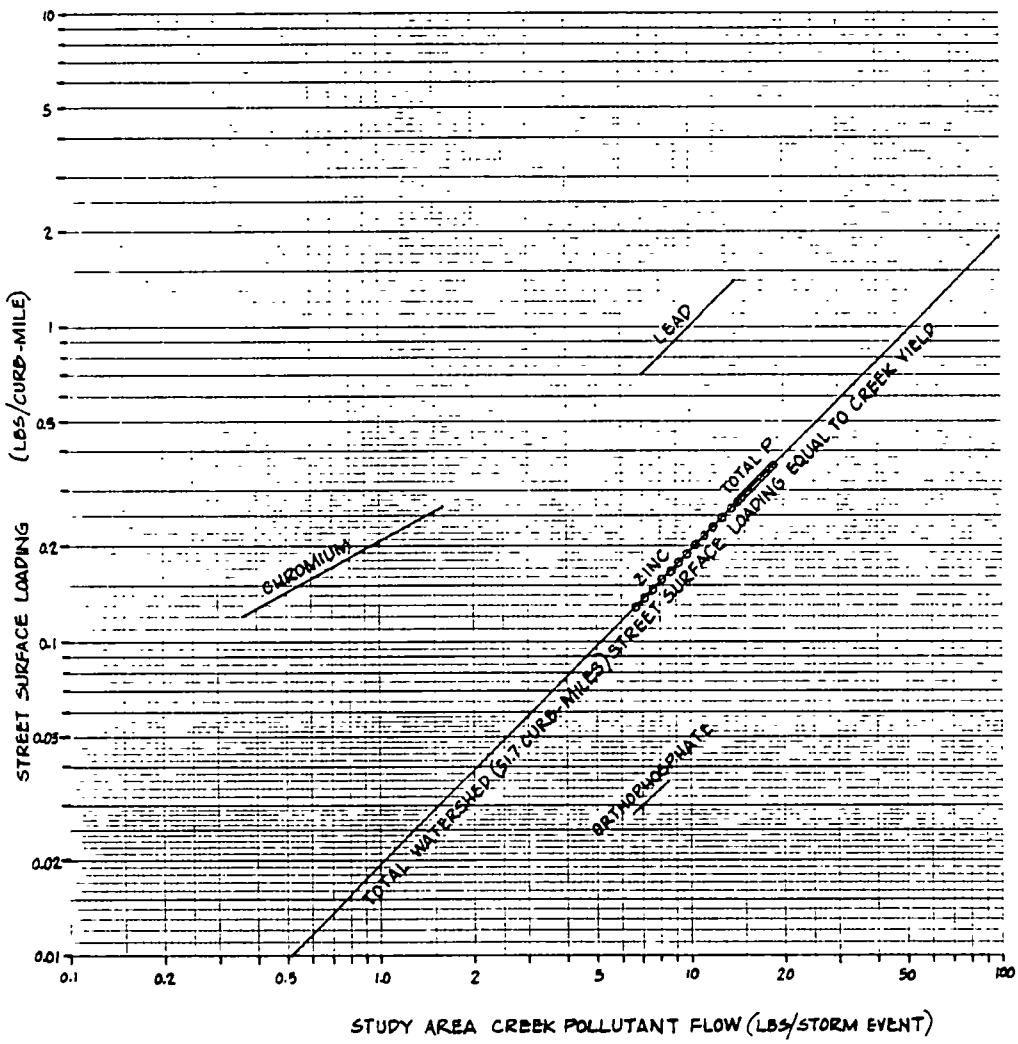


FIGURE 17

LEAD, ZINC, CHROMIUM, ORTHOPHOSPHATE AND TOTAL PHOSPHORUS CREEK YIELDS FOR STORMS OF RELATIVELY LARGE RAINFALL QUANTITIES AND SHORT DRY ACCUMULATION PERIODS

