Pollutant Load Removal From Street Sweeping Best Management Practices

Development of Typical Concentration Values for Pollutants of Concern in Contra Costa County, CA

Prepared for:

Contra Costa Clean Water Program
255 Glacier Drive
Martinez, CA 94543

Prepared by:

Eisenberg, Olivieri and Associates, Inc. (EOA)
1410 Jackson St.
Oakland, CA 94612

May 10, 2007

Executive Summary

Street sweeping conducted by municipalities in Contra Costa County, California removes trash and debris from roadways and prevents potential pollutants from entering stormwater conveyance systems and causing impacts to beneficial uses in surface water bodies (i.e., creeks, lakes, rivers, estuaries, bays and/or the oceans). The Contra Costa Clean Water Program previously developed mass removal estimates for conventional constituents (e.g., oil and grease). However, the mass of pollutants removed via street sweeping that are currently impacting the San Francisco Bay (e.g., PCBs and mercury) have not been estimated. This study characterizes the concentrations of pollutants in street sweeping material and provides preliminary estimates of the mass of constituents removed via street sweeping activities.

Polychlorinated biphenyls (PCBs), mercury, copper, nickel, Polybrominated diphenyl ethers (PBDEs), pyrethroid pesticides, and other chemical and physical parameters were analyzed in samples collected from 17 different street sweeping routes in seven cities located in Contra Costa County. Results were analyzed based on age-of-urbanization and land uses to account for differences in constituent concentrations. Additionally, results for Contra Costa were compared Alameda County to assess regional differences.

Results indicate that PCBs, mercury, copper, nickel and PBDEs were consistently detected in street sweeping material. Pollutant concentrations appear to have a significant correlation with age-of-development, as opposed to land use. On average, concentrations of PCBs and total recoverable mercury were the highest in street seeping material collected from municipalities developed in the early 20th century. In contrast, copper concentrations were not significantly different among age-of-development categories.

Average annual mass of specific constituents were estimated based on the volume of material removed via street sweeping and the average concentration of the constituent in street sweeping material from the applicable age-of-development category. The estimated mass of PCBs, and total recoverable mercury and copper removed by Contra Costa municipalities is 1.00, 1.85 and 2,022 kilograms per year, respectively. In the future, removal estimates may be improved by increasing the number of municipalities participating, increasing sampling size per municipality, and/or sampling more frequently.

Table of Contents

Executive Summary ... ii
List of Tables ... iv
List of Figures ... iv
List of Appendices ... iv

1.0 INTRODUCTION ... 1

1.1 Background ... 1
1.1.1 Pollutants of Concern and Total Maximum Daily Loads ... 1
1.1.2 Current Constituent Removal Estimates ... 2
1.2 Study Scope ... 3

2.0 STUDY DESIGN AND METHODS ... 3

2.1 Study Areas ... 3
2.2 Field Methods ... 4
2.2.1 Collection of Analytical Samples ... 4
2.2.2 Assessment of Trash within Waste Stream ... 1
2.3 Laboratory Analyses ... 1
2.4 Data Quality Assurance and Control ... 7
2.4.1 Field Quality Control ... 7
2.4.2 Laboratory Quality Control ... 7

3.0 RESULTS AND DISCUSSION ... 7

3.1 Constituent Concentrations in Contra Costa Street Sweeping Samples ... 8
3.1.1 PCBs and PBDEs ... 8
3.1.2 Mercury and Other Trace Metals ... 11
3.1.3 Pyrethroid Pesticides ... 11
3.1.4 Particle Size and Total Organic Carbon ... 11
3.2 Variables Explaining POC Concentrations ... 11
3.2.1 Land Use ... 12
3.2.2 Age-of-Urbanization ... 12
3.3 Constituents in Fine-Grained Street Sweeping Material ... 13
3.4 Estimating Annual Constituent Mass Removal ... 13
3.4.1 Recommended Formula ... 14
3.4.2 Input Variables ... 14
3.4.3 Current Constituent Removal Estimates ... 17

4.0 CONCLUSIONS AND RECOMMENDATIONS ... 18

5.0 REFERENCES ... 20

List of Tables

Table 1. Number of samples collected from street sweeping routes in three land use classes and three age-of-urbanization classes located in participating Contra Costa municipalities.

Table 2. Constituents and analytical methods used for CCCWP street sweeping investigation.

Table 3. Street sweeping sample details, including sweeper type and approximate curb miles swept.

Table 4. Analytical results for PCBs, PBDEs and pyrethroid pesticides in material collected from street surfaces in Contra Costa County.

Table 5. Analytical results for trace metals, total organic carbon (TOC) and fines in material collected from street surfaces in Contra Costa County.

Table 6. Results of one-tailed t-tests performed on PCBs and mercury (Hg) concentrations in street sweeping samples collected in Contra Costa and Alameda Counties from three land use category combinations

Table 7. Results of two-tailed t-tests performed on PCBs and mercury (Hg) concentrations in street sweeping samples collected in Contra Costa and Alameda Counties from three age-of-development category combinations

Table 8. Comparisons of constituent concentrations in bulk street sweeping material (<2 mm) and fine-grained (<63 um) sieved samples collected from street surfaces in Contra Costa County.

Table 9. Typical concentration values (TCVs) for selected constituents in street sweeping material collected by Contra Costa County municipalities.

Table 10. Average percentages (by volume) of types of waste found in street sweeping material collected in Contra Costa County.

Table 11. Annual reported volumes (cy) of material removed from street surfaces by Contra Costa County Co-permittees categorized by age-of-urbanization.

Table 11. Calculated annual mass of selected constituents removed from street surfaces by Contra Costa County Co-permittees categorized by age-of-urbanization.

List of Figures

Figure 1. Contra Costa Clean Water Program Co-permittees who participated in the Street Sweeping Study.

Figure 2. City of Pinole (Department of Public Works) Personnel Depositing Street Sweeping Waste in Preparation for Sampling.

Figure 3. Field Personnel Sampling Street Sweeping Waste.

List of Appendices

A - Literature Review of Case Studies

B - Data Quality Assessment

C - Sampling and Analysis Plan

D - Laboratory and Field Data Sheets

1.0 INTRODUCTION

Municipalities throughout the world conduct street sweeping activities to reduce trash and debris from roadways in urban and suburban areas. Additionally, many municipalities are required by National Pollutant Discharge Elimination System (NPDES) permits to implement street sweeping and other best management practices (BMPs) designed to prevent constituents[1] from entering stormwater conveyance systems and surface water bodies (i.e., creeks, lakes, rivers, estuaries, bays and/or the oceans). Studies have previously attempted to assess the effectiveness of street sweeping activities and characterize the concentrations of constituents in street sweeping material with some success (see Appendix A). However, limited information on some pollutants of concern (i.e., PCBs and mercury) in street sweeping material currently exists. The objective of this study was to collect data needed to characterize the concentration of pollutants of concern (POCs) in material collected via street sweeping and provide preliminary estimates of the mass of constituents removed via street sweeping activities by municipalities in Contra Costa County (i.e., Co-permittees).

1.1 Background

1.1.1 Pollutants of Concern and Total Maximum Daily Loads

Over the past 12 years, the State Water Resources Control Board (State Water Board) has listed segments of the San Francisco Bay estuary as impaired by a variety of constituents, including polychlorinated biphyenls (PCBs), mercury, copper, nickel and selenium (SWRCB, 2006). In an effort to control these constituents, the Central Valley and San Francisco Regional Water Quality Control Boards have or are currently developing Total Maximum Daily Loads (TMDLs)[2] for waterways in the San Francisco Bay Area. TMDLs may require Co-permittees to increase BMP implementation in an effort to increase the mass of constituents removed. Therefore, estimations of removal from current BMP implementation are needed to establish baseline.

PCBs

Polychlorinated biphenyls are mixtures of up to 209 individual chlorinated compounds (known as congeners). PCBs were manufactured in the United States and used widely from the late 1920s through the 1970s. Due to their non-flammability, chemical stability, high boiling point and electrical insulating properties, PCBs were used in hundreds of industrial and commercial applications including electrical, heat transfer, and hydraulic equipment; as plasticizers in paints, plastics and rubber products; in pigments, dyes and carbonless copy paper and many other applications. Because of their persistent qualities, and physical and chemical characteristics, PCBs are found in environmental media worldwide.

Mercury

Mercury is a naturally occurring persistent, bioaccumulative metal that does not degrade in the environment. Historically, mercury has been used in a variety of products. In 1976, U.S. consumption of mercury was 2240 metric tons, and since that time, the consumption of mercury in the US has drastically decreased to 346 metric tons in 1997 (USGS, 2002). Primary among the over 3000 historical industrial uses in the US were battery manufacturing and chlorine-alkali production. Paints and industrial instruments have also been among the major uses. Until paint manufacturers agreed to eliminate the use of mercury in interior paints, 480,000 pounds of mercury were used in paints and coatings each year. Mercury is also used in laboratories for making thermometers, barometers, diffusion pumps, and many other instruments, including mercury switches and other electrical apparatuses. Mercury is used as an electrode in some types of electrolysis and in some types of batteries (mercury cells). Gaseous mercury is used in mercury-vapor lamps (e.g., fluorescent tubes)

[1] Constituents include known pollutants and substances that may cause adverse impacts to beneficial uses of water bodies.

[2] TMDL or Total Maximum Daily Load is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources.

and advertising signs. Mercury is also the basis of dental amalgams and preparations, and can be a byproduct of burning fossil fuels and refining petroleum.

Copper

Copper is a natural occurring metal that has historically been used in a variety of products. Copper is used in the manufacturing of electronic equipment, but also as a product used in automobiles (e.g., brake pads) and building construction (e.g., piping and wiring). Additionally, copper has a wide spectrum of effectiveness against the many biological agents of timber and fabric decay. It renders them unpalatable to insects and protects them from fungus attack. Copper sulphate has been in use since 1838 for preserving timber and is today the base for many proprietary wood preservatives. Copper is also present in some algaecides used in fountains, spas and swimming pools.

Nickel

Like mercury and copper, nickel is a naturally occurring hard, malleable, ductile, silvery-white metal that is used in alloys, magnets, coinage, and stainless steel. Nickel is also used for armor plate, plating, and produces a green color in glass. Nickel is an alloy metal, and its chief use is in the nickel steels and nickel cast irons, of which there are many varieties. It is also widely used for many other alloys, such as nickel brasses and bronzes, and alloys with copper, chromium, aluminum, lead, cobalt, silver and gold.

