APPENDIX B

BASMAA Source Control Loads Reduction Accounting for RAA Report

SOURCE CONTROL LOAD REDUCTION ACCOUNTING

FOR REASONABLE ASSURANCE ANALYSIS

Prepared for

Bay Area Stormwater Management Agencies Association

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ACRONYMS AND ABBREVIATIONS

ACCWP	Alameda Countywide Clean Water Program
BASMAA	Bay Area Stormwater Management Agencies Association
CCCWP	Contra Costa Clean Water Program
GSI	Green Stormwater Infrastructure
GIS	Geographic Information System
IMR	Integrated Monitoring Report
mg/ac/yr	milligram per acre per year
mg/kg	milligram per kilogram
MPC	Monitoring and Pollutants of Concern Committee
MRP	Municipal Regional Permit
MS4	Municipal Separate Storm Sewer System
NPDES	National Pollutant Discharge Elimination System
O&M	Operation and Maintenance
OFEE	Oil-Filled Electrical Equipment
PCBs	Polychlorinated Biphenyls
PG&E	Pacific Gas and Electric Company
POC	Pollutants of Concern
POTW	Publically Owned Treatment Works
RAA	Reasonable Assurance Analysis
ROW	Right-of-Way
SCVURPPP	Santa Clara Valley Urban Runoff Pollution Prevention Program
SFEI	San Francisco Estuary Institute
SFBRWQCB	San Francisco Bay Regional Water Quality Control Board
SMCWPPP	San Mateo Countywide Water Pollution Prevention Program
TMDL	Total Maximum Daily Load
WY	Water Year

1. INTRODUCTION

1.1 Background

Municipal Regional Permit (MRP; SFBRWQCB, 2015[1]) Provisions C.11.b and C.12.b required the Permittees to develop and implement an assessment methodology and data collection program to quantify mercury and polychlorinated biphenyls (PCBs) loads reduced through implementation of pollution prevention, source control, and treatment control measures. BASMAA prepared the report *Interim Accounting Methodology for TMDL Loads Reduced* (BASMAA, 2017a), which was approved by the Water Board for use during MRP 2.0. The Permittees have used this assessment methodology to demonstrate progress towards achieving the load reductions required in the MRP 2.0 permit term. This report has been prepared to address the requirements of MRP Provisions C.11.b.iii.(3) and C.12.b.iii.(3), which require the Permittees to submit, for Executive Officer approval, refinements to the Interim Accounting Methodology to assess mercury and PCBs load reductions in the next permit term (i.e., MRP 3.0).

MRP Provisions C.11.d. and C.12.d. require the Permittees to prepare plans and schedules for mercury and PCBs control measure implementation and a reasonable assurance analysis (RAA) demonstrating that those control measures will be sufficient to attain the mercury total maximum daily load (TMDL) wasteload allocations by 2028 and the PCBs TMDL wasteload allocations by 2030. The *Bay Area RAA Guidance Document* (BASMAA, 2017b) establishes a regional framework and guidance for conducting RAAs in the Bay Area, including the types of modeling and data inputs that may be used by the Programs and Permittees for estimating loads reduced by green stormwater infrastructure (GSI). Section 4.2 of the *Bay Area RAA Guidance Document* states that load reductions for source control measures should be calculated based on methods provided in an approved refinement of the Interim Accounting Methodology, which was previously developed by BASMAA. This report refines the Interim Accounting Methodology for the purposes of non-green infrastructure load reduction accounting in the RAAs.

This report does not include methods used to account for the implementation of GSI and other types of stormwater treatment control measures. The RAA methodologies for GSI are preliminarily described in countywide reports submitted to the SFBRWQCB in September 2018 (ACCWP, 2018; CCCWP, 2018; FSURMP, 2018; SMCWPPP, 2018; and SCRURPPP, 2018) and will be more fully described in the countywide RAA reports that will be submitted in September 2020. The GSI RAA methodologies have undergone external peer review and the results of the countywide GSI RAA modeling for each county will be submitted to the SFBRWQCB in September 2020. Non-GSI treatment control measure[2] load reductions would be modeled similarly to GSI load reductions, so are not discussed in this report.

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[1] Reissued November 19, 2015 with effective date January 1, 2016, to 77 Phase I municipal stormwater Permittees in five Bay Area counties which are among over 90 local agencies comprising the Bay Area Stormwater Management Agencies Association (BASMAA).

[2] Non-GSI treatment control measures that are not included in this report, for example, include treatment wetlands or media filters. Full trash capture devices, enhanced operations and maintenance activities, and diversion to POTW could also be considered as treatment control measures; these measures are included in this report.

1.2 Report Overview

A description of the source control measures, load reduction accounting methodologies, reporting requirements, and assumptions are presented in Sections 2 through 10 of this report for the following mercury and PCBs source control measure categories:

- Source Property Identification and Abatement;
- Management of PCBs in Building Materials;
- Management of PCBs in Electrical Utilities;
- Management of PCBs in Roadway and Storm Drain Infrastructure;
- Enhanced Operations and Maintenance Control Measures;
- Trash Full Capture Systems Implementation;
- Diversion to Publicly Owned Treatment Works (POTW); and
- Mercury Load Avoidance and Reduction.

The appendices present:

- A summary of how the land used-based PCBs and mercury yields were developed;
- A statistical summary of the observed urban sediment concentrations;
- Source area investigation and abatement guidance and referral/self-abatement forms;
- An estimate of load reductions for the PCBs in Electrical Utilities Management Program and the PCBs in Roadway and Storm Drain Infrastructure Program;
- Enhanced inlet cleaning efficiency factor data analysis for storm drain inlets with and without inlet-based full trash capture devices;
- Enhanced street sweeping efficiency factors; and
- Non-inlet-based trash capture device unit efficiency factor data analysis.

1.3 Source Control Load Reduction Accounting Basis

The source control load reduction accounting methodology outlined in this report is based on relative mercury and PCBs yields from different land use categories. This methodology was first outlined in the 2014 Integrated Monitoring Reports (IMRs) (ACCWP, 2014; CCCWP, 2014; SCVURPPP, 2014; SMCWPPP, 2014) and was described in the MRP 2.0 Fact Sheet. The method involves using default factors for PCBs and mercury load reduction credits resulting from foreseeable control measures. This report updates and refines the accounting system to account for new information; justifies the assumptions, analytical methods, sampling schemes, and parameters used to quantify the load reduction for each type of control measure; and indicates what information will be collected and submitted to confirm the calculated load reduction for each unit of activity for each control measure.

As described in the MRP 2.0 Fact Sheet, a land use-based yield is an estimate of the mass of a contaminant contributed by an area of a particular land use per unit time. Essentially, different types of land uses yield different amounts of pollutants because land use types differ in their degree of contamination resulting from differing intensities of historic or ongoing use of pollutants. The land use categories used to calculate land use-based yields were identified from studies conducted to identify potential POC sources and source areas, as described below.

The Regional Watershed Spreadsheet Model (RWSM) was developed as part of the Regional Monitoring Program's Small Tributaries Loading Strategy as a regional-scale planning tool primarily for the purpose of estimating long-term average annual pollutant loads from the small tributaries surrounding San Francisco Bay, and secondarily to provide supporting information for prioritizing watersheds or areas within watersheds for management actions (Wu et al, 2016). The RWSM is structured with three stand-alone empirical models: the hydrology model, sediment model, and pollutant models. The hydrology model uses runoff coefficients based on land use-soil-slope combinations to estimate annual runoff from a watershed. The sediment model uses a function of geology, slope, and land-use to simulate suspended sediment transport in the landscape while adjusting for watershed storage factors. The pollutant model is essentially a "concentration map" that can be driven by either the hydrology model (for pollutant concentrations in water) or the sediment model (for pollutant concentrations on fine sediment particles as particle ratios[3] for specific land use or source areas). Starting in 2010, a multi-year effort was undertaken to systematically develop and calibrate the RWSM. Calibration was completed[4] and the model was released in 2018.

A PCBs source property yield was derived as the product of a representative PCBs concentration in shallow surface soils at known source properties and a representative soil/sediment yield for Old Industrial land use areas. The derivation of the estimated PCBs source property yield is described in Appendix A.