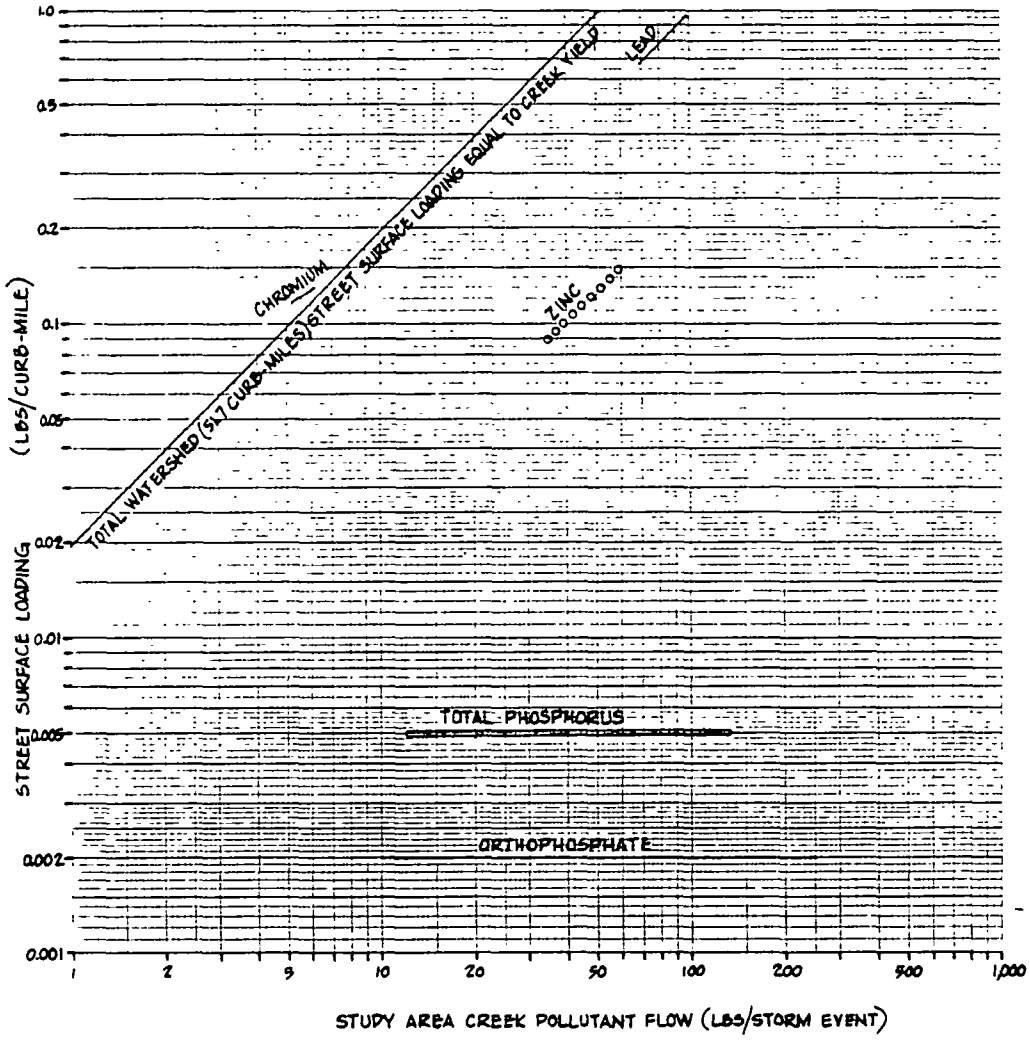


FIGURE 18

ARSENIC, COPPER AND KJELDAHL NITROGEN CREEK FLOWS FOR VARIOUS STREET SURFACE LOADING VALUES

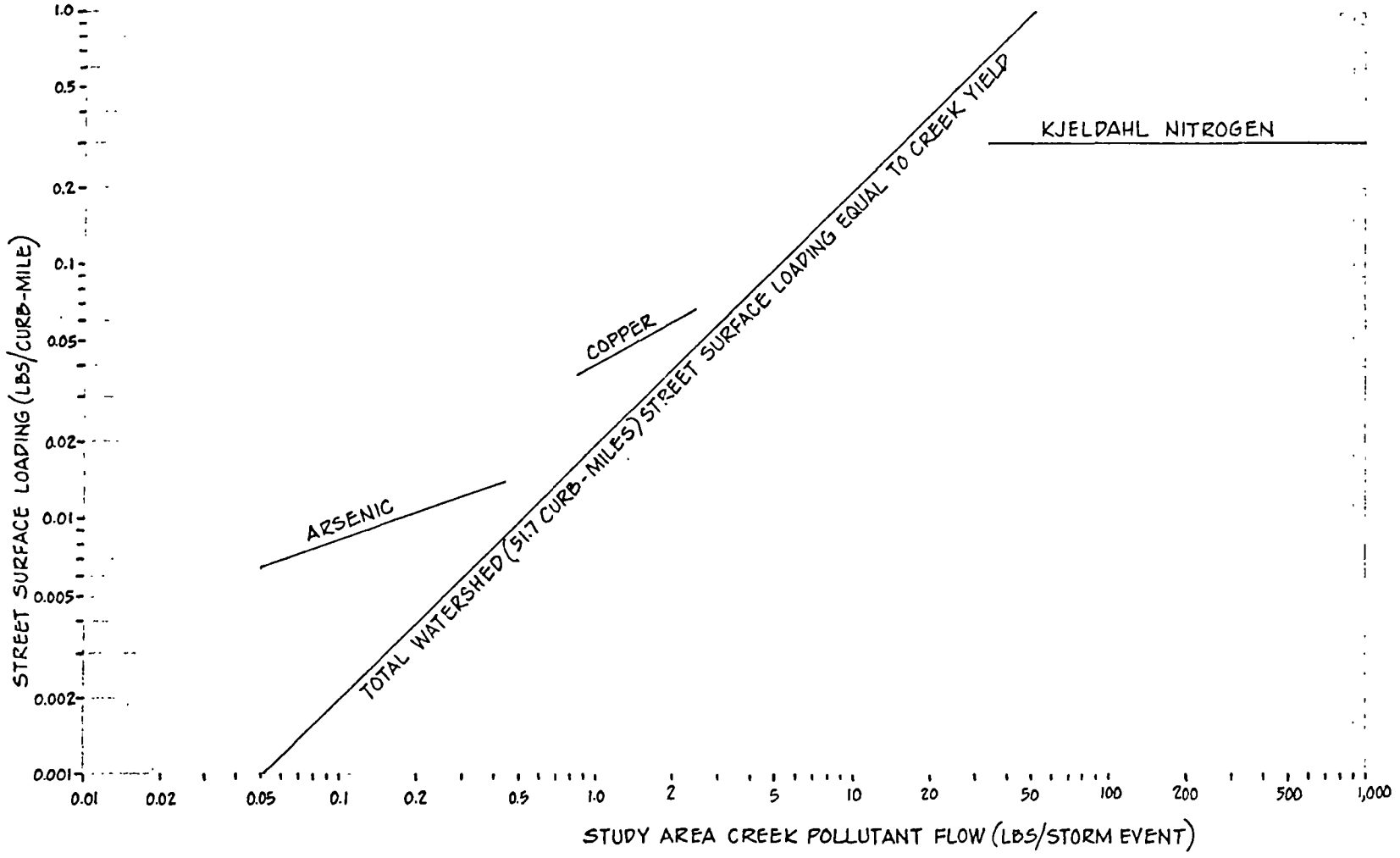


TABLE 16. ESTIMATED EFFECTIVENESS OF STREET CLEANING IN IMPROVING RECEIVING WATER QUALITY

and if new program is:	Percentage change in receiving water lead* yield of current street cleaning program is: None		Quarterly		Monthly		Weekly		3 to 7 times a week
none	0	-	15	-	25	-	100	-	200
quarterly	10	-	0	-	10	-	80	-	200
monthly	20	-	10	-	0	-	60	-	150
weekly	50	-	40	-	40	-	0	-	0
3 to 7 times a week	65	-	60	-	60	-	30	-	0