PBDEs

Polybrominated diphenyl ethers (or PBDEs) are flame-retardants in the sub-family of the brominated flame-retardant group. They have been used in a wide array of household products, including fabrics, furniture, and electronics. There are three main types, referred to as penta, octa and deca for the number of bromine atoms in the molecule. The manufacture, distribution and processing of products containing pentabrominated diphenyl ether (pentaBDE) and octabrominated diphenyl ether (octaBDE) flame retardants were prohibited in California as of June 1, 2006. This prohibition was prompted by findings that exposures to PBDEs are widespread, and may pose health risks.

Pyrethroid Pesticides

Pyrethroids are a category of insecticides that have recently gained a large market share of the over-the-counter insecticides that are used in urban areas (TDC Environmental, 2003). Pyrethroids are usually broken down by sunlight and the atmosphere in one or two days, and do not significantly affect groundwater quality, although surface water quality effects have been documented (Amweg and Weston 2006).

1.1.2 Current Constituent Removal Estimates

Co-permittees conduct routine municipal maintenance best management practices (BMPs) including, but not limited to, road repair and maintenance, street sweeping, litter control, and stormwater conveyance system cleaning and maintenance. Municipal maintenance BMPs are designed to: 1) prevent or minimize pollutant discharges to the stormwater conveyance system, and 2) maximize the removal of constituents during routine maintenance activities. Some concentrations of constituents are likely attached to material collected from streets and paved areas. Therefore, periodically sweeping streets reduces some mass of constituents from entering the stormwater conveyance system.

In an effort to estimate the mass of constituents removed from municipal maintenance activities, each Co-permittee has tracked and recorded street sweeping data on a monthly basis since the Program's inception in 1991. Data include the volume of material collected and curb miles swept for residential, commercial and industrial areas in the incorporated and unincorporated areas of Contra Costa County. Additionally, sampling and analysis of street sweeping and catch basin material was also conducted by Co-permittees between the years of 1993 and 1997 (Contra Costa Clean Water Program unpublished data). The Program used these data to develop mean (average) concentrations or "typical concentration values" (TCVs) for constituents typically found in street sweeping and catch basin sediment samples (e.g., copper, lead, zinc, total petroleum hydrocarbons (TPH), and oil and grease) (WCC, 1996, 1997, 1998). However, TCVs for other pollutants of concern (POCs) (i.e., PCBs and mercury) have not been developed.

1.2 Study Scope

In an effort to assess the effectiveness of best management practices (BMPs) designed to reduce constituents in stormwater discharges, the Contra Costa Clean Water Program (Program)[3] conducts special studies in coordination with requirements in its NPDES Permit. This special study was designed to assist the Program in characterizing concentrations of constituents in street sweeping material collected from Contra Costa County, which will assist Co-permittees in estimating the mass removal of POCs. In particular, the study was designed to answer the following questions, based on street sweeping data:

1. What concentrations of POCs are detected in street sweeping material collected in Contra Costa County?
2. What explanatory variables best describe the distribution of POC concentrations in street sweeping material?
3. Do concentrations of constituents in street sweeping material vary on different grain size fractions?
4. What formula is recommended to estimate annual constituent mass removal via street sweeping activities?
5. What is the estimated annual mass of constituents currently removed via street sweeping activities conducted by Co-permittees?

2.0 STUDY DESIGN AND METHODS

2.1 Study Areas

Samples were collected from material picked up from 17 different street sweeping routes in seven cities located in Contra Costa County (Table 1 and Figure 1). Cities and street sweeping routes were selected based on the following considerations: 1) if the City owns and operates their own street sweeping equipment; 2) age-of-urbanization; and, 3) land uses within each city. Ownership and operation of street sweeping equipment by cities allowed Program staff to easily plan field sampling events. Age-of-urbanization and land use were used as potential explanatory variables for differences in constituent concentrations. Cities participating in the study were categorized into one of the following three categories, based on general knowledge of age-of-urbanization, with particular emphasis on industrialization:

- Early 20th Century – Represents the earliest and most extensive degree of urbanization/industrialization. May include municipalities where shipping and railways were used extensively for transporting industrial materials. Includes data collected from the cities of Richmond and Martinez.
- Mid-Century – Represents the intermediate range in both time and degree of urbanization/industrialization. Includes data collected from the cities of Pinole, Concord, Orinda and Walnut Creek.

[3] The Contra Costa Clean Water Program is comprised of Contra Costa County, all nineteen of its incorporated cities and the Contra Costa County Flood Control & Water Conservation District (i.e., Co-permittees).

- Late 20th Century – Represents the geographical area with the most recent urbanization. Includes areas where heavy industry never or minimally existed. Data collected from the City of Brentwood represented this category.

The study also attempted to incorporate land use into the sampling design. Land uses were grouped into broad categories of industrial, residential and mixed to examine whether different land uses generate significantly different concentrations of constituents in street sweeping material. In most cases, mixed land uses represented predominantly commercial areas within each municipality.

Table 1. Number of samples collected from street sweeping routes in three land use classes and three age-of-urbanization classes located in participating Contra Costa municipalities.

Municipality	Residential	Mixed	Industrial	Total
Early 20th Century				
Richmond	Not Sampled	2	1	**6**
Martinez	1	1	1	
Mid-Century				
Concord	1	1	1	**9**
Pinole	1	1	Not Sampled	
Orinda	1	1	Not Sampled	
Walnut Creek	1	1	Not Sampled	
Late 20th Century				
Brentwood	1	1	Not Sampled	**2**
Total	**6**	**8**	**3**	**17**

2.2 Field Methods

Methods used for this investigation are consistent with those employed during the recent Alameda Countywide Clean Water Program (ACCWP) street sweeping analyses (Salop, *in prep*). Rationale and general procedures followed for the investigation are contained within the Program's Sampling and Analysis Plan (CCCWP, 2006). Additional information pertaining to specific sampling and analytical methods employed is presented below.

2.2.1 Collection of Analytical Samples

All sampling was conducted between July 17th and July 31st, 2006. Streets were swept per current Co-permittee practices, using typical routes and equipment.[4] At the end of each swept route, the collected material was transported to a municipal facility and deposited by maintenance personnel in an isolated area (Figure 2). All street sweeping occurred during dry weather conditions to represent materials localized along a street and not a composite of materials transported by stormwater runoff.

Once deposited, field personnel flattened the street sweeping material into a rectangle at uniform depth. Using a systematic grid design, one composite sample was then taken from four points in each block within the grid system using a Kynar-coated stainless steel scoop/spoon (Figure 3). The four points were selected along the major and minor axes, between the midpoint and edge, of each block. The number of grids used was determined in the field based upon the volume of material collected. All field sampling was conducted by Applied Marine Sciences (Oakland, CA).

[4] Two types of sweepers, broom and regenerative air, were employed for this investigation. This investigation makes no attempt to draw conclusions about the difference in sweeping efficiency associated with different types of sweepers.

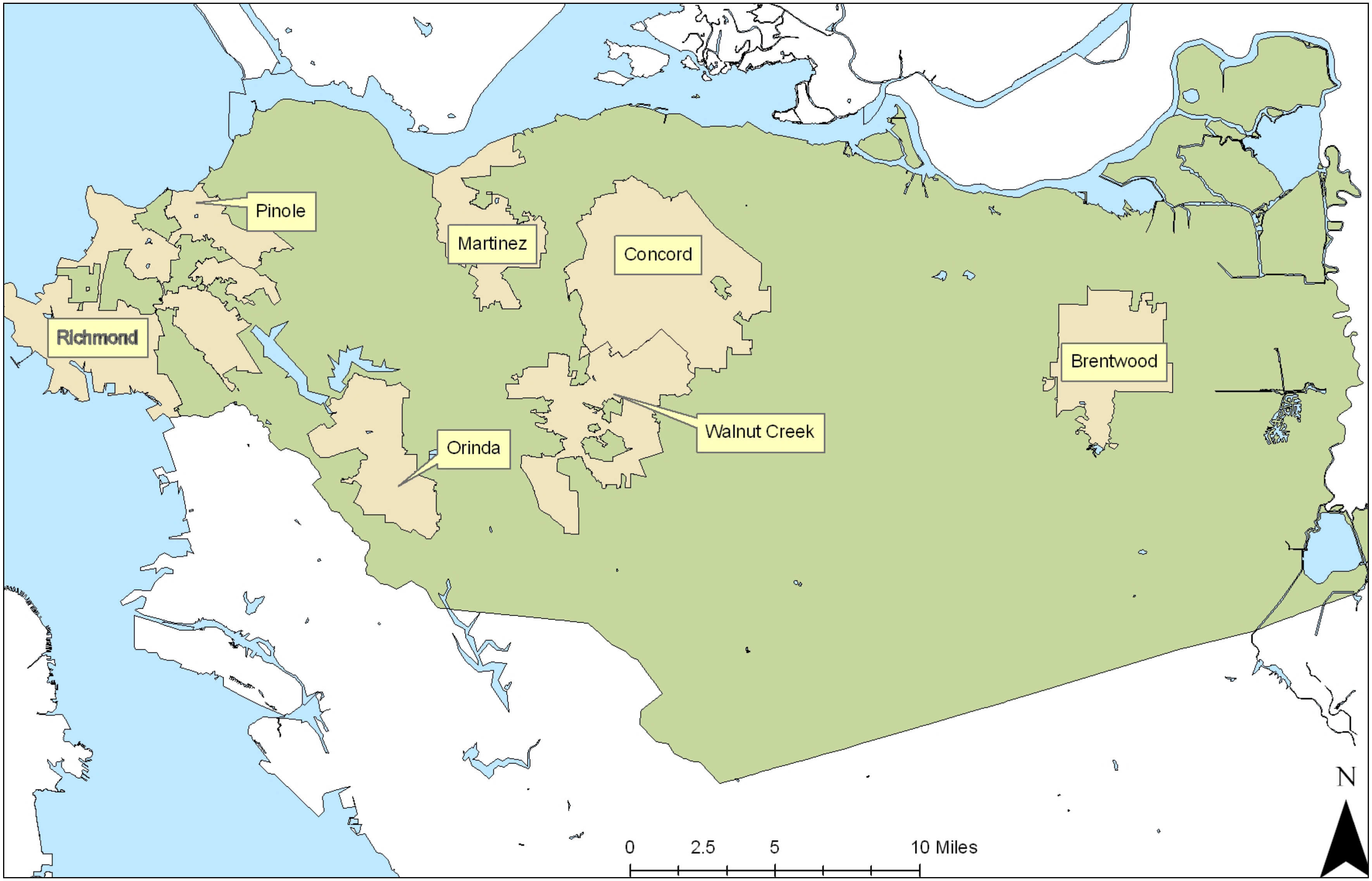

Figure 1. Contra Costa Clean Water Program Co-permittees who participated in the Street Sweeping Study.