PCBs were more heavily used in older industrial areas so older industrial land use areas yield a much higher mass of PCBs per unit area than newer urban land use areas. The estimated average PCBs and mercury yields from the RWSM are summarized for six land use yield categories in Table 1-1 below. These yields are assigned based on land use but may also be assigned by the Permittees based on monitoring data and/or inspection results (e.g., to assign the Source Property yield to a parcel mapped as Old Industrial). These yield values have been developed using the best available data and technical approach at this time. The Permittees may re-evaluate these yields in the future as more information becomes available.

[3] Particle ratios = pollutant concentration in water (ng/L) / suspended sediment concentration (mg/L), equivalent to mg/kg.
[4] The calibration for PCBs is "reasonable" but there remains a lower confidence in the calibration for mercury (SFEI, 2017).

Table 1-1: Land Use-Based Yields for PCBs and Mercury

Land Use Category	Assumed Average PCBs Yield (mg/ac/yr)	Assumed Average Mercury Yield[1] (mg/ac/yr)
Source Property	5,078	53
Old Industrial	259	53
Old Commercial / Old Transportation	49	57
Old Residential	2.8	57
New Urban	0.4	4
Agriculture/Open Space	0.4	81

mg/ac/yr – milligrams per acre per year
Source: RWSM Toolbox v1.0 Pollutant Model, Pollutant Spreadsheet Model Calculations – Region. Spreadsheet dated 6/9/2017.
1. The model calibration for PCBs is "reasonable" but there remains a lower confidence in the calibration for mercury (Wu et al., 2017).

Appendix B presents concentration statistics for PCBs and mercury observed in street, storm drain, and private property sediment samples collected by BASMAA from 1999 through 2019. The data are summarized by the predominant land use within the vicinity of where the sediment was collected.

2. SOURCE AREA IDENTIFICATION AND ABATEMENT PROGRAM

2.1 Control Measure Description

Source area identification and abatement involves investigations of properties located in historically industrial land use or other land use areas where PCBs were used, released, and/or disposed of and/or where sediment concentrations are significantly elevated above urban background levels[5] and are being transported to the municipal separate storm sewer system (MS4). The source area identification and abatement control measure begins with performing investigations in High Likelihood/Interest areas to identify PCBs sources. Once a source property is identified, the source of PCBs on the property may be abated or caused to be abated directly by the Permittee or the Permittee may choose to refer the source property to the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB) for investigation and abatement by the SFBRWQCB. Source properties may include sites that were previously remediated but still have soils concentrations of PCBs that are elevated above urban background levels or may be newly identified source properties. Source properties may also include industrial facilities with ongoing industrial activities that are covered under the General Permit for Stormwater Discharges Associated with Industrial Activities (Industrial General Permit) or another National Pollutant Discharge Elimination System (NPDES) permit.

The Permittees identify significantly elevated PCBs concentrations through surface soil/sediment sampling in the right-of-way or through water sampling where visual inspections and/or other information suggest that a specific property is a potential source of significantly elevated PCBs concentrations. Where data confirm significantly elevated concentrations (e.g., a sediment PCBs concentration equal to or greater than 1.0 mg/kg or a sediment concentration greater than 0.5 mg/kg and other lines of evidence) are present in soil/sediment from a potential source property or in stormwater samples, the Permittees may take actions to cause the property to be abated or may refer that property to the SFBRWQCB to facilitate the issuance of orders for further investigation and remediation of the subject property.

For each referred source property, the applicable Permittee will implement or cause to be implemented one or a combination of interim enhanced operation and maintenance (enhanced O&M) measures in the street or storm drain infrastructure adjacent to the source property during the source property abatement process, or will implement a stormwater treatment system downstream of the property to intercept historically deposited sediment. The intent is to prevent further contaminated sediment from being discharged from the storm drain system. These enhanced O&M measures and/or treatment systems will be described in the source property referral form that is sent to the SFBRWQCB.

The selected enhanced O&M control measure(s) or stormwater treatment must be implemented and maintained during the source property abatement process and should be sufficient to intercept historically deposited sediment in the public right-of-way and prevent additional contaminated sediment from being discharged from the MS4. The Permittee should discuss the

[5] See Appendix B for a statistical summary of urban sediment concentrations.

referral and achieve resolution with the SFBRWQCB prior to submitting the source property referral.

When a referred industrial facility is considered to be abated by the Permittee and the SFBRWQCB, the enhanced O&M measures may be discontinued, and ongoing facility inspections would be conducted as appropriate as part of the Permittee's routine industrial inspection program.

Source area investigation and abatement program guidance is provided in Appendix C.

2.2 Loads Reduced Accounting Methodology

The amount of PCBs loads (i.e., annual mass or milligrams per year (mg/yr)) reduced will be assessed for source properties using the following accounting method:

$$Load\ of\ PCBs\ Reduced = SP_A \bullet (SP_Y - OCOT_Y)$$

Where:

SP_A	=	Source property area (acres (ac))
SP_Y	=	Source property PCBs yield (mg/ac/yr)
$OCOT_Y$	=	Old Commercial/Old Transportation land use PCBs yield (mg/ac/yr)

Thus, the PCBs load reduced in mg/yr will be calculated as the area of the source property in acres multiplied by 5,029 mg/ac/yr (i.e., 5,078 – 49 mg/ac/yr).

There is no mercury load reduction credit given to PCBs source property referrals, as there is not a significant difference between the estimated source property, old industrial, old residential, and old commercial/old transportation mercury yield values.

Fifty percent of this load reduction will be credited to the Permittee for properties that are referred to the SFBRWQCB for abatement at the time of referral provided that enhanced O&M measures or stormwater treatment are implemented or caused to be implemented in the vicinity of the referred source property to prevent further contaminated sediment from being discharged from the storm drain system. The remaining 50% load reduction for referred properties will be credited to the Permittee upon completion of the abatement process or at ten years, whichever occurs first. The SFBRWQCB will notify the Permittee when the abatement process is complete.

Source properties that drain directly to the Bay (as opposed to the street or public storm drain infrastructure) do not allow for implementation of enhanced O&M measures or stormwater treatment by the Permittee. These properties may be submitted to the SFBRWQCB as a referral; 100% load reduction credit will be awarded upon completion of the abatement process, after ten years, or the TMDL compliance date (i.e., 2030 for PCBs), whichever occurs first.

If a source property has been abated without referral to the SFBRWQCB, either through voluntary actions by the property owner or using municipal enforcement powers, then 100% of the load reduction will be credited to the Permittee at the time that the abatement is complete. The Permittee shall provide documentation to the SFBRWQCB that abatement has effectively eliminated the transport of PCBs or mercury to the MS4 or directly to the Bay for all transport mechanisms that apply to the site (e.g., stormwater runoff, wind, vehicle tracking). The documentation shall include information on the type and extent of abatement that has occurred (e.g., have the sources of PCBs to the MS4 been eliminated via soil removal, capping, paving, walls, plugging/removal of internal storm drains, etc.). Documentation may be from a cleanup regulatory agency such as the US Environmental Protection Agency (USEPA) or the California Department of Toxic Substances Control (DTSC). For sites with ongoing industrial activities, water or sediment monitoring data that demonstrates the effective elimination of transport of PCBs offsite into the MS4 or to the Bay should be provided. Information that supports the determination of abatement should be submitted to the SFBRWQCB for review using the Abatement Form in Appendix D.

For source properties that include a combination of industrial area and area that is not likely to be a source of PCBs (e.g., unimpacted open space area), the source property yield will only be applied to the portion of the property that is an industrial area.

Load reduction credit for enhanced O&M measures conducted as a part of a source property referral is included in the credit afforded by the source property referral. Enhanced O&M measures conducted adjacent to a source property that has not been referred to the SFBRWQCB may receive load reduction credit under the enhanced O&M control measure category using the source property yield (see Section 6).

2.3 Reporting

Standard report forms are provided for Source Property Referral and Source Property Self Abatement in Appendix D.

For load reduction reporting associated with the source property identification and abatement control measure, the area of each property will be estimated using the County Assessor's parcel map or an equivalent method. For those source properties that are referred to the SFBRWQCB for abatement, the referral form has a space to describe any enhanced O&M control measures or downstream treatment control measures that have been implemented or are planned to be implemented at the source property. For those source properties that have been abated, the Permittee will provide a statement that the property has been abated, along with documentation on the date, type, and extent of abatement, as described above.