*Adjustment factors for other parameters include:

- Approximately the same as for lead: total solids and zinc for most storms and orthophosphate and total phosphorous for the initial rains of the season only.
- Approximately one-half as sensitive to street cleaning operations as lead: chromium, copper, arsenic and COD for most storms.
- Not sensitive at all to street cleaning oeprations: Kjeldahl nitrogen for all storms and orthophosphate and total phosphorous for most storms.

Chromium, copper, arsenic and chemical oxygen demand would also be affected by street cleaning, but only to about one-half the level as lead. Changing from monthly to weekly cleaning schedules would, therefore, correspond to a maximum mass flow reduction of about 20 percent for these parameters. The nutrients Kjeldahl nitrogen, orthophosphates, and total phosphorus would hardly be affected by street cleaning, except for the initial hard rains when the phosphorus and orthophosphate street surface loadings and storm runoff yields may be substantially decreased by street cleaning.

These preliminary results should be viewed only as indicative of impacts that street cleaning operations can have on the quality of receiving waters. The results of the second year will include more storm-related data points. These extra data points will consider a wider variety of storm conditions, especially smaller storms, than were monitored during the first year. Therefore, these preliminary results will most likely be significantly different in the final report.

SECTION 6

REFERENCES

Ellefsen, R. and R. Raburn. A Remote Sensing Method For Mapping Urban Land Cover In A Water Quality Assessment Program. CARTREMS Laboratory, San Jose State University. Unpublished, 1978.

Farmer, J. and T. Lyon. Lead in Glasgow Street Dirt and Soil. The Science of the Total Environment 8:89-93, 1977.

McMullen, T. and R. Faoro. Occurrence of Eleven Metals in Airborne Particulates and Surficial Materials. Journal Air Pollution Control Association 27:12:1198-1202. December, 1977.

Olson, K. and R. Skogerboe. Identification of Soil Lead Compounds from Automotive Sources. Environmental Science and Technology 9:3:227-230. March, 1975.

Pitt, R. Demonstration of Non-Point Pollution Abatement through Improved Street Cleaning Practices. EPA Grant No. S-804432, 289, pp, 1979.

Pitt, R. and G. Amy. Toxic Materials Analyses of Street Surface Contaminants. EPA-R2-734-383. U.S. Environmental Protection Agency, Washington, D.C., 135 pp, August, 1973.

Pitt, R. and M. Bozeman. Water Quality and Biological Effects of Urban Runoff on Coyote Creek, EPA Grant No. R805418010, 66 pp, June, 1979.

Pitt, R. and G. Shawley. Workplan Demonstration of Non-Point Pollution Management on Castro Valley Creek. Alameda County Flood Control and Water Conservation District. Unpublished, January, 1979.

Sartor, J. and G. Boyd. Water Pollution Aspects of Street Surface Contaminants. EPA-R2-72-081, U.S. Environmental Protection Agency, Washington, D.C., 1972.

Shawley, G. First Technical Progress Report, Castro Valley Demonstration Project. Alameda County Flood Control and Water Conservation District. Unpublished, May, 1979.

Sylvester, M. and W. Brown. Relation of Urban Land-use and Land-surface Characteristics to Quantity and Quality of Storm Runoff in Two Basins in California. Geological Survey Water-Supply Paper 2051, 1978.

SECTION F

APPENDIX

The raw data (i.e., street surface loading values, water quality values and calculations) is not included in this annual report. It is available at the Alameda County Flood Control and Water Conservation District Office in Hayward, CA. The raw data will be included in the final report.