Sampled material was then placed in a Kynar-coated compositing bucket and homogenized by stirring. Five one-liter sub-samples were placed in I-Chem series 200 jars, frozen in –20º C freezers, and shipped to the analytical laboratory in two batches following the completion of a sampling week.

Figure 2. City of Pinole (Department of Public Works) Personnel Depositing Street Sweeping Waste in Preparation for Sampling.

Figure 3. Field Personnel Sampling Street Sweeping Waste.

2.2.2 Assessment of Trash within Waste Stream

After collection of analytical samples, sampling personnel performed a visual trash assessment of the material removed during street sweeping. The assessment recorded presence/absence and estimated percentage of the volume of the following categories:

- Trash, dense
- Trash, light
- Sediment
- Leaves
- Other vegetative matter

2.3 Laboratory Analyses

All samples were analyzed for constituents shown in Table 2. With the exception of pyrethroid pesticides, all analyses were conducted by Columbia Analytical Services in Kelso, WA. Pyrethroid analyses were conducted by Pacific Agricultural Laboratory of Portland, OR.

Table 2. Parameters and analytical methods used for CCCWP street sweeping investigation.

Constituent	Method
PCBs (congeners)	EPA 8082
PBDEs	EPA 8270C
Pyrethroid Pesticides	EPA 8081M
Grain Size	ASTM C422M/PSEP
TOC, % Solids	EPA 9060
Total Mercury	EPA 7471A
Al, Cr, Mn, Ni, Cu, Zn, Ag, Cd, Pb, As, Se	EPA 6020

Analytical constituents were chosen based on high priority POCs identified in the Program's NPDES permit (e.g., PCBs and mercury) and emerging POCs that have little data related to street sweeping or stormwater (e.g., PBDES and pyrethroids). All samples were sieved in the laboratory at 2 mm prior to analysis, per National Water Quality Assessment (NAWQA) procedures (Shelton, et al., 1994) and consistent with previous Bay Area Stormwater Management Agencies Association (BASMAA) sediment sampling studies (e.g., Salop et al., 2002; KLI and EOA, 2002). Additionally, one sample was selected from each of the three land use classes for analysis of constituent concentration on the fine grained (<63um) fraction of the sample. These samples are reported as "SS" in Appendix D.

2.4 Data Quality Assurance and Control

2.4.1 Field Quality Control

Cleaning methods followed protocols adapted from the NOAA National Status and Trends Program for use by the Regional Monitoring Program for Water Quality in the San Francisco Bay (RMP) (Bell et al., 1999). Appropriate sampling equipment was prepared in the laboratory a minimum of four days prior to sampling. Equipment that was pre-cleaned includes:

- Kynar coated sample scoops,
- Kynar coated compositing bucket,
- Teflon wash bottles for deionized water, hydrochloric acid, and methanol.

Prior to sampling, all equipment was soaked (fully immersed) for three days in a solution of Liquinox detergent and deionized water. Equipment was then rinsed three times with deionized water. Equipment was next rinsed with a dilute solution (1-2%) of hydrochloric acid, followed by a rinse with reagent-grade methanol, followed by another set of three rinses with deionized water. All equipment was then allowed to dry in a clean place. The cleaned equipment was then wrapped in aluminum foil and stored in clean Ziploc bags until used in the field.

All sampling equipment used a second time in the field to collect a subsequent sample was field-cleaned. The field-cleaning protocol called for 1) removal of sediments using municipal or deionized water and a scrub brush; 2) scrubbing of the sampling gear and compositing equipment with a Liquinox solution; 3) rinse with deionized water; 4) rinse with dilute hydrochloric acid (1-2%); 5) rinse with reagent-grade methanol; and 6) rinse with deionized water.

To assess variability in constituent concentrations, two field duplicate samples were collected. Constituent concentrations in original samples and field duplicates were then compared to assess differences in measurements.

2.4.2 Laboratory Quality Control

Matrix spikes and laboratory blank samples were analyzed for all chemical constituents to assess laboratory quality. If concentrations of analytes in laboratory blanks were detected, the potential for cross-contamination was investigated and reconciled if necessary. Matrix spikes were compared against laboratory acceptance limits. If spikes were outside of acceptance limits, data points for these analytes were flagged (See Appendix D).

3.0 RESULTS AND DISCUSSION

This study was designed to assist Contra Costa Clean Water Program Co-permittees in estimating constituent mass removals via street sweeping activities that are conducted in compliance with NPDES Permit requirements. The following section provides a discussion of data and information collected through this and previous studies used to answer the following questions:

1. What concentrations of POCs are detected in street sweeping material collected in Contra Costa County (Section 3.1)?
2. What explanatory variables best describe the distribution of POC concentrations in street sweeping material (Section 3.2)?
3. Do concentrations of constituents in street sweeping material vary on different grain size fractions (Section 3.3)?

4. What formula is recommended to estimate annual constituent mass removal via street sweeping activities (Section 3.4)?
5. What is the estimated annual mass of constituents currently removed via street sweeping activities conducted by Co-permittees (Section 3.4)?

It is important to note that pollutant concentrations in street sweeping material can vary greatly over time and space, and the representativeness of the samples analyzed during this study is currently unknown. If additional data are collected, temporal and spatial variability can be better assessed and incorporated into analyses similar to those conducted here.

3.1 Constituent Concentrations in Contra Costa Street Sweeping Samples

Details of street sweeping conducted during this study are presented in Table 3. Analytical results are presented in Table 4 and 5, and briefly summarized in this section. An assessment of data quality is presented in Appendix B.

Table 3. Street sweeping sample details, including sweeper type and approximate curb miles swept.

Municipality	Sample	Land Use	Sweeper Type	Curb Miles Swept (mi)	Description/Location
Brentwood	Brentwood-1	MIXED	RA	~ 30	Mainly commerical (Hwy 4) with residential intertwined
	Brentwood-2 & 2SS	RES	RA	~ 25-30	Newer subdivision
Concord	Concord-1	IND	RA	13.3	Willow Pass Road (Arterial Route 15)
	Concord-2	RES	RA	24.6	Myrtle Drive/Laurel Drive Area (Zoned C-6)
	Concord-3	MIXED	RA	8.2	Downtown (Arterial Route 17)
Martinez	Martinez-1& 1SS	MIXED	RA	27	Residential and commercial (St Sweeping Route 4)
	Martinez-2 & 2FD	RES	RA	29	Includes small length of light commercial (Route 7)
	Martinez-3	IND	RA	~3	Howe Avenue - light ind/comm with some res.
Orinda	Orinda-1& 1FD	RES	MB	4	NA
	Orinda-2	MIXED	MB	12	Commercial areas downtown
Pinole	Pinole-1	RES	RA	12.5	Street Sweeping Area H
	Pinole-2	MIXED	RA	18.5	San Pablo Ave. and Arterial Rds. (Area Black)
Richmond	Richmond-1	MIXED	MB	6.6	Blocks between MacDonald and Ohio Avenues, and 23rd Street and Marina Blvd.
	Richmond-2	MIXED	MB	6	Blocks between MacDonald and Ohio Avenues, and Marina Blvd. and Garrard Blvd.
	Richmond-3 & 3SS	IND	MB	~3	Cutting Blvd / Garrard Blvd/Richmond Pkwy area
Walnut Creek	WC-1	MIXED	RA	26	Commercial areas downtown
	WC-2	RES	RA	6	Southeast portion of town by Rudgear Rd.

Notes: FD - Field Duplicate collected; SS - Special Study conducted, analytical results reported for an additional size fraction <63 µm; MIXED – Mixed land use; IND – Industrial land use; RES – Residential land use; RA – Regenerative air sweeper; MB – Mechanical broom sweeper; NA – Not Available at time of sampling; ~ - Approximately; Mixed land use category represents predominantly commercial areas.

3.1.1 PCBs and PBDEs

The Program analyzed street sweeping samples for 40 of the 209 PCB congeners to remain consistent with RMP methods[5] and previous sampling conducted on behalf of BASMAA. In calculating total PCBs it is typical that some or all of the individual congeners measured are at concentrations below laboratory method detection limits (MDLs). This introduces uncertainty into the interpretation of the results

[5] IUPAC PCB congener numbers 8, 18, 28, 31, 33, 44, 49, 52, 56, 60, 66, 70, 74, 87, 95, 97, 99, 101, 105, 110, 118, 128, 132, 138, 141, 149, 151, 153, 156, 158, 170, 174, 177, 180, 183, 187, 194, 195, 201, 203.

Table 4. Analytical results for PCBs, PBDEs and pyrethroid pesticides in material collected from street surfaces in Contra Costa County.