3. PCBS IN BUILDING MATERIALS MANAGEMENT PROGRAM

3.1 Control Measure Description

The MRP Permittees have developed and implemented a process, beginning in July 2019, for managing materials with PCBs concentrations of 50 ppm or greater in applicable structures at the time such structures undergo demolition. Applicable structures include commercial, public, institutional, and industrial buildings constructed or remodeled between the years 1950 and 1980 undergoing full-building demolition. Single-family residential and wood frame structures are exempt.

Permittees have implemented the following process for this control measure:

- Municipalities inform applicable demolition permit applicants that their projects are subject to the program for managing materials with PCBs, necessitating, at a minimum, an initial screening for priority PCBs–containing materials.
- For every applicable demolition project, applicants implement the BASMAA protocol for identifying building materials with PCBs concentrations of 50 ppm and then complete and submit a version of BASMAA's model "PCBs Screening Assessment Form" (Screening Form) or equivalent to the municipality.
- The municipality reviews the Screening Form to make sure it is filled out correctly and is complete and works with the applicant to correct any deficiencies.
- The municipality then issues the demolition permit or equivalent, according to its procedures.
- The municipality sends each completed Screening Form for applicable structures and any supporting documents to its countywide program. The countywide program compiles the forms and works with the other MRP countywide programs to manage and evaluate the data, and to assist Permittees with associated MRP reporting requirements.

3.2 Loads Reduced Accounting Methodology

The load of PCBs reduced through implementation of the PCBs in Building Materials Management Program will be assessed using the following accounting method:

$$Load\ of\ PCBs\ Reduced = \left[\sum_{i=1}^{n}(N_i \bullet M_i \bullet SW_i)\right] \bullet E_f$$

Where:

N_i	=	Number of applicable buildings demolished each year (units/yr)
M_i	=	Average mass of PCBs per applicable building (mg/unit)
SW_i	=	Average fraction of PCBs that enters the MS4 due to demolition without controls (%)

E_f = Average fraction of PCBs prevented by controls from entering MS4 (%)

Reasonable values were used to assign the load reduction for this control measure in MRP 2.0. Permittees received a total of 2,000 g/yr (2 kg/yr) PCBs load reduction value in 2019 when protocols for managing PCBs-containing materials during demolition, as required in MRP 2.0 Provision C.12.f., were developed and implemented. Table 3-1 below lists the four terms and the assumed values used to derive the 2 kg/yr credit. These values may be updated based on data gathered in the future, as described below.

Table 3-1: Terms Used to Estimate the Loading of PCBs in Building Materials for MRP 2.0

Term	Estimated Value	Units
1. Number of applicable buildings[1] demolished per year	50	buildings/year
2. Average mass of PCBs per applicable building	5	kg
3. Average fraction of PCBs that enters MS4s due to demolition without controls[2]	0.01	dimensionless fraction
4. Average fraction of PCBs prevented by controls[2] from entering MS4	0.8	dimensionless fraction

[1]Applicable buildings: constructed from 1950 through 1980 with PCBs concentration in caulks/sealants greater than 50 ppm, excluding single family residential and wood frame buildings.

[2]The term "controls" refers to the proposed new demolition management program, not existing construction controls.

The 2 kg/yr PCBs load reduction stipulated during MRP 2.0 will be retained. During the MRP 3.0 permit term, Permittees may, with the necessary supporting data, request an increase in the credit received for the current program and/or expand the scope of the program to increase loads reduced. Any proposed revision of load reduction credit and/or program expansion would be submitted to the Regional Water Board for Executive Officer approval.

The new management program implemented by Permittees as of July 1, 2019 requires that demolition project proponents identify priority materials in applicable buildings, collect representative samples for analysis, and report the concentrations of PCBs. When a sample concentration is equal to or greater than 50 ppm, the estimated amount of material in the building associated with that sample (and presumably removed and properly disposed of before the demolition occurs) is also reported. These concentration and quantity data can be combined to determine the mass of PCBs removed from the building. These data represent an estimate of the mass of PCBs removed from the building via removal of the priority materials (rather than the estimate provided in the MRP 2.0 fact sheet of the total mass of PCBs in the building in all PCBs-containing materials). Thus, the value of Term 4 in Table 3-1 may be set to 1 when evaluating the PCBs load avoided using data from the new program, since it may be assumed that the program removes 100% of the priority materials identified by the sampling.

3.3 Reporting

BASMAA is developing a regional data management system for compiling the data reported by demolition project applicants. This data for applicable structures, listed below, may be used to support a request for additional loads reduced by the existing program and/or an expansion of the program:

- Project information (e.g., address, APN, year building built, type of construction, estimated demolition date).
- Is building subject to the PCBs screening requirement based on type, use, and age of the building?
- PCBs concentration in each sample of a priority material. Currently, the BASMAA protocol identifies priority materials as caulk, thermal insulation, fiberglass insulation, adhesive mastics, and rubber window gaskets.
- When PCBs equal to or greater than 50 ppm are measured in a priority material sample, the estimated amount of that material in the building (only required to report on sampling of priority materials but reporting any available data on other materials is encouraged).

Permittees will provide documentation of each of the following items:

- The number of applicable structures that applied for a demolition permit during the reporting year; and
- A running list of the applicable structures that applied for a demolition permit (since the date the PCBs control protocol was implemented) that had material(s) with PCBs at 50 ppm or greater, with the address and demolition date.

4. PCBS IN ELECTRICAL UTILITIES MANAGEMENT PROGRAM

4.1 Control Measure Description

The Electrical Utilities Management Program will include improved procedures for documenting removal and disposal of PCBs-containing electrical equipment as part of ongoing equipment maintenance practices.

Electrical utility equipment in both the transmission and distribution systems are distributed across the MRP region. In the past, PCBs were routinely used in electrical utility equipment that contained dielectric fluid as an insulator. This is because prior to the 1979 PCBs ban, dielectric fluid was typically formulated with PCBs due to a number of desirable properties (e.g., high dielectric strength, thermal stability, chemical inertness, and non-flammability). Electrical equipment containing dielectric fluid is typically identified as Oil-Filled Electrical Equipment (OFEE). Any OFEE that contained PCBs in the past could still potentially contain PCBs today. The most common types of OFEE that may contain PCBs are transformers, capacitors, circuit breakers, reclosers, switches in vaults, substation insulators, voltage regulators, load tap changers, and synchronous condensers (PG&E, 2000).

There are hundreds of thousands of pieces of OFEE in public rights-of-way and at hundreds of electrical sub-station facilities across the MRP region. Some portion of these OFEE that are older and/or refurbished may contain (or contained in the past) dielectric fluids with PCBs at concentrations that are of concern if released to MS4s. Due to their large quantity, dispersed nature, and the difficulty in tracking and monitoring discharges, Permittees are limited in their ability to implement and/or enforce consistent and appropriate control measures to reduce releases of PCBs from this source category. This creates a potential missed opportunity to account for past and ongoing removal of PCBs-containing OFEE which has been and continues to reduce loads of PCBs from MS4s to the Bay.

For this control measure, Permittee owned electrical utilities will document the removal of PCBs-containing OFEE since the start of the TMDL and in the future until all PCBs-containing OFEE have been removed from active service, and provide data to support calculations of the associated stormwater load reductions due to these efforts. Additionally, it is anticipated that non-municipally owned regional electrical utilities that are not currently subject to PCBs load reduction requirements (i.e., PG&E) have been and will continue to remove PCBs-containing OFEE and document these efforts, past and present, consistent with methods used by applicable MRP permittees.

4.2 Loads Reduced Accounting Methodology

The load of PCBs reduced through implementation of the Electrical Utilities Management Program will be assessed using the following accounting method:

$$Load\ of\ PCBs\ Reduced = \left[\sum_{i=1}^{n}(LR_i)\right]$$

Where:

LR_i = Load of PCBs reduced for Action i during a given time period of interest (kg/yr).

The PCBs loads reduced in mg/yr will be assessed using the following equation:

$$Load\ of\ PCBs\ Reduced\ (LR) = L_0 \bullet ER_1 \bullet Y_i$$

Where:

L_0 = Estimated annual load of PCBs that enters MS4 from OFEE at the start of the PCBs TMDL.

ER_1 = Estimated percent of PCBs load prevented from entering the MS4 each year due to equipment removal (percent per year); the percent of loads prevented each year is assumed equivalent to the annual average rate of PCBs-containing equipment removal.

Y_i = Number of Years during the time period of interest i.

The above equation assumes the rate of load reduction achieved over the time period of interest is approximately equivalent to the equipment removal rate.

Reasonable values were developed for each of the terms shown in the equation above in order to calculate the total load reduction credit for implementing the Electrical Utilities Management Program (Table 3, see Appendix E for further detail). Based on equipment removal rates of 1.3% to 4.8% per year (average = 2.3% per year) for municipally-owned electrical utilities between 2005 and 2020 (calculated as described in detail in Appendix E), equipment removals since the start of the PCBs TMDL have reduced PCBs loads each year between 0.014 kg/yr to 0.053 kg/yr (average = 0.025 kg/yr). This equates to a total load reduction achieved by 2020 of between 0.210 kg/yr and 0.795 kg/yr (average = 0.375 kg/yr) due to equipment removals across the Bay Area. Assuming the same annual equipment removal rates in the future, then during the five-year term of MRP 3.0, additional load reductions will range from 0.072 kg/yr to 0.264 kg/yr (average 0.127 kg/yr) for equipment removals. Table 4-1 below identifies the assumed ranges of values for the terms in the above equation that were used to calculate the load reductions achieved since the start of the PCBs TMDL and during MRP 3.0. The derivation of each of the terms shown in Table 4-1 is presented in detail in Appendix E. These values may be updated based on data gathered during MRP 3.0.

Table 4-1: Range of Values used to Estimate the Load Reductions due to the Electrical Utilities Management Program Actions Since the Start of the PCBs TMDL and for MRP 3.0.

Term	Description	Estimated Values	Units
L_0	Annual load of PCBs to MS4 from OFEE at the start of the PCBs TMDL; this value is assumed to be the TMDL-normalized McKee et al. (2006) estimated load to stormwater from transformers and large capacitors in 2005 (see Appendix E for details on how this value was developed).	1.1	kg/yr
ER_1	Percent of PCBs prevented from entering MS4 due to ongoing equipment removals; these values are assumed equivalent to the annual equipment removal rates for municipally owned electrical utilities in the Bay Area between 2005 and 2020 (see Appendix E for details on how these values were developed).	1.3 - 4.8 (Average=2.3)	%/year

Term	Description	Estimated Values	Units
Y_i	The time period of interest since the start of the PCBs TMDL is the fifteen years between 2005 and 2020.	15	years
Y_i	The time period of interest during MRP 3.0 is the five years of the permit term.	5	years

All Permittees will receive a share of the total PCBs load reductions achieved as a result of program implementation based on the accepted countywide apportionment method (e.g., population).

4.3 Reporting

Permittees will summarize the steps they have taken to begin implementing this control measure, either collectively or individually.

Additionally, a report will be developed and provide the following information:

- Estimates of the current annual PCBs loads released to the MS4 from OFEE, based on the best available data;
- Permittees will document efforts by municipally owned electrical utilities in the MRP area to remove PCBs-containing equipment since the TMDL baseline period (i.e., 2003). The report will include the following information:
    - Describe actions that remove PCBs-containing OFEE, including handling and disposal methods; and
    - Document loads avoided calculations, inputs, and assumptions.

5. PCBS IN ROADWAY AND STORM DRAIN INFRASTRUCTURE CAULK MANAGEMENT PROGRAM

5.1 Control Measure Description

The BASMAA study *Evaluation of PCBs in Caulk and Sealants in Public Roadway and Storm Drain Infrastructure* (BASMAA, 2018) sampled caulk and sealant materials from public roadway and storm drain infrastructure around the Bay Area. The sampling program was designed to specifically target roadway and storm drain structures that were constructed during the most recent time period when PCBs were potentially used in caulk and sealant materials (i.e., prior to 1980, with a focus on the 1960's and 1970's). A total of 54 caulk and sealant samples were collected from ten different types of roadway and storm drain structures in the right-of-way (ROW), including concrete bridges/overpasses, sidewalks, curbs and gutters, roadway surfaces, above and below ground storm drain structures (i.e., flood control channels and storm drains accessed from manholes), and electrical utility boxes or poles attached to concrete sidewalks. The individual samples were grouped by structure type and sample appearance (color and texture) and the groups were combined into 20 composites; 10 of these groups were collected from concrete bridges, overpasses, or roadways.

Total PCBs concentrations across the 20 composite samples ranged from non-detect to greater than 4,000 mg/kg. The majority of the composites had PCBs concentrations that were below 0.2 mg/kg. PCBs were not detected in ten of the composite samples, representing nearly 60% of the individual samples collected during this program. PCBs in twenty-five percent (5 of 20) of the composites were above 1 mg/kg. Of these, two composites had very high PCBs concentrations (greater than 1,000 ppm) that indicate PCBs were likely part of the original caulk or sealant formulations. Both of these composites were comprised of black, pliable joint filler materials that were collected from concrete bridges/overpasses.

This control measure has been developed as a result of the outcome of this study. For this control measure, Permittees will track development of a Caltrans specification for managing PCBs-containing caulks and sealants on bridges or roadway overpasses during bridge replacement or joint maintenance. The Caltrans standard specifications for removal, handling, and disposal of caulk or sealant materials during infrastructure replacement or joint maintenance projects will be used to prevent the release of PCBs to the MS4. The Caltrans specification will be applied to all applicable public bridges or roadway overpass structures when the bridge infrastructure undergoes replacement or joint maintenance. Additionally, Permittees will implement the following actions:

1. Maintain a list of applicable bridges that are scheduled for replacement or joint maintenance.
2. Implement or cause to be implemented the Caltrans specifications during applicable bridge projects that are under the direction of the Permittee.
3. Track and report on the use of the specifications for all applicable bridge projects within the Permittee's jurisdiction.

5.2 Loads Reduced Accounting Methodology

A detailed load reduction accounting methodology is provided in Appendix F and summarized here.

Total PCBs load contained in bridges built and/or reconstructed prior to 1981 within the jurisdictions subject to the MRP was estimated using the following equation:

$$\text{Total Load}_{\text{PCBs, Bridges}} = \text{Density}_{\text{sealant}} * \text{Concentration}_{\text{PCBs}} * \sum \text{Volume}_{\text{sealant, bridges}}$$

Where:

$\text{Density}_{\text{sealant}}$ = average sealant density [kg/m^3]

$\text{Concentration}_{\text{PCBs}}$ = empirically derived concentration of PCBs [mg/kg]

$\sum \text{Volume}_{\text{sealant, bridges}}$ = Volume of sealant in all applicable bridges [m^3]

The volume of joint sealant was calculated using an assumed cross-section of sealant, multiplied by the assumed length of applied sealant:

$$\text{Volume}_{\text{sealant, bridges}} = \text{Cross-Section}_{\text{sealant}} * \text{Length}_{\text{sealant}}$$

Where:

$\text{Cross-Section}_{\text{sealant}}$ = Cross-section of applied sealant

$\text{Length}_{\text{sealant}}$ = Length of applied sealant

A summary of the data inputs is provided in Table 5-1 below. The derivation of the values presented in Table 5-1 is described in Appendix F.

Table 5-1: Bridge Load Calculation Data Inputs

Input	Result	Units	Source
Density of Sealant	1,100	kg/m^3	Takhar, 2013
Cross-Section of Sealant	1	square inch	Caltrans, 2007
PCBs Concentration	184	mg/kg	See Section 2.2.1

The estimated total PCBs load contained in bridges built and/or reconstructed prior to 1981 within the jurisdictions subject to the MRP is provided in Table 5-2.

Table 5-2: Total Calculated Loads for Bridges within the MRP Area, Built and/or Reconstructed Prior to 1981

County	Total Sealant PCBs Mass - Joints Only (kg)	Total Sealant PCBs Mass - Joints and Longitudinal Seal (kg)	Number of Bridges[1]
Alameda	3.8	11.2	340
Contra Costa	1.7	7.3	277
San Mateo	2.5	7.2	254
Santa Clara	3.7	10.1	473
Solano	0.9	3.2	133

County	Total Sealant PCBs Mass - Joints Only (kg)	Total Sealant PCBs Mass - Joints and Longitudinal Seal (kg)	Number of Bridges[1]
Total	**12.6**	**39.0**	**1,477**

1. U.S. Department of Transportation Federal Highway Administration, 2019. National Bridge Inventory. Visited 24 March 2020.