Sample	Land Use	PCBs (ug/kg)		PBDEs (ug/kg)		Pyrethroid Pesticides (mg/kg)					
		ND=0	ND=MDL/2	ND=0	ND=MDL/2	Bifenthrin	Cyfluthrin	Cypermethrin	Deltamethrin	Esfenvalerate	Permethrin
Brentwood-1	MIXED	49	84	288	314	0.039	ND	ND	ND	ND	ND
Brentwood-2	RES	0	15	20	71	0.25	ND	ND	ND	ND	ND
Concord-1	IND	9	23	128	151	ND	ND	ND	ND	ND	ND
Concord-2	RES	9	27	6	64	ND	ND	ND	ND	ND	ND
Concord-3	MIXED	40	63	270	295	ND	ND	ND	ND	ND	ND
Martinez-1	MIXED	151	174	50	136	ND	ND	ND	ND	ND	ND
Martinez-2	RES	99	114	187	215	0.049	ND	ND	ND	ND	ND
Martinez-3	IND	104	120	32	85	ND	ND	ND	ND	ND	ND
Orinda-1	RES	15	46	7	56	ND	ND	ND	ND	ND	ND
Orinda-2	MIXED	49	67	351	372	ND	ND	ND	ND	ND	ND
Pinole-1	RES	68	86	30	94	ND	ND	ND	ND	ND	ND
Pinole-2	MIXED	18	36	246	276	ND	ND	ND	ND	ND	ND
Richmond-1	MIXED	221	244	183	205	ND	ND	ND	ND	ND	0.14
Richmond-2	MIXED	898	932	681	733	ND	ND	ND	ND	ND	ND
Richmond-3	IND	369	399	237	262	ND	ND	ND	ND	ND	ND
WC-1	MIXED	51	72	288	319	ND	ND	ND	ND	ND	ND
WC-2	RES	21	62	141	167	ND	0.085	ND	ND	ND	ND

Notes: ND = Non-detect ; MDL = Method Detection Limit (see Appendix D)

Table 5. Analytical results for trace metals, total organic carbon (TOC) and fines in material collected from street surfaces in Contra Costa County.

Sample	Land Use	Al	As	Cd	Cr	Cu	Pb	Mg	Ni	Se	Ag	Zn	Hg	TOC	Fines
		(mg/kg)												(%)[6]	
Brentwood-1	MIXED	8030	3	0.257	41.5	75.5	20.6	366	36.3	0.3	0.263	249	0.079	2.69	12.9
Brentwood-2	RES	5590	2.11	0.212	35.1	186	14	334	28.4	ND	0.166	182	0.048	4.72	20.9
Concord-1	IND	12100	2.21	0.639	17.7	105	22.9	503	21	ND	0.367	141	0.185	3.10	10.7
Concord-2	RES	9460	4.17	0.262	22.1	248	19.3	417	32.6	0.3	0.408	159	0.072	6.03	9.4
Concord-3	MIXED	8600	3.42	0.728	23.6	202	36.7	469	31.1	0.4	0.995	213	0.085	4.54	9.4
Martinez-1	MIXED	21700	4	0.611	30.2	85.4	62.7	713	38.4	0.5	2.03	344	0.344	7.14	17.1
Martinez-2	RES	9960	2.58	0.456	36.5	70	34.9	347	32.9	ND	1.36	293	0.143	5.80	28.3
Martinez-3	IND	10700	2.47	0.492	34.5	180	122	357	31.9	ND	3.03	206	0.173	7.00	30.2
Orinda-1	RES	18300	2.66	0.271	25.7	28.8	20.9	392	34.9	0.5	0.072	175	0.05	7.02	18.4
Orinda-2	MIXED	12900	3.34	0.691	43.8	170	64.9	425	41.1	0.4	0.393	857	0.152	17.1	38.7
Pinole-1	RES	16800	2.86	0.791	20.9	62	28.6	563	28.9	0.5	0.246	277	0.292	6.96	19.5
Pinole-2	MIXED	11600	3.37	0.819	60.2	128	42.8	467	115	0.3	0.162	362	0.225	8.67	14.8
Richmond-1	MIXED	9790	3.12	0.666	22.5	182	83.2	326	30.5	0.3	0.171	277	0.322	3.72	11.2
Richmond-2	MIXED	10400	4.23	1.17	22.7	129	121	432	31.4	0.4	0.235	434	0.196	5.65	18.5
Richmond-3	IND	11800	5.08	1.52	67.5	146	188	492	63.8	0.3	2.12	554	0.406	8.87	37.4
WC-1	MIXED	8960	2.08	0.453	21	203	42	330	22.9	0.3	0.167	727	0.128	10.9	17.1
WC-2	RES	7040	1.67	0.253	11.7	73.7	13.4	310	17.1	0.3	0.252	260	0.106	12.1	17.8

Notes: Al–Aluminum; As–Arsenic; Cd–Cadmium; Cr-Chromium; Cu- Copper; Pb- Lead; Mg- Manganese; Ni-Nickel; Se-Selenium; Ag-Silver; Zn-Zinc; Hg-Mercury; TOC-Total Organic Carbon

[6] Represents the % fines (<63 um) and TOC in material sieved through a 2 mm sieve.

depending on how the non-detects (NDs) are quantified. In order to gauge the effect of NDs, total PCBs were calculated in two ways: (1) summing results for individual congeners substituting a value of zero for any non-detects, and (2) summing individual congeners with results for non-detects set to one-half the associated MDL. Table 4 summarizes the results for each sample. The effect of non-detects on total PCBs appears to be minor, with the difference between the two calculations being below 50 µg/kg. Therefore, non-detects were treated as zero during analyses presented later in this report. Method detection limits (MDLs) for use in interpreting these results are included within Appendix D.

Similar to PCBs, there are a total of 209 possible PBDE congeners. Street sweeping samples were analyzed for 17 of the most common PBDE congeners found in environmental media.[7] Table 4 summarizes the PBDE results for each sample. As with PCBS, the effect of non-detects on total PBDEs appears to be minor, with the difference between the two calculations being below 50 µg/kg. Method detection limits (MDLs) for use in interpreting these results are included within Appendix D.

3.1.2 Mercury and Other Trace Metals

Mercury, copper and nickel are currently defined as POCs in the Program's NPDES Permit. Concentrations of total mercury, copper, nickel and nine other trace metals detected in street sweeping samples are presented in Table 5. MDLs for use in interpreting these results are included within Appendix D.

3.1.3 Pyrethroid Pesticides

Six pyrethroid compounds (i.e., bifenthrin, cyfluthrin, cypermethrin, deltamethrin, esfenvalerate, and permethrin) were analyzed for this investigation. The six specific pesticides were selected for analysis based on their expected level of usage in the San Francisco Bay area and potential to cause harm to the aquatic environment (TDC Environmental, 2003). Table 4 summarizes the results for each compound in each sample. Results were almost exclusively non-detects. MDLs for use in interpreting these results are included within Appendix D.

3.1.4 Particle Size and Total Organic Carbon

Results for ancillary constituents percent fines and Total Organic Carbon (TOC) are presented in Table 5. Results for particle size analysis were reported by the laboratory in thirteen size fractions, ranging from gravel to less than 0.98 µm (see Appendix D). The results for percent fines are summarized as the sum of all particle size classes less than 63 µm.

3.2 Variables Explaining POC Concentrations

The concentration of constituents in the environment can significantly vary in space and time. This variability complicates the development of "average or typical" concentration values used to estimate constituent mass removed via management actions (e.g., street sweeping). Previous street sweeping studies have characterized constituent concentrations based on the type of urban land use (e.g., commercial, industrial and residential) swept (USEPA, 1983; City of Austin, 1990; EOA, 1996a, b; EOA, 1999; Salop, *in prep*). The underlying assumption is that constituent concentrations are significantly different (on average) among different land uses. However, data from most studies designed to detect differences generally did not have the statistical power necessary to test this assumption. County regions have also been used in previous studies in an attempt to explain differences in constituent concentrations (Salop, *in prep*).

This study was designed to incorporate elements of space by using two types of variables to categorize street sweeping routes: land use and age-of-urbanization[8]. Due to a lack of sampling resources, temporal changes in constituent concentrations were not addressed during this study, but should be addressed in future investigations. To assess whether significant differences in POC concentrations

---

[7] IUPAC PBDE congener numbers 17, 28, 47, 66, 71, 85, 99, 100, 128, 138, 153, 154, 183, 190, 203, 206, 209.

[8] A comparable variable, age-of-development, was used in this investigation to assess differences in geopolitical areas in Contra Costa County.

exist between land use or age-of-urbanization categories, data were first normalized to percent fines. Normalized concentrations were then log transformed[9]. Statistical comparisons were then made using a students t-test to test the following hypotheses:

> H_2 = Concentrations of constituents in street sweeping material are significantly different between three general land use categories (i.e., industrial, mixed and residential).
>
> H_3 = Concentrations of constituents in street sweeping material are significantly different between three age-of-urbanization categories (i.e., early 20th century, mid 20th century and late 20th century).

For additional analytical power in performing the statistical tests, mercury and PCBs data from Alameda County were combined with those collected from Contra Costa County[10]. Only data collected in Contra Costa County were available for other constituents. The following paragraphs briefly describe the results of the analyses.

3.2.1 Land Use

Based on the statistical analyses (i.e., students t-tests) conducted on Alameda and Contra Costa data, differences in the concentrations of PCBs and mercury were not observed between land use categories, with the exception of mercury concentrations between industrial and residential land uses (Table 6). Therefore, concentrations of PCBs and mercury between land uses are assumed to be equal at this time.

Table 6. Results of one-tailed t-tests performed on PCBs and mercury (Hg) concentrations in street sweeping samples collected in Contra Costa and Alameda Counties from three land use category combinations. Bolded/underlined values indicate significant differences ($p<0.05$).

	Industrial vs. Residential	Industrial vs. Mixed	Mixed vs. Residential
PCBs	0.147	0.367	0.273
Hg	**0.046**	0.244	0.878

3.2.2 Age-of-Urbanization

Results of analyses conducted on age-of-urbanization categories indicate that significant differences ($p < 0.05$) in PCBs and mercury concentrations exist between most age-of-development categories (Table 7). Based on these results, concentrations of PCBs and mercury between most age-of-development categories are assumed to be different at this time.

Table 7. Results of two-tailed t-tests performed on PCBs and mercury (Hg) concentrations in street sweeping samples collected in Contra Costa and Alameda Counties from three age-of-development category combinations. Bolded/underlined values indicate significant differences ($p<0.05$) between categories.

	Early 20th vs. Mid-Century	Early 20th vs. Late 20th	Mid-Century vs. Late 20th
PCBs	**0.00003**	**0.011**	0.201
Hg	**0.0005**	**0.000004**	**0.022**

---

[9] The concentrations of pollutants in street sweeping material are assumed to be log-normally distributed (USEPA 1983).
[10] Variables used in the ACCWP investigation, land use and region (synonymous with age-of-urbanization), were comparable to those used in this study.

3.3 Constituents in Fine-Grained Street Sweeping Material

To assess the percentage of constituents present on fine grained sediment in street sweeping material, three samples (Brentwood-2, Martinez-1 and Richmond-3) originally sieved in the laboratory at 2 mm were sieved again at 63 µm (i.e., fines). An additional suite of analyses was then conducted on the fine-grained fraction. These samples were intended to represent the concentration of constituents on fine-grained particles. Results are presented in Table 8 for both the bulk (<2000 um) and fine-grained (<63 um) sieved samples.

As expected, results indicate that the concentrations of POCs were generally greater on samples sieved at 63 um, compared to concentrations in bulk sediment (< 2mm). Fine-grained materials typically have a greater surface area for constituent to adsorb and therefore concentrations tend to be higher on smaller particles

Table 8. Comparisons of constituent concentrations in bulk street sweeping material (<2 mm) and fine-grained (<63 um) sieved samples collected from street surfaces in Contra Costa County.

Sample	∑PCBs	∑PBDEs	Cd	Cu	Pb	Ni	Hg	Fines
	(µg/kg)[1]		mg/kg					%
Brentwood-2 (< 2000 um)	0	20	0.212	186	14	28.4	0.048	20.86
Brentwood-2 (< 63 um)	0	159	0.222	458	10.1	56.6	0.04	100
Richmond-3 (<2000 um)	369	237	1.52	146	188	63.8	0.406	37.42
Richmond-3 (< 63 um)	530	508	2.48	308	352	82.9	0.902	100
Martinez-1 (<2000 um)	151	50	0.611	85.4	62.7	38.4	0.344	17.08
Martinez-1 (< 63um)	71	225	0.743	118	55.4	21.6	0.598	100

Notes:
[1] Non-detects calculated as 0 µg/kg
Cd–Cadmium; Cu- Copper; Pb- Lead; Ni-Nickel; Se-Selenium; Hg-Mercury; TOC-Total Organic Carbon

3.4 Estimating Annual Constituent Mass Removal

Estimations of constituent mass removal can be informative when assessing stormwater program effectiveness or comparing the costs and benefits of removing constituents via multiple mechanisms (e.g., street sweeping vs. treatment). Mass removal estimates can also be used in concert with water quality measurements to develop correlations in water quality improvements. The following section describes an initial formula and associated variables that can be used to develop first-order "average" estimates of annual constituent mass removal. It is important to note that uncertainty currently exists in most of the variables described. If additional data are collected, variables can be revised and uncertainty will likely be reduced.

3.4.1 Recommended Formula

A standardized formula is needed to estimate constituent mass removal via street sweeping activities in Contra Costa County. Formulas have been utilized in previous street sweeping studies discussed in Appendix A. Based on a review of these formulas, the following formula is recommended to calculate the mass of constituents removed via street sweeping:

$$M_x = C_x PVF/10^6$$

where:

M_x	=	*Dry mass of constituent "x" in kilograms (kg)*
C_x	=	*Typical Concentration Value of constituent "x," dry basis in mg/kg*
P	=	*% of "sediment" (by volume) in street sweeping material collected that is less than 2mm*
V	=	*Total volume (cy) of street sweeping material collected*
F	=	*Factor for converting sediment volume (cy) to dry mass (kg)*
10^6	=	*Conversion of milligrams (mg) to kilograms (kg)*

3.4.2 Input Variables

Based on information gained through sampling and analysis conducted during this and previous street sweeping investigations, the following input variables are recommended for use when calculating constituent mass removal via street sweeping activities in Contra Costa County.

Constituent Typical Concentration Values (C_x)

A typical concentration value (TCV) represents the estimated "average" constituent concentration that one would expect to find in environmental media. Based on the results of the street sweeping data analyses described in Section 3.3, TCVs (averages), low estimates (25th percentile) and high estimates (75^{h} percentile) were developed for each constituent of interest and age-of-urbanization category where statistically different concentrations were observed. TCVs, high and low estimates for seven constituents are listed in Table 9.

Table 9. Typical concentration values (averages), low estimates (25th percentile) and high estimates (75^{h} percentile) for selected constituents in street sweeping material collected by Contra Costa County municipalities.

Constituent (mg/kg)	Municipality Age-of-Urbanization								
	Early 20th Century			Mid-Century			Late 20th Century		
	Low	Ave	High	Low	Ave	High	Low	Ave	High
Total PCBs	0.10	0.18	0.22	0.01	0.03	0.44	0.01	0.03	0.44
Total Mercury	0.17	0.25	0.32	0.05	0.11	0.14	0.03	0.05	0.07
Total Copper	76	134	182	76	134	182	76	134	182
Total Nickel	29	38	40	29	38	40	29	38	40
Total Cadmium	0.27	0.61	0.73	0.27	0.61	0.73	0.27	0.61	0.73
Total Lead	21	55	65	21	55	65	21	55	65
Total Selenium	0.30	0.37	0.40	0.30	0.37	0.40	0.30	0.37	0.40

Sediment Volume to Mass Conversion (F)

In support of implementation requirements developed through the California Integrated Waste Management Act of 1989, volume to mass conversion factors for a variety of waste materials were developed by FEECO International, Inc. and utilized by the California Integrated Waste Management Board (CIWMB, 2003). The weights included in this study may not be representative of every jurisdiction within the county, but are considered the best conversion factors currently available. The volume to mass conversion factor used was 918.4 kg per cy.

Percentage of Sediment Containing Constituents (P)

It is generally believed that sediment-associated constituents typically adsorb to smaller sediment grain sizes due to the increased surface area available. However, it is currently unknown what grain size fractions in street sweeping material constitute the largest percentage of constituents. This issue continues to be studied and information gained through future investigation will assist in defining the proportion of street sweeping material which is heavily associated with sediment-associated constituents.

During this investigation, the types of wastes in street sweeping material were visually characterized by field personnel. For each volume of street sweeping material where sediment samples were collected, the percentages of material (by volume) in five waste categories were documented on field data sheets. Based on this information, the average percentage for each waste category is listed in Table 10.

Table 10. Average percentages (by volume) of types of waste found in street sweeping material collected in Contra Costa County.

Category of Material	Average % of Total Volume
Trash – Dense	0 %
Trash – Light	1 %
Sediment	37 %
Leaves	35%
Other Vegetative Matter	27 %

Additionally, ACCWP recently estimated that roughly 55% (dry mass) of street sweeping material collected was less than 2 mm in diameter (Salop, *in prep*). Based on the results of this analysis, 55% was used as the input parameter to the loads removed formula. It is important to note, however, that leaf material greater than 2mm may have some concentration of constituents attached. If concentrations are significant, the percentage of street sweeping material estimated to have POCs attached (i.e., 55%) may be underestimated.

Volume of Street Sweeping Material Collected (V)

The volume of street sweeping material collected by each Co-permittee is reported annually. Volumes are typically visually estimated by municipal maintenance staff. Volumes reported for fiscal years 2001/2002 through 2005/2006 are summarized in Table 11. The average volume collected by each Co-permittee during this timeframe was used as an input variable. The distribution of the annual volumes is assumed to be normally distributed.

Table 11. Annual reported volumes (cy) of material removed from street surfaces by Contra Costa County Co-permittees categorized by age-of-urbanization.

Co-permittee	FY 01/02	FY 02/03	FY 03/04	FY 04/05	FY 05/06	Average
Early 20th Century						
El Cerrito	495	495	1560	1610	960	1024
Martinez	1440	1448	1464	1500	1500	1470
Pittsburg	1889.5	1957.25	1454	2007.5	1945	1851
Richmond	2541	1690.9	2400	1800	1532	1993
San Pablo	688	890	776	808	958	824
Mid-Century						
Concord	5078	5332	5806	4719	5116	5210
County	1942.5	2087.9	2233.6	1889	1666	1964
Hercules	225	225	225	504	305	297
Lafayette	1385.5	966	914	816	919	1000
Moraga	76	132.5	159.5	159.5	201	146
Orinda	140	234.6	180	498	281.2	267
Pinole	453	470	456	451	239	414
Pleasant Hill	880	1240	1442	356	1683	1120
Walnut Creek	2325	2175	1921	1770	1840	2006
Late 20th Century						
Antioch	2473	3602.5	2392	2343	2491	2660
Brentwood	5280	3840	1982	2087	2189	3076
Clayton	100	100	266	164	164	159
Danville	1920	1996	2233	2123	2138	2082
Oakley	562.25	563	446.5	451.25	512	507
San Ramon	1492	1637	2097	1874	1899	1800
Totals	**31,385**	**31,082**	**30,407**	**26,430**	**33,984**	**29,870**

3.4.3 Current Constituent Removal Estimates

Using the formula described in Section 3.4.1 and input variables described in Section 3.4.2, average annual removal estimates were calculated for total recoverable PCBs, mercury, copper, nickel, cadmium, lead and selenium[11]. Results are presented in Table 12.

Table 12. Estimated annual mass of selected constituents removed from street surfaces by Contra Costa County Co-permittees categorized by age-of-urbanization.

Co-permittee	Annual Constituent Mass (Kg) Removed Via Street Sweeping						
	Total PCBs	Total Mercury	Total Copper	Total Nickel	Total Cadmium	Total Lead	Total Selenium
Early 20th Century							
El Cerrito	0.09	0.13	69.3	19.7	0.32	28.4	0.19
Martinez	0.13	0.19	99.5	28.2	0.45	40.8	0.28
Pittsburg	0.17	0.23	125.3	35.5	0.57	51.4	0.35
Richmond	0.18	0.25	134.9	38.3	0.61	55.4	0.37
San Pablo	0.08	0.1	55.8	15.8	0.25	22.9	0.15
Sub-Total	0.65	0.9	484.8	137.5	2.21	199.0	1.34
Mid-Century							
Concord	0.08	0.29	352.6	100.0	1.61	144.7	0.97
County	0.03	0.11	132.9	37.7	0.61	54.6	0.37
Hercules	0.01	0.02	20.1	5.7	0.09	8.3	0.06
Lafayette	0.02	0.06	67.7	19.2	0.31	27.8	0.19
Moraga	0.00	0.01	9.9	2.8	0.05	4.1	0.03
Orinda	0.00	0.02	18.1	5.1	0.08	7.4	0.05
Pinole	0.01	0.02	28.0	7.9	0.13	11.5	0.08
Pleasant Hill	0.02	0.06	75.8	21.5	0.35	31.1	0.21
Walnut Creek	0.03	0.11	135.8	38.5	0.62	55.7	0.38
Sub-Total	0.19	0.69	840.9	238.5	3.83	345.2	2.32
Late 20th Century							
Antioch	0.04	0.07	180.0	51.1	0.82	73.9	0.50
Brentwood	0.05	0.08	208.2	59.0	0.95	85.5	0.58
Clayton	0.00	0.00	10.8	3.1	0.05	4.4	0.03
Danville	0.03	0.05	140.9	40.0	0.64	57.8	0.39
Oakley	0.01	0.01	34.3	9.7	0.16	14.1	0.10
San Ramon	0.03	0.05	121.8	34.6	0.56	50.0	0.34
Sub-Total	0.16	0.26	696.1	197.4	3.17	285.7	1.92
Total	1.00	1.85	2021.8	573.3	9.20	829.8	5.58

[11] The average volume of material removed by each co-permittee from Fiscal Years 2000-01 to 2005-06 was used as an input parameter.