To estimate the load reduction associated with long-term bridge or expansion joint replacement, it is assumed that an ongoing PCBs release rate from bridge joints is mitigated through bridge joint maintenance and whole bridge replacement projects. The load reduction estimation is based on the assumption that PCBs in caulk are leaching from bridge joints and longitudinal seals over their lifetime. When that PCBs-containing caulk is replaced or removed through maintenance or replacement projects, the source of PCBs release is removed, and the associated annual released load is also removed. PCBs leaching from the material could occur through incremental wear or through larger damage (e.g., pieces of caulk torn out) over the lifetime of the caulk.

Lacking a literature-based release rate of sealant over time, two potential average annual release rates (i.e., average over the life of the seal) were assumed to calculate an estimated load reduction from removing the joint seal –0.5% and 1.0%. These average annual release rates were applied to the estimated mass for the 1,477 bridges meeting the identified age criteria (Table 5-3). These releases would be eliminated through removal of the joint seal through joint replacement or bridge replacement.

Table 5-3: Long-Term Load Reduction (i.e., Replacement of PCBs-Containing Joints in All Older Bridges)

County	Total Sealant PCBs Load Reduced - Joints Only (g/year)		Total Sealant PCBs Load Reduced - Joints and Longitudinal Seal (g/year)	
	0.5% annual loss rate over life	1% annual loss rate over life	0.5% annual loss rate over life	1% annual loss rate over life
Alameda	19	38	56	112
Contra Costa	8	17	37	73
San Mateo	12	25	36	72
Santa Clara	19	37	50	101
Solano	5	9	16	32
Total	63	126	195	390

This load reduction would occur no later than 2080, based on the assumption that all older joints will be removed/replaced within 100 years of installation.

5.3 Reporting

Permittees will report on the development and use of the Caltrans specification during all applicable replacement activities.

6. ENHANCED OPERATIONS AND MAINTENANCE PROGRAM

6.1 Control Measure Description

Routine MS4 operation and maintenance (O&M) activities include street sweeping, drain inlet cleaning, and pump station maintenance. In addition, culverts and channels are also routinely maintained (i.e., desilted). Enhancements to routine operations and new actions such as storm drain line and street flushing may enhance the Permittees' ability to reduce PCBs and mercury in stormwater. PCBs load reductions achieved through implementation of enhanced O&M control measures, aside from enhanced O&M control measures associated with source property referrals, may be counted as part of the overall load reductions expected during this permit term.

6.2 Loads Reduced Accounting Methodology

6.2.1 Enhanced Inlet Cleaning (With and Without Small Full Trash Capture Devices) and Street Sweeping

Load reductions for enhanced inlet cleaning and street sweeping will be calculated as follows:

$$\boldsymbol{Annual\ Load\ of\ PCB\ Reduced = P_A \bullet P_Y \bullet EE_f}$$

Where:

P_A	=	Catchment area for enhanced O&M measure (acres)
P_Y	=	Area-weighted PCBs yield (mg/acre-year) for the enhanced O&M catchment area based on land use yield (see Table 1-1)
EE_f	=	Enhancement Efficiency factor for enhanced O&M control measure (See Appendix G for enhanced inlet cleaning with and without small full trash capture devices and Appendix H for enhanced street sweeping).

6.2.2 Pump Station Cleanout, Storm Drain Line Cleanout, Street Flushing, and Culvert/Channel Desilting

Load reductions for enhanced pump station cleanout, storm drain line cleanout, street flushing, and culvert/channel desilting will be calculated as follows:

$$Enhanced_{LR} = Current_{LR} - Baseline_{LR}$$

Where:

$Current_{LR}$	=	$Vol_{Current} \bullet \%Sed \bullet \rho \bullet Conc$
$Baseline_{LR}$	=	$Vol_{Baseline} \bullet \%Sed \bullet \rho \bullet Conc$
$Vol_{Current}$	=	Average volume of material collected via the enhanced O&M control measure in current year(s) (post-Fiscal Year 2001-02) (m3/yr)

$Vol_{Baseline}$	=	Average volume of material collected via the O&M control measure in baseline years (prior to and including Fiscal Year 2001-02) (m^3/yr) (assumed to be zero for storm drain line cleanout and street flushing)
%Sed	=	Percent of material collected (by volume) by the enhanced O&M control measure that is sediment < 2mm in diameter (measured)
ρ	=	Sediment density of the material collected by the enhanced O&M control measure (weight per unit volume) (measured)
Conc	=	Average concentration of PCBs in sediments collected by the enhanced O&M control measure (mg/kg; see Appendix B for land use-based sediment concentrations to calculate area-weighted concentrations or alternatively use project-specific measurements).

6.3 Reporting

The following information will be reported for this control measure:

- Description of O&M measure enhancement, including the location of the enhanced measure and description of the enhancement (e.g., increased frequency of implementation over the baseline frequency).
- Baseline and current volumes of material collected.
- Assumptions/data on the percent of the material that was < 2 mm
- Assumptions/data on sediment density
- The calculated loads reduced.

7. TRASH FULL CAPTURE SYSTEMS IMPLEMENTATION PROGRAM

7.1 Control Measure Description

This control measure includes the implementation of large (non-inlet based) full trash capture devices, including hydrodynamic separators (HDS), gross solids removal devices (GSRDs), and baffle boxes in existing developed areas for the purposes of MRP Provision C.10 compliance. These devices collect sediment and debris along with trash, so are considered as a source control measure for the PCBs and mercury associated with the sediment that is captured.

7.2 Loads Reduced Accounting Methodology

The Permittees will quantify and report the amount of PCBs and mercury loads reduced from implementation of large full trash capture devices using the following accounting method:

$$Load\ of\ POC\ Reduced = P_A \bullet P_Y \bullet E_f$$

Where:

P_A	=	Tributary area treated by large full trash capture device (acres)
P_Y	=	Area-weighted PCBs or mercury yield (mg/acre-year) (see Table 1-1)
E_f	=	Efficiency factor for large full trash-capture devices (assumed to be 20%)[6]

7.3 Reporting

The following information will be reported for large full trash capture projects:

- Project name, type of device, and location.
- The year that project construction was completed.
- Total project tributary drainage area.
- The land use area(s) for the project and the area-weighted land use-based yield for the project area.
- POC loads reduced for each project.

[6] See Appendix I for large trash capture device unit efficiency factor data analysis.

8. DIVERSION TO POTW PROGRAM

8.1 Control Measure Description

This control measure consists of diverting dry weather and/or first flush events from MS4s to publicly owned treatment works (POTWs) as a method to reduce loads of PCBs and mercury in urban runoff.

8.2 Loads Reduced Accounting Methodology

The load reduction calculation method for this control measure is:

$$EnhancedReductionDiversion = CurReductionDiversion - BaseReductionDiversion$$

Where:

BaseReductionDiversion	=	Mass of PCBs or mercury reduced via POTW diversions of urban stormwater in 2010 (assume zero for all diversions prior to MRP 1.0 except the Palo Alto Diversion Structure)
CurReductionDiversion	=	Mass of PCBs or mercury reduced via POTW diversions of urban stormwater in Year of Interest

And:

Base or Cur ReductionDiversion = ConcDiversion • VolDiversion

Where:

ConcDiversion	=	Average concentration of PCBs or mercury in sediment and/or water diverted to POTW (measured)
VolDiversion	=	Volume of sediment and/or water diverted to POTW (measured)

8.3 Reporting

For diversions, a project-specific report will be prepared that describes the diversion and project-specific load reduction calculations.

9. MERCURY LOAD AVOIDANCE AND REDUCTION PROGRAM

9.1 Control Measure Description

Mercury load avoidance and reduction includes a number of source control measures listed in the California Mercury Reduction Act adopted by the State of California in 2001. These source controls include material bans, reductions of the amount of mercury allowable for use in products, and mercury device recycling. The following source controls bans are included:

- Sale of cars that have light switches containing mercury;
- Sale or distribution of fever thermometers containing mercury without a prescription;
- Sale of mercury thermostats; and,
- Manufacturing, sale, or distribution of mercury-added novelty items.

In addition, fluorescent lamps manufacturers continue to reduce the amount of mercury in lamps sold in the U.S. Manufactures have significantly reduced the amount of mercury in fluorescent linear tube lamps and streetlamps. The use of mercury containing bulbs has also decreased through replacement of these bulbs with LED lamps.

Mercury Device Recycling Programs resulting in Mercury load reduction generally include three types of programs that promote and facilitate the collection and recycling of mercury–containing devices and products:

1. Permittee-managed household hazardous waste (HHW) drop-off facilities and curbside or door-to-door pickup;
2. Private business take-back and recycling programs (e.g., Home Depot); and,
3. Private waste management services for small and large businesses.

9.2 Loads Avoided/Reduced Accounting Methodology

The load avoidance/reduction methodology for this control measure is:

$$HgReductionL/S/T = BaseLoadLST - CurLoadLST$$

Where:

BaseLoadLST	=	Baseline load of mercury in urban stormwater in 2002 from lamps (L), switches (S), and thermostats (T)
CurLoadLST	=	Current load of mercury in urban stormwater in year of interest from lamps (L), switches (S), and thermostats (T)

And:

BaseLoadLST	=	BaseMassL/S/T • BaseNumL/S/T • T
CurLoadLST	=	CurMassL/S/T • CurNumL/S/T • T

Where:

$BaseMass_{LST}$	=	Average mass of total mercury in each lamp (L), switch (S), and thermostat (T) in 2002 (Assume: 93mg per kilogram of linear fluorescent lamp or Compact Fluorescent Lamp (CFL); 2.9g per switch; and 4g per thermostat).
$CurMass_{LST}$	=	Average mass of total mercury in each lamp (L), switch (S), and thermostat (T) recycled in year of interest (Assume: 35mg per kilogram of linear fluorescent lamp or CFL; 2.9g per switch; and 4g per thermostat).
$BaseNum_{LST}$	=	Number or weight of lamps (L), switches (S), and thermostats (T) improperly discarded into the environment in 2002.
$CurNum_{LST}$	=	Number or weight of lamps (L), switches (S), and thermostats (T) discarded into the environment improperly in year of interest.
T	=	% of total mercury in lamps (L), switches (S), and thermostats (T) that when improperly discarded are transported to the Bay via urban stormwater (Assume 4.8%).

And:

BaseNumLST	=	BaseSpentL/S/T - BaseRecycleL/S/T
CurNumLST	=	CurSpentL/S/T - CurRecycleL/S/T

Where:

BaseSpentLST	=	Number or weight of lamps (L), switches (S), and thermostats (T) that reached their end-of-life in 2002
BaseRcyLST	=	Number or weight of lamps (L), switches (S), and thermostats (T) recycled in 2002
CurSpentLST	=	Number or weight of lamps (L), switches (S), and thermostats (T) that reached their end-of-life in year of interest
CurRecycleLST	=	Number or weight of lamps (L), switches (S), and thermostats (T) recycled in year of interest

Table 9-1 below provides conversion factors and references for the assumed values used in these calculations.

Table 9-1: Mercury Recycling Conversion Factors and References

Item	Conversion and Citation
Fluorescent Lamps	The average mercury content for a four-foot linear fluorescent lamp is 8.3 milligrams (mg). This is equal to 2.075 mg (2.075 X 10 -6 kilograms (kg)) per linear foot. Source: NEMA 2005. Fluorescent and Other Mercury-Containing Lamps and the Environment: Mercury Use, Environmental Benefits, Disposal Requirements. National Electrical Manufacturers Association. March 2005. 14p.

Item	Conversion and Citation
Compact Fluorescent Lamps (CFLs)	The National Electrical Manufacturers Association (NEMA) announced that under the new voluntary commitment, effective October 1, 2010, participating manufacturers will cap the total mercury content in CFLs that are under 25 watts at 4 mg per unit, and CFLs that use 25 to 40 watts of electricity will be capped at 5 mg per unit. Each CFL recycled is assumed to have an average mass of 4.5 mg (4.5 X 10 -6 kg). New CFLs are also assumed to have 4.5 mg on average. Source: NEMA 2010. NEMA Lamp Companies Agree to Reduction in CFL Mercury Content Cap. Available at http://www.nema.org/media/pr/20101004a.cfm. Accessed April 11, 2012.
High Intensity Discharge (HID) Lamps	The average content of a HID bulb is .5 milligrams of mercury (0.5 x 10 -6 kg). Source NEMA Opposition to Ban on Mercury Containing Headlamps, 2004 http://www.nema.org/Policy/Environmental-Stewardship/Lamps/Documents/HID%20Headlamps%2010%2004.pdf
Thermostats	The amount of mercury in a thermostat is determined by the number of ampoules. There are generally one or two ampoules per thermostat (average is 1.4) and each ampoule contains an average of 2.8 grams (g) of mercury. Therefore, each thermostat recycled is assumed to contain approximately 4.0 g (0.004 kg) of mercury. Source: TRC 2008. Thermostat Recycling Corporation's Annual Report for the U.S. Prepared by the Thermostat Recycling Corporation. http://www.thermostat-recycle.org/files/u3/2008 TRC Annual Report.pdf. Each thermostat recycled is assumed to contain approximately 4.0 g (0.004 kg) of mercury. The average weight of one thermostat is 12 ounces. There are 1.3333 thermostats in a pound of thermostats (1 pounds/0.75 pounds = 1.33 thermostats. It is estimated that 0.005333 kg of mercury is recycled for every pound of thermostat recycled (1.333*0.004= 0.005333). Source: Average weight of thermostat obtained from retail websites - www.amazon.com.
Switches	The Recycling Corporation reports that one mercury switch contains 2.87 g (0.00287 kg) of mercury. Source: TRC 2010. Thermostat Recycling Corporation's Annual Report for California. Prepared by the Thermostat Recycling Corporation. Prepared for the State of California's Office of Pollution Prevention and Green Technology, Department of Toxic Substances Control. March 31, 2010.

9.3 Reporting

The Permittees will provide a description of their ongoing mercury recycling program and activities.

10. PROGRAM UPDATES AND REFINEMENTS

The accounting methodology outlined in this report may be updated and refined to account for significant new information as it becomes available. If needed, the proposed updates will be submitted as an addendum to this report for Executive Office approval during the MRP 3 permit term.

11. REFERENCES

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San Mateo Countywide Water Pollution Prevention Program (SMCWPPP), 2014. Integrated Monitoring Report – Part C Pollutants of Concern Load Reduction Opportunities. March 2014.

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Wu, J., Gilbreath, A.N., McKee, L.J., 2016. Regional Watershed Spreadsheet Model (RWSM): Year 5 Progress Report. A technical report prepared for the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP), Sources, Pathways and Loadings Workgroup (SPLWG), Small Tributaries Loading Strategy (STLS). Contribution No. 788. San Francisco Estuary Institute, Richmond, California.

APPENDIX A
Land Use-Based Yield Analysis

A.1 METHODOLOGY

The methodology presented in this appendix was developed to assist the MRP Permittees in identifying which watershed characteristics correlate well with areas that have high, moderate, and low rates of pollutant of concern (POC) (i.e., mercury and PCBs) loading to receiving waters via stormwater runoff. The methodology was developed using the collective local understanding of the types of land areas, facilities, and activities that generate POCs, with a focus on PCBs. The ultimate goal of the analysis was to provide first order estimates of POC loading rates from high, moderate, and low likelihood source areas and to assist Permittees in identifying areas for implementing POC load reduction measures that would have the greatest load reduction benefit.

A.1.1 Source Area Mapping

Documented uses and sources of PCBs and mercury in the urban environment and the results of PCBs source identification and abatement studies described in the 2014 Integrated Monitoring Report (IMR) Part B (BASMAA, 2014) have been used to identify PCBs source areas. Findings demonstrate that PCBs (and to a lesser extent mercury) sources are generally associated with watershed areas where equipment containing POCs were transported or used and facilities that recycle POCs or POC-containing devices and equipment. These sources include current and historic metal, automotive, and hazardous waste recycling and transfer stations; electrical properties and power plants; and rail lines. These sources are typically located in areas that were industrialized between the late 1920's and the late 1970's, the timeframe when PCBs and mercury production were the greatest in the U.S.

To assist Permittees in identifying potential POC sources and source areas, a number of preliminary GIS data layers were developed using existing and historical information on land use and facility types that were located in the Bay Area during the early to mid-20th century. GIS data layers included a revised "Old Industrial" land use layer that attempted to depict industrial areas that were present in the year 1968; an "Old Urban" land use layer that depicts urban areas developed by 1974, other than those depicted as Old Industrial; points depicting current facilities that have the potential to have or have had PCBs on-site; and historical and current rail lines where PCBs may have been transported.