4.0 Conclusions and Recommendations

Municipal staff, concerned citizens and regulators are interested in gaining information on the effectiveness of stormwater BMPs in reducing the mass of pollutants discharged to local creeks and the San Francisco Bay. For street sweeping, estimates of pollutant mass removal are typically difficult to develop with a high level of confidence due to the inherent heterogeneity of street sweeping material and concentrations of constituents within. Previous studies have collected data to assist stormwater management programs in developing estimates, however, numerous information gaps remain. Data collected during this investigation were used to fill information gaps regarding the concentrations of specific pollutants of concern (POC), PCBs and mercury, in material collected via street sweeping; and to develop preliminary estimates of the mass of constituents removed via street sweeping activities by municipalities in Contra Costa County (i.e., Co-permittees). Due to limited resources available and the difficulty detecting POC source areas, this study was not designed (nor did it attempt) to identify specific land areas where existing BMPs could be optimized or additional BMPs could be implemented. Additionally, the study was not intended to evaluate the effectiveness of different types of street sweepers, nor did it assess the removal potential based on frequency of sweeping, although these are important topics that should continue to be investigated.

The investigation generated the following preliminary conclusions:

- Concentrations of various constituents, including mercury and PCBs, were consistently detected in material collected by street sweepers in Contra Costa County. Based on these results, current street sweeping activities appear to provide a mechanism for removing some mass of POCs from streets in Contra Costa County. Through the development of "typical concentration values" and a preliminary load removal formula, pollutant removal estimates were developed for POCs and other constituents. It is estimated that roughly 1.0 kg of PCBs and 1.9 kg of mercury are annual removed via street sweeping conducted by Contra Costa Clean Water Program Co-permittees. This mass of mercury is roughly 8.6% of the estimated current load for stormwater in Contra Costa County, which was recently developed by the San Francisco Bay Water Board (2006) in the *Mercury TMDL for the San Francisco Bay*.

- Based on preliminary statistical analyses, PCBs and mercury concentrations appear to be significantly greater in street sweeping material collected from cities that were urbanized/industrialized during the early 20th century. These conclusions are consistent with information on the extent, magnitude and timeframe that materials containing these pollutants were used. Somewhat surprisingly, the type of urban land use (i.e., residential, mixed and industrial) where street sweeping was conducted had little affect on the concentrations of mercury or PCBs observed. This result could be caused by the lack of consistent definitions of land use categories used by municipalities. In contrast to mercury and PCBs, copper, lead, nickel and selenium concentrations were consistent among all land use and age-of-urbanization categories, suggesting that these constituents are relatively ubiquitous in the environment.

- The emerging pollutant Polybrominated Diphenyl Ethers (PBDEs) were consistently detected in street sweeping material collected in Contra Costa County. Based on the known uses and perceived ubiquity of this constituent in the environment, PBDEs are likely present in street sweeping material from other Bay area counties as well.

- Pyrethroid pesticides have continued to gain market share in urban applications since the phase out of diazion, a popular pesticide used primarily for ant control. However, pyrethroids were not consistently detected in street sweeping samples, suggesting that either: 1) current method detection limits (MDLs) for pyrethoids are not adequate; 2) pyrethroids are degraded in the environment prior to laboratory analysis; or 3) pyrethroids are not consistently applied in, or transported to streets.

- As an input parameter to the preliminary load removal formula presented in this report, the percentage of street sweeping material containing pollutants is estimated to be 55%, based on recent work conducted by the Alameda Countywide Clean Water Program. This estimate is based on the percentage of material that is less than 2mm and assumes that all pollutants in street sweeping material are attached to particles in this size range. While it is believed that fine-grained sediments typically have a greater surface area to volume ratio, and therefore pollutants have a greater tendency to adsorb, the exact size range for these sediments is currently unknown. In this study, results confirm the notion that fine-grained (<63um) sediments in street sweeping material generally have greater concentrations of constituents, compared to larger (<2mm) sediments, but a range of sizes were not analyzed. Future studies should continue to address this issue if uncertainty in pollutant load removal estimates is to be reduced.

As resources are available, the following recommend future studies and data collection should be considered to reduce uncertainties associated with estimating constituent removal via street sweeping.

- Characterization of street sweeping material may be improved by increasing the number of Co-permittees participating, increasing sampling size per Co-permittee, and/or sampling more frequently;

- Investigations of pollutant concentrations on multiple (>3) sediment grain size fractions sieved from a single sample; and,

- Considerations of reporting the amount of street sweeping material collected in volume (cubic yards) and weight (lbs) to reduce uncertainties regarding volume to mass conversion factors.

5.0 References

Amweg, E.L., D.P. Weston, N.M. Ureda. 2005. Use and toxicity of pyrethroid pesticides in the Central Valley, California. Environ. Toxicol. Chem. 24:966-972 (erratum in Vol. 24, number 5).

Bell, D., Gold, J., and P. Salop. 1999. *Field Sampling Manual for the Regional Monitoring Program for Trace Substances*. Prepared for the San Francisco Estuary Institute.

City of Austin, TX, 1990. Stormwater Pollutant Loading characteristics For Various Land Uses in the Austin Area. Environmental and Conservation Services Department, Environmental Resources Management Division.

Contra Costa Clean Water Program (CCCWP). 2006. *Street Sweeping Pollution Concentrations for TMDL Implementation for Contra Costa County, Sampling and Analysis Plan*. Prepared for the Contra Costa Clean Water Program Management Committee.

EOA, Inc, 1999. Analysis of Street Sweeping Data. Prepared for Alameda Countywide Clean Water Program. June.

EOA, Inc, 1996a. Estimation of Copper Collected Through Street Sweeping Efforts. Prepared for San Mateo Countywide Stormwater Pollution Prevention Program. October.

EOA, Inc, 1996b. Street Sweeping Study. Prepared for San Mateo Countywide Stormwater Pollution Prevention Program. October.

Kinnetic Laboratories, Inc. (KLI) and Eisenberg, Olivieri, and Associates (EOA). 2002. *Joint Stormwater Agency Project to Study Urban Sources of Mercury, PCBs and Organochlorine Pesticides*. Prepared for SCVURPPP, CCCWP, SMCSPPP, MCSPPP, VFCSD, and FSSD. April 2002.

Salop, P., Abu-saba, K., Gunther, A., and A. Feng. 2002. 2000-01 *Alameda County Watershed Sediment Sampling Program: Two-Year Summary and Analysis*. Prepared for the Alameda Countywide Clean Water Program. Hayward, CA.

Salop, P., in prep. *Municipal Maintenance and Sediment Management: Evaluation of Source Control Options for TMDL Implementation*. Prepared for the Alameda Countywide Clean Water Program. Hayward, CA.

San Francisco Bay Regional Water Quality Control Board. 2006. *Total Maximum Daily Load for Mercury in the San Francisco Bay Estuary*. Adopted Basin Plan Amendment. Oakland, CA. July.

Shelton, L.R., and P.D. Capel. 1994. *Guidelines for Collection and Processing Samples of Stream Bed Sediment for Analysis of Trace Elements and Organic Contaminants for the National Water-Quality Assessment Program*. U.S. Geological Survey, Sacramento, CA. USGS Open-File Report, 94-458.

State Water Resources Control Board (SWRCB). 2006. 303(d) List of Water Quality Limited Segments. State of California 2004/2006 303(d) list.

TDC Environmental. 2003. *Insecticide Market Trends and Potential Water Quality Implications*. Prepared for the San Francisco Estuary Project.

U.S. Environmental Protection Agency. (USEPA). 1983. Results of the Nationwide Urban Runoff Program, Final Report. NTIS #PB84-185552. Washington, D.C.

United States Geological Survey (USGS) 2002. *The Materials Flow of Mercury in the Economies of the United States and the World*. Prepared by J. Sznopek and T. Goonan. U.S. Geological Survey Circular 1197. U.S. Department of the Interior.

Woodward-Clyde Consultants (WCC). 1998. *Catch Basin and Street Sweeping Sediment Typical Concentration Values in Contra Costa County*, 1993-1997.

Woodward-Clyde Consultants (WCC). 1997. *Catch Basin and Street Sweeping Sediment Quality in Contra Costa County*, 1993-1996.

Woodward-Clyde Consultants (WCC). 1996. *Pollutant Concentrations in Catch Basin and Street Sweeping Sediments in Contra Costa County.*

Appendix A - Literature Review of Case Studies

During the past thirty years, many scientists have studied varying aspects of street sweeping with regard to pollutant removal and sweeper efficiencies (WCC 1994). Several early studies were very comprehensive in nature allowing more recent studies to be more directed in their scope. This section reviews the findings of projects sponsored by the National Urban Runoff Program (NURP) and highlights the findings of other studies that are relevant to the estimation of pollutants in street sweeping material in Contra Costa County.

National Urban Runoff Program (1983)

The studies sponsored by NURP were designed to provide a large data base of urban runoff water quality concentrations for both swept and unswept conditions (USEPA 1983). Additionally, street sweeper removal rates were also examined. Street sweeping case studies were carried out in the following cities:

- ◊ Castro Valley, CA
- ◊ Milwaukee, WI
- ◊ Champaign-Urbana, IL
- ◊ Winston-Salem, NC
- ◊ Bellevue, WA

Despite encouraging results from several of the individual studies (see Castro Valley below), the principal conclusions that were drawn from the composite study were that the changes in event mean concentrations were more likely due to random sampling than actual effects of sweeping operations (USEPA 1983). Additionally, composite results from the NURP studies reported that the underlying probability distribution of event mean concentration data at individual sites is best characterized as lognormal. The findings of three of the most pertinent NURP case studies are presented in the following sections.