A.1.1.1. Old Industrial Land Areas

Three sets of data layers were acquired and served as the primary sources of information used to create the Old Industrial data layer: 1) the 2005 version of the Association of Bay Area Governments (ABAG) land use data layers for the five Bay Area counties, which depicts current industrial land use areas; 2) 1968 aerial photographs for the Bay Area at 30,000 scale acquired from the United States Geological Survey's (USGS) Earth Explorer website; and 3) the most currently available County Assessor parcel data layers for Bay Area counties. Through the development of the Old Industrial layer, two data layers were created. The first depicts industrial land areas in 1968 that are not currently characterized as industrial by ABAG. This data layer was created by panning through 1968 aerial photography and identifying industrial land areas outside of the areas characterized as industrial land use in roughly 2005 by ABAG. The purpose of this layer was to identify potential industrial facilities that were present in 1968, but possibly redeveloped or incorrectly identified within the ABAG land use data. The second data layer that was created depicts areas characterized by ABAG in 2005 as industrial land uses that were clearly not industrial in the 1968 aerial photographs. Most of these areas were developed into industrial land uses after 1968 and are most commonly agricultural in the aerial photographs. All parcels that were identified as at least partially industrial in 1968 were visually checked in the data layer to provide greater confidence in its accuracy. Minor edits were then made based on this quality assurance check. If there was uncertainty as to whether a parcel in the 1968 photographs was industrial, then the parcel was classified based on the ABAG land use data. As a final check, the 1968 aerial photographs were also compared to current aerial photographs and each parcel that had been redeveloped was attributed with the current land use, even if that land use remained industrial.

A.1.1.2. Old and New Urban Land Areas

Old Urban and New Urban land use data layers that depict areas urbanized prior to and after 1974, respectively, were developed using an urban extents data layer from 1974, the closest year to 1968 that the data were available. All areas that were within the urban extent in 1974 were defined as Old Urban; those areas that fell outside of this definition were classified as New Urban. Old Urban areas have been further divided into residential and parks areas versus commercial areas in the current land use classification schema.

A.1.1.3 Identification of Potential POC Associated Facilities

Point data were collected for a number of facility types that may be associated with either PCBs or mercury. These facility types include those associated with electrical generation, known mercury emitters, metal manufacturing, drum recycling, metal recycling, shipping, automotive recycling, general recycling, and those known to have or historically have had PCBs in use. This information was primarily gathered by the San Francisco Estuary Institute (SFEI) as part of the Urban Stormwater Best Management Practices (BMPs) Proposition 13 Grant project and contains data from a variety of sources, including the California Air Resources Board, EnviroStor, Superfund, Department of Toxic Substances Control, and the State Water Resource Control Board.

Certain facility types for which point data were developed were mapped in greater detail to develop polygons to allow area calculations to be performed. Of particular interest for PCBs were the several hundred electrical substations in the Bay Area. Areas for these facilities were delineated using current and 1968 aerial photographs to attribute whether each facility was built prior to or after 1968. Additionally, military, port, and railroad land use areas were developed using ABAG 2005 land use data and the latest assessor's parcel data. Military parcels were further edited to only include developed areas.

Land use and facility data layers created as part of this effort were then combined to create one contiguous data layer. This data layer was attributed with additional information such as city, county, and watershed.

A.2 Regional Watershed Spreadsheet Analysis

A.2.1 Background

The Regional Watershed Spreadsheet Model (RWSM) was developed as part of the Regional Monitoring Program's (RMP) Small Tributaries Loading Strategy as a regional-scale planning tool primarily for the purpose of estimating long-term average annual loads from the small tributaries surrounding San Francisco Bay, and secondarily to provide supporting information for prioritizing watersheds or areas within watersheds for management actions (Wu et al., 2016).

The RWSM is structured with three stand-alone empirical models: the hydrology model, the sediment model, and the pollutant model (Wu et al., 2016). The hydrology model uses runoff coefficients based on geospatially identified land use-soil-slope combinations along with rainfall based on PRISM average precipitation[7] to estimate annual runoff from a defined watershed area. The sediment model uses a function of geology, slope, and land-use to simulate suspended sediment transport in the landscape of a defined watershed while adjusting for watershed storage factors. The pollutant model is a spreadsheet model that combines land use-based pollutant concentrations (i.e., pollutant concentrations in water or pollutant concentrations on fine sediment particles as particle ratios[8] corresponding with specific land use types or source areas) with land use-based hydrology model output or sediment model output. Land use-based loading results are compiled to obtain pollutant loading across a defined watershed.

Starting in 2010, a multi-year effort was undertaken to systematically develop and calibrate the RWSM for San Francisco Bay watersheds using RMP data. Calibration was completed[9] and the model was released in 2018 (SFEI, 2018). For further detail about each component of the model, see the RWSM User Manual (SFEI, 2018).

A.2.2 RWSM Results

The estimated average PCBs and mercury yields from the RWSM Toolbox v1.0 Pollutant Model, "Pollutant Spreadsheet Model Calculations – Region" for the modeled land use yield categories are provided in Table A-1 below. The "Region" spreadsheet results were developed using RMP data from well-sampled watersheds to calibrate pollutant concentration coefficients and applying the resulting coefficients to the region to get average pollutant yield results (Gilbreath, 2019).

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[7] 800-m grid, from PRISM Climate Group, Oregon State University, http://prism.oregonstate.edu.

[8] Particle ratios = pollutant concentration in water (ng/L) / suspended sediment concentration (mg/L), equivalent to mg/kg.

[9] The calibration for PCBs is "reasonable" but there remains a lower confidence in the calibration for mercury (Wu et al., 2017).

Table A-1: RWSM Land Use-Based Yields for PCBs and Mercury

Land Use Category	Average PCBs Yield (mg/ac/yr)	Average Mercury Yield[1] (mg/ac/yr)
Old Industrial and Source Areas	259	53
Old Commercial and Old Transportation	49	57
Old Residential	2.8	57
New Urban	0.4	4
Agriculture/Open Space	0.4	81

mg/ac/yr – milligrams per acre per year
Note: RWSM Toolbox v1.0 Pollutant Model, Pollutant Spreadsheet Model Calculations - Region. Spreadsheet dated 6/9/2017.
1. The model calibration for PCBs is "reasonable" but there remains a lower confidence in the calibration for mercury (Wu et al., 2017).

Table A-2 below presents the RWSM Toolbox v1.0 Pollutant Model, "Pollutant Spreadsheet Model Calculations – Region" results for PCBs and mercury average concentrations in runoff for the five RWSM modeled land use categories (SFEI, 2018).

Table A-2: Regional Watershed Spreadsheet Model PCBs and Mercury Concentrations in Runoff

Land Use Category	Total PCBs (ng/L)	Total Mercury[1] (ng/L)
Old Industrial and Source Areas	204	40
Old Commercial and Old Transportation	40	63
Old Residential	4	63
New Urban	0.2	3
Agriculture/Open Space	0.2	80

1. The model calibration for PCBs is "reasonable" but there remains a lower confidence in the calibration for mercury (Wu et al., 2017).

A.3 Source Area/Property PCBs Yield

The derivation of the estimated PCBs source property yield is described below. The PCBs source property yield was derived as the product of a representative PCBs concentration in surface soils at known source properties and a representative soil/sediment yield for old industrial areas.

Table A-3 and Table A-4 present descriptive statistics for measured concentrations of PCBs from source properties located in Alameda, Contra Costa, Santa Clara, and San Mateo Counties. This dataset includes 670 PCBs surface soil samples from twelve source property locations as well as on-site source property data identified in the street and storm drain sediment dataset that has been compiled by BASMAA to-date (see Appendix B). All soil samples included in the analysis were collected from the 0 to 0.5-foot depth interval, with the exception those collected at one site, based on the assumption that the top six inches of soil would have the most potential to mobilize offsite via wind or rainfall erosion. Data collected from the 0 to 1.0-depth interval were included for the General Electric site in Oakland, as this represented the shallowest reported depth for that site. The range of PCBs concentration (mg/kg) in surface soils for individual Bay Area source properties are provided in Table A-3 and the summary statistics for all sites combined are provided in Table A-4.

Table A-3: Site specific PCBs concentration in surface soil collected on-site from source properties located in Alameda, Contra Costa, Santa Clara, and San Mateo Counties.