Castro Valley, CA

In 1979, the US EPA evaluated the effectiveness of street sweeping in improving stormwater runoff quality in the Castro Valley as part of NURP (Pitt and Shawley 1981). This was a comprehensive two-year study whose results would be used to guide local public works agencies in incorporating street sweeping into their water quality control policies. The study showed that sweeping streets three times per week in the Castro Valley reduced the amount of copper collected in receiving waters by seven percent and total solids by twenty-seven percent. More frequent sweeping had no additional benefits. The study also pointed out the difficulties associated with timing sweeping with storm events.

Additionally, the data showed that accumulation rates were high immediately after streets were cleaned, either by a storm or by sweeping. Equilibrium rates were then reached in one to two weeks, meaning that the mass of pollutants did not increase beyond this level. Pollutant loadings were lowest in non-urbanized areas of the study and little variation in the chemical quality was found due to season or location.

The highest pollutant concentrations were found on the smallest particles (<63 um). Levels of copper were found to be approximately 0.15 lb/tons of street material collected.

Economic benefits were evaluated in terms of dollars per pound of pollutant saved from reaching receiving waters. On that economic basis, the study recommended a street sweeping program for the Bay Area. Their recommendation was to sweep streets three times per week before the start of the rainy season, once or twice per week during the rainy season, and to reduce the frequency to an aesthetically acceptable level after the rainy season. These results do not necessarily take total cost into consideration, but rather are based on minimizing cost per pound saved from reaching the receiving waters, which is highly site specific. Furthermore, since there were other sources of pollution to stormwater besides street runoff, there is considerable uncertainty in the study's conclusions on water quality effectiveness (USEPA 1983).

Milwaukee, WI

Another NURP-sponsored study designed to evaluate the effectiveness of street sweeping on stormwater quality was conducted in the early 1980's in Milwaukee (Bannerman 1983). Tests were conducted in commercial and medium to high density residential areas. The effectiveness of street sweeping was measured by comparing before sweeping and after sweeping discharges from paired watersheds. Area loading was estimated through modeling techniques.
Results indicated that street particles were found to range in size from 30-1,000 um. Rainfall and runoff were found to effectively mobilize small particles (<100 um). Removal efficiencies were found to be lower in areas where parking controls were not enforced.

Notably, pollutant loads on street surfaces after storm events were found to be higher than those before storm events. This result was presumably due to wash-off from adjacent areas. The study concluded that water quality improvements due to street sweeping were difficult to detect primarily because of data variability and the difficulties associated with sampling.

Bellevue, WA

This study provided a well-documented assessment of the application and effectiveness of BMPs in urban stormwater quality control (WCC 1994). Particular objectives of this NURP sponsored project were to assess street sweeping effectiveness, equipment performance, and to identify the relative distribution of material across street surfaces. Broom and regenerative air sweepers were evaluated. The study concluded that street sweeping is effective at removing pollutants from street surfaces. However, significant water quality improvements were not found.

Reno/Sparks, NV (1982)

A comprehensive multi-year study was designed to combine the management of urban stormwater, air quality and aesthetics (CH2MHill 1982). The study included characterizing street material and evaluating performance data of street sweeping equipment. The results were used to estimate pollutant loads using a particulate transfer model. Rates of street material accumulation were measured as a function of location on the street. The sweeping frequency was varied from daily to monthly and particle size analysis was conducted.

The study found that the average particle size ranged from 300 to 700 um, with median-sized particles on rough streets larger than those on smooth streets. The highest pollutant concentrations were found on smaller particles, which is consistent with other studies. Mean particle sizes were found to be higher in the middle of the streets (driving lanes) than next to curbs. The implication is that the concentration of pollutants is highest close to the curb.

Particular accumulation rates were highest when streets were clean, and equilibrium levels were reached in one to two weeks. A street sweeping frequency of at least every two weeks was therefore considered to be sufficient. The two types of sweepers tested, mechanical and vacuum, demonstrated little difference in results. Both were found to be effective in picking up material from street surfaces provided that they were driven at the recommended speed of four miles per hour. Vehicles driven at faster speeds were unable to collect material as efficiently.

Austin, TX (1990)

Several related reports were published by the City of Austin (1990) including a report on stormwater pollutant loading characteristics for various land uses. The purpose of that study was to develop stormwater pollutant loading rate data for various land use types in the Austin area.

Stormwater quality was analyzed in terms of constituent event mean concentrations (EMCs), degree of urbanization and storm loadings. Lognormal distributions were used to develop regression equations relating pollutant, runoff and rainfall variables for various watersheds. The study found that the EMCs for all residential and commercial land uses were similar. Furthermore, the EMCs for different land use types in Austin were compared to NURP results. It was shown that for newer suburban residential and commercial areas the median copper EMCs were relatively constant. The conclusion that can be drawn from these results is that similar land use areas nationwide are likely to demonstrate similar pollutant street loadings, at least with regard to copper.

Portland, OR (1993)

The 1993 Portland Interim Control Measure Study was designed to quantify and compare the effects of three alternative street cleaning practices on street dirt accumulation and pollutant wash-off (HDR Engineering 1993). The standard Portland practice of mechanical sweeping with light flushing was compared to two intensified practices; heavy flushing[12] and tandem sweeping.
Tandem sweeping uses a vacuum assisted sweeper to follow the standard sweeping methods.

The most relevant results to this study were that the highest pollutant concentrations were found in the fine to medium size particles and that their standard removal was only 40% efficient for particles smaller than 250 um. The effect of street sweeping on pollutant loading in the receiving waters was then modeled using a program similar to the one used in the Reno/Sparks study (Otak 1990). The concentration of copper in street dirt ranged from 85 mg/kg in particles greater than 250 um in diameter to 220 mg/kg for those smaller than 65 um.

San Jose, CA (1978 & 1994)

Several relevant studies have been conducted in the City of San Jose. In 1978 the US EPA conducted a study to measure the effectiveness of street sweeping on water quality (Pitt 1978). Streets in the study area were swept using two different types of sweepers and varying frequencies. The study examined street loadings, accumulation rates, pollutant loads in the storm drains, and equipment performance.

Results from this study indicated that significant amounts of heavy metals are found in street dirt and urban runoff. It was reported that the average nationwide copper concentration on street surface particulates is approximately 100 mg/kg with a standard deviation of 110 mg/kg. Furthermore, it was estimated that the removal rate of copper for a single pass by a mechanical sweeper is 38%. It was also noted that brake linings may be a significant contributor to copper pollutant levels in urban runoff. The study concluded that conventional street sweepers were considered effective at picking up relatively large particles and that runoff and erosion from off-street areas were responsible for a majority of the organic and nutrient loads in stormwater discharges.

An additional study was conducted in San Jose in 1994 to evaluate several different types of street sweepers (WCC 1994). The city's old broom sweepers were compared to two new broom sweepers and two regenerative air sweepers. The results indicated that the regenerative air sweepers pick up smaller particles and therefore higher copper concentrations than broom sweepers. The results also indicated that the types of sweepers may demonstrate differences in total mass of material removed per curb mile and copper mass removed per curb mile. Specifically, the new broom sweepers picked up a greater total mass of sediment and greater mass of copper per curb mile than the old broom sweepers.

---

[12] It should be noted that heavy flushing is not an option in the Fairfield – Suisun Sewer District (not the Bay Area in general), because it requires a combined sewer system to catch the wash water.

This study also reported that the principle variable affecting copper loading on street surfaces may be traffic volume. It was reported that the concentration of copper for preliminary study was approximately 135 mg/kg with a standard deviation of 130 mg/kg. The mass of copper collected per curb mile by the new broom sweeper ranged between 0.010 and 0.016 lb/curb mile. There were significant differences between routes swept which accounted for some variation in the results.

Contra Costa Clean Water Program (1998)

Street sweeping sediment quality data collected in Contra Costa County between 1993 and 1997 were sorted into residential, commercial and industrial land use categories where possible and mean (average) concentrations were used to develop "Typical Concentration Values" for copper (60 mg/kg), lead (60 mg/kg), zinc (180 mg/kg), total petroleum hydrocarbons (2200 mg/kg), and oil and grease (4800 mg/kg). These TCVs were then used by Co-permittees of the Contra Costa Clean Water Program to calculate the annual mass of pollutants removed via street sweeping. Of note, TCVs for copper were less than average concentrations found in San Jose (1994), but well within one standard deviation.

Alameda County, CA

Street Sweeper Solids Evaluation (1998)

A study was carried out in 1998 to characterize the lead and petroleum content of street sweepers in Alameda County. The study also followed up on a previous study conducted in 1994 that collected samples from two different locations. In this study, samples from six cities throughout the Alameda County region were analyzed for lead and petroleum content in the sweeper material and how that has changed since 1994.

From four separate sampling events, the range of constituents were as followed: total lead ranged from 5.1-1,120 mg/kg, soluble lead ranged from 0.5-12.5 mg/L, Gasoline range hydrocarbon ranged from 1-160 mg/Kg, heavier hydrocarbons ranged from 840-3,100 mg/Kg, and total hydrocarbons ranged from 1,067-3,865 mg/Kg. Of note, the soluble lead content in the cities in the north (Oakland and Berkeley) had higher soluble content then cities in the south.

The total and soluble lead content of this study were significantly lower than that of the 1994 study. Diesel and heavier hydrocarbons were similar for both studies. The decrease in lead maybe due to the phase out of use of lead in gasoline and elimination of lead paint, which occurred between the years of the two studies.

Street Sweeping Data Analysis (1999)

This study provided an overview of the operations and data collection of the street sweeping programs throughout Alameda County. Nine of fifteen agencies' data were part of the analysis. The analysis found that increasing street sweeping to twice a month did not affect material removal rates, suggesting maximum accumulation of material is less than 2 weeks. The study estimated removal rates of 260-520 lbs of material per curb-mile, which is comparable to literature reports of 20 to 540 lb/curb-mile (USEPA 1983).

Source Control Options for Selected TMDL Pollutants (2004)

This report assessed the potential for several source control activities to meet TMDL waste load allocations that are currently under development for mercury and PCBs. Street sweeping operations were estimated to remove annually 0 kg and 2 kg of PCBs and mercury, respectively (Salop and Akashah 2004). The use of high-efficiency sweepers was estimated to increase removal of PCBs from 0 to 3 kg and mercury from 1 to 3 kg annually. Five types of sweepers were identified: (1) mechanical broom, (2) Vacuum-assisted Wet, (3) Vacuum-assisted Dry, (4) Regenerative Air, and (5) Tandem sweepers. The most efficient of the systems was the vacuum-assisted dry sweepers (50% efficiency). This system uses a broom in combination with a vacuum to collect fine particles. Vacuum-assisted wet and regenerative air systems had efficiencies of 30%. Mechanical broom sweepers had the lowest efficiency of 10%. The most efficient model of sweepers, the Schwarze EV2, cost between $200,000 and $250,000.

San Mateo County, CA

Street Sweeping Study (1996)

This study quantifies the variability in the concentration of copper in street sweeper materials. Samples were taken from two different sweepers, mechanical broom and regenerative air sweeper, and analyzed. The study found that variability in copper from samples taken from the same composite can be as great as those taken from a completely different composite. There was also no significant difference in copper composition between the two sweeper types. The copper composition from the mechanical broom and regenerative air sweeper ranged, respectively, between 41 to 439 mg/kg and between 22 to 439 mg/kg (EOA 1996b). These results are within the range of nationally estimated concentrations for copper.

Estimation of Copper Collected Through Street Sweeping Efforts (1996)

In this report, the annual mass of copper collected throughout the county was estimated. Due to high variability of copper in the sweeper material the estimated range of copper is large. A Monte Carlo simulation with 4,000 trials was performed, assuming certain distributions for the density of material, concentration of copper and percent copper contributed from the material. Based on the simulation the median mass of copper removed was 2100 lbs with lower and upper 95th percentile confidence levels of 910 and 4130 lbs (EOA 1996a).

Australia (1999)

This Australian study looked at the effectiveness of street cleaning sweepers. Distributions of various pollutants according to particle size were provided in the report. Half of heavy metals (e.g. Cu, Pb, Zn) are found between the 60 to 200 µm range and about 75% of all heavy metals are under 500 µm (Walker and Wong 1999). Oil content was highest in sediment between 200 and 400 µm. Organic material is bimodally distributed at 2 to 6.3 µm and 63 to 200 µm. PCB and PAH should be distributed similarly since they are correlated to amount of organic material and not particle size.

Sweepers were found to be effective for removing particles above 500 µm, but very ineffective for finer particles. Because of their inability to pick up finer particles where most pollutants are found, using either mechanical broom or regenerative air sweepers were ineffective as a water quality BMP for reducing end-of-pipe urban runoff. A new generation of sweepers called small-micron surface sweepers reported higher removal efficiencies especially for small particles, up to 4 µm, and thus maybe more effective in pollution reduction. Sweeping frequency and storm interval were the dominant influence in the effectiveness of a street sweeping program.

Tampa, Fl (1999)

This study analyzed the viability of recycling street sweeping sediments for use as a soil amendment. Physical and chemical properties of street sweeping collected throughout the city of Tampa are assessed. Chemical analysis was done for several metals, such as Ni, Cu, and Zn. Physical analysis involves grain-size analysis of the sediments (Brinkman 1999). Because of the large number of samples, 75, this study provides valuable insight into composition of street sweeping material. It found that less than 63 micron size grains made up 20 percent of street sediments. The highest levels of these grains were found in industrial areas and the lowest in residential areas.

Tel Aviv, Israel (2001)

This paper is based on a presentation on the features of highway runoff that should be considered in investigating effects on storm water quality. Particles less than 63 um have a washout rate of 35-50% (Pitt 2001). Conventional street sweeping has overall effect of 8% reduction in total solids loading with an effectiveness of 35% for the largest particles and 10% for the smallest particles. On smooth asphalt street there is only a 12% reduction in loading for the smallest particles. The paper also found that highway runoff concentrations were substantially higher than that found in the NURP study in 1983 (USEPA 1983)

Montgomery County, MD (2002)

This report documents the status of street sweeping in Montgomery County, Maryland. It found that monthly sweeping was only 60% as effective as weekly sweeping (Curtis 2002). Parked cars reduced the effectiveness by as much of 75% of the base reduction rates. Vacuum-assisted sweepers were able to reduce total suspended solids (TSS) by 78-79% and nitrogen by 53-62%. Regenerative air sweepers were less effective, with reduction of TSS by 22% and nitrogen by 18%.

References (Appendix A)

Bannerman, R., K. Bohn and M. Bohn, 1983. Evaluation of Urban Non-Point Source Pollution Management in Milwaukee County Wisconsin, Volume I. Urban Storm Water Characteristics, Sources, and Pollutant Management by Street Sweeping. Prepared for the U.S. Environmental Protection Agency, Chicago, IL.

Brinkman et al. 1999. Chemical and Physical Characteristics of Street Sweeping Sediments in Tampa, Florida. Florida Center for Solid and Hazardous Waste Management. May.

CH2M Hill, 1982. Washoe County Urban Storm Water Management Program. Volume II. Street Particulate Data Collection and Analysis. Prepared for Washoe Council of Governments.

City of Austin, TX, 1990. Stormwater Pollutant Loading characteristics For Various Land Uses in the Austin Area. Environmental and Conservation Services Department, Environmental Resources Management Division.

Curtis, M. February 2002. Street Sweeping For Pollutant Removal, Department of Environmental Protection-Montgomery County Maryland.

EOA, Inc, 1999. Analysis of Street Sweeping Data. Prepared for Alameda Countywide Clean Water Program. June.

EOA, Inc, 1996a. Estimation of Copper Collected Through Street Sweeping Efforts. Prepared for San Mateo Countywide Stormwater Pollution Prevention Program. October.

EOA, Inc, 1996b. Street Sweeping Study. Prepared for San Mateo Countywide Stormwater Pollution Prevention Program. October.

HDR Engineering, 1993. Combined Sewer Overflow SFO Compliance Interim Control Measures Study, Section 7. Prepared for City of Portland, Bureau of Environmental Services.

Otak, Incorporated, 1990. Tulatin Basin Nonpoint Source Plan, Technical Appendix 2-Modeling of Runoff Quality Using SIMPTM. Prepared for the City of Portland Bureau of Environmental Services.

Pitt, R. 2001. Symposium on the pollution of Water sources from Road Run-Off, March 2001 at Tel Aviv University. University of Alabama. March.

Pitt, R. and G. Shawley, 1981. A Demonstration of Non-point Source Pollution Management on Castro Valley Creek. Main Report. Prepared for U.S. E.P.A. Water Planning Division.

Salop, P and Akashah, M. 2004. A Review of Source Control Options for Selected Particulate-Associated TMDL Pollutants, Prepared for Alameda Countywide Clean Water Program. March.

U.S. Environmental Protection Agency, 1983. Results of the Nationwide Urban Runoff Program, Final Report. NTIS #PB84-185552. Washington, D.C.

USGS. 2003. Data and Methods of a 1999-2000 Street Sweeping Study on an Urban Freeway in Milwaukee County, Wisconsin, Middleton WI. March.

Walker, T. and Wong, T. 1999. Effectiveness of Street Sweeping For Stormwater Pollution Control. Cooperative Research Centre for Catchment Hydrology. December.

Woodward Clyde Consultants, 1998. Street Sweeper Solids Evaluation. Prepared for Alameda Countywide Clean Water Program. Mar.

Woodward Clyde Consultants, 1994a. Street Sweeping/Storm Inlet Modification Literature Review. Prepared for Alameda County Urban Runoff Clean Water Program. Dec.

Woodward Clyde Consultants, 1994b. San Jose Street Sweeping Equipment Evaluation. Prepared for City of San Jose. Environmental Services Department Oct.

Woodward-Clyde Consultants, 1994c. Contribution of Heavy Metals to Storm Water from Automotive Disc Brake Pad Wear. Santa Clara Valley Nonpoint Source Pollution Control Program. October

Appendix C – Sampling and Analysis Plan (Included in Final Report)

Appendix D - Data Quality Assessment

There are several quality assurance issues associated with the analyses conducted for this investigation, as is typical with any large dataset. In several cases, analyses for organic constituents failed laboratory primary evaluation criteria. However, these QA issues are common with the media analyzed and consistent with previous analyses of street sweeping waste (e.g., Salop, *in prep*). All data in question are noted with appropriate qualifiers in Appendix D. An explanation of specific issues associated with laboratory analyses performed for this investigation is presented below.

Holding Times

There were a few samples that required an additional extraction within the laboratory that occurred one day after the recommended hold time for PCBs and PBDEs had expired. As the analytes in question that are associated with these samples are persistent in the environment and this data is not intended for strict regulatory action, AMS believes that the minor lapse beyond the recommended hold time does not affect its use for interpretive purposes.

Non-homogeneous Nature of Samples

The underlying reason behind many of the QA issues associated with this dataset is the heterogeneous nature of street sweeping waste itself. The waste undergoes some degree of sorting both during sweeping operations and as the waste is dumped off the back of the sweeper. In order to collect as homogenous a sample as possible, AMS employed a systematic grid design to collect waste for analyses; this technique composites a small amount of material from multiple points uniformly spread throughout the waste pile in order to generate analytical samples. AMS personnel then mixed the sample thoroughly in the field prior to generating aliquots. However, a truly homogenous sample is unable to be achieved due to the differences in sediment particle size and other materials present in the sample material that preclude achieving uniformity within the homogenate produced.

Dilutions

In some instances, constituent concentrations were high relative to concentrations typically found in environmental media using low detection level analyses. In these cases, results from initial analyses were above the ability of the method employed to quantify. For these cases, laboratory analysts had to dilute the samples and rerun analyses in order to quantify the results. Dilution adds some uncertainty to interpretation of the data, but is not expected to greatly impact the findings of this investigation.

Pyrethroids Data

All data for CAS analyses were provided to AMS electronically in Microsoft Excel spreadsheets. Pyrethroids analytical data were provided to AMS via a hard copy report from PAL. Pyrethroids data were then hand entered into an electronic spreadsheet for reporting purposes. Ten percent (10%) of all entries were inspected for accuracy as a QA check on data entry. No recorded errors were found and the results of the pyrethroids analyses are assumed to be accurately reported.

Appendix D – Laboratory and Field Data Sheets (CD-ROM Only)