Site Location	Minimum (mg/kg)	Average (mg/kg)	Maximum (mg/kg)	Count	Reference
1411 Industrial Rd, San Carlos	1.66	236.31	418.00	5	EKI Environment and Water, 2018. Letter from EKI to Mark Johnson, RWQCB, October 8, 2018. Subject: PCB Storm Drain Sediment Sampling Results 1411 Industrial Road, San Carlos, CA (EKI B80090.00)
270 Industrial Road and 495 Bragato Rd, San Carlos (Delta Star Inc./Tiegel Manufacturing Co.)	3.40	28.36	122.00	14	GHD, 2016. Incremental Sampling Investigation Report. August 4.
335 Brokaw Road, Santa Clara	3.56	3.56	3.56	1	SCVURPPP POC Monitoring
1645 Old Bayshore Highway, San Jose	11.91	11.91	11.91	1	SCVURPPP POC Monitoring
1695 and 1775 Monterey Highway, San Jose	5.47	6.26	7.06	2	SCVURPPP POC Monitoring
1800 South Monterey Road, San Jose	1.79	2.70	3.61	2	SCVURPPP POC Monitoring
Union Pacific Railroad at Schallenberger Road, San Jose	2.80	2.80	2.80	1	CW4CB Final Report/database (http://basmaa.org/Clean-Watersheds-for-a-Clean-Bay-Project)
Union Pacific Railroad Leo Avenue, San Jose	0.02	12.86	127.00	45	GHD, 2017. Remedial Investigation Report. Union Pacific Railroad Property, Leo Avenue ROW, San Jose, CA. September.
ETT111, Oakland	3.70	3.70	3.70	1	Kleinfelder, 2006. Private Property Sediment Sampling Report: Ettie Street Watershed, Oakland, California. Kleinfelder West, Inc.
3430 Wood Street, Oakland (Granite Expo)	93.41	93.41	93.41	1	ibid
1797 12th St, Oakland (Cole Brothers Auto Wrecker)	1.67	1.67	1.67	1	ibid
3015 Adeline St, Oakland (California Electric)	6.08	6.08	6.08	1	ibid
1266 14th St, Oakland (Amtech Lighting)	5.70	5.70	5.70	1	ibid
3425 Ettie St, Oakland (Allied Painter)	1.75	1.75	1.75	1	ibid
2838 Hannah St, Oakland (Former Giampolini)	0.74	9.23	17.73	2	ibid
3428-3434 Helen Street, Oakland (ACM)	10.62	10.62	10.62	1	ibid

Site Location	Minimum (mg/kg)	Average (mg/kg)	Maximum (mg/kg)	Count	Reference
1639 18th St, Oakland (Martinez Bros Trucking)	1.95	1.95	1.95	1	ibid
2601-2812 Peralta St, Oakland (Custom Alloy Scrap Sales)	1.78	7.09	14.73	4	ibid
280 West MacArthur Blvd, Oakland (Kaiser Oakland)	0.01	1.67	27.20	101	Forensic Analytical Environmental Health Consultants, 2017. PCB Soil and Sediment Waste Characterization and Disposal Plan, Kaiser Permanente Medical Center Oakland Legacy Tower Demolition Project, 280 West MacArthur Boulevard, Oakland, CA. Revised April 21, 2017.
710 73rd Avenue, Oakland (Former Aero Plating)	0.01	101.42	790.00	8	Fugro Consultants, Inc. 2016. Limited Soil Sampling Investigation, 710 73rd Avenue, Oakland, CA. January.
700 73rd Avenue, Oakland (Union Pacific Railroad)	0.92	88.16	1,100	14	CDM Smith, 2014. Report of Findings for Data Gaps Investigation Phase B - On-site Investigations, Union Pacific Railroad Company Property, 700 73rd Avenue Oakland, CA. November 14.
5441 International Boulevard, Oakland (General Electric)	0.03	248.36	11,000	134	Geosyntec Consultants, 2009. Feasibility Study Report for the GE Site at 5441 International Boulevard, Oakland, CA. June.
4560 Horton Street, Emeryville (Former South Southern Pacific Railroad)	0.03	0.40	1.91	6	EKI, 2016. Corrective Action Work Plan – Shallow Soil Excavation, Former SPRR Parcel South of 53rd Street, Emeryville, CA. June 29.
One Cyclotron Rd, Berkeley (Lawrence Berkeley National Laboratory)	0.0019	3.23	135.0	227	Lawrence Berkeley National Laboratory, 2016. Quarterly and Semiannual Progress Reports, for the LBNL Hazardous Waste Facility Permit. Environmental Restoration Program. August 1993 through February 2016.
CC-SPL-600-P	1.29	1.29	1.29	1	Contra Costa County 2015 POC Sampling
San Diego St, Richmond (San Diego St)	0.03	0.12	1.20	14	Arcadis, 2016. San Diego Street Transformer Oil Release Cleanup and Closure Report, West End of San Diego Street Richmond, CA, February.
1014 Chesley Ave, Richmond (World Oil)	0.01	0.79	6.50	70	APEX, 2018. PCB Characterization Report, World Oil Corporation Property, 1014 Chesley Avenue, Richmond, California. July 13.
1215 Willow Pass Road, Pittsburg (Molino)	0.02	1.19	5.60	10	Ground Zero Analysis, 2016. Phase II Investigation at 1215 Willow Pass Road, Pittsburg, November 11.
Average for All Properties		**31.88**			

Table A-4: Summary of PCBs concentration in surface soil collected on-site from source properties located in Alameda, Contra Costa, Santa Clara, and San Mateo Counties.

Statistic	PCBs (mg/kg)
Maximum	11,000
90^{th} Percentile	36.90
75th Percentile	4.80
Average	57.71
Median	0.57
25^{th} Percentile	0.069
10^{th} Percentile	0.0020
Minimum	0.0019
N	670

Based on the data reviewed, the Bay Area wide average of PCBs in surface soil from known source properties based on individual property averages is 31.9 mg/kg (Table A-3) and the average based on individual sample concentrations is 57.7 mg/kg (Table A-4). An average concentration is the appropriate metric to use for the yield estimate as it is representative of the total expected loading, which is affected by very high concentrations.

A sediment yield for Old Industrial land uses within the Santa Clara Basin watersheds was estimated based on a Loading Simulation Program – C++ (LPSC) watershed model developed for the Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP) as part of their reasonable assurance analysis (Paradigm Environmental, 2019 (attached)). The sediment yield estimated from the LPSC watershed model represents baseline hydrology and water quality, specifically sediment and solids. The median, LPSC-modeled sediment yield from Old Industrial land uses in the Santa Clara Basin is 39 grams/m^2/year or 157.8 kg/acre/year. Using the average PCBs concentration, estimated in two different approaches, of 31.9 mg/kg and 57.7 mg/kg from surface soils on Bay Area source properties presented above and the median Old Industrial sediment yield of 157.8 kg/acre, the estimated PCBs yield from source properties is 5,031 mg/acre/year and 9,108 mg/acre/year, respectively.

For mercury, the RWSM yield value for old industrial/source areas will be used for load reduction accounting.

A.4 LIMITATIONS AND UNCERTAINTY

Land use is used as a surrogate for actual PCBs and mercury sources, and although the types of potential sources have been identified, the actual locations and sizes of sources are difficult to determine at this level of analysis. While categorized the same for modeling and analysis purposes, similar land use in different locations may have very different sources and thus distinctly different PCBs and mercury concentrations in runoff.

It is difficult to quantitatively assess the implications of these limitations on the projected magnitude of loads, especially as analysis shifts from regional to more refined spatial scales. The projected loads should be considered first order approximation and reflective of the central tendency of the data for the Bay Area as a whole.

A.5 REFERENCES

Gilbreath, Alicia, 2019. Personal communication via email, 2/26/2019.

McKee, L.J., Gilbreath, A.N., Wu, J., Kunze, M.S., Hunt, J.A., 2014. Estimating Regional Pollutant Loads for San Francisco Bay Area Tributaries using the Regional Watershed Spreadsheet Model (RWSM): Year's 3 and 4 Progress Report. A technical report prepared for the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP), Sources, Pathways and Loadings Workgroup (SPLWG), Small Tributaries Loading Strategy (STLS). Contribution No. 737. San Francisco Estuary Institute, Richmond, California.

San Francisco Estuary Institute (SFEI), 2018. Regional Watershed Spreadsheet Model (RWSM) Toolbox v1.0 User Manual and Pollutant Model. Available here: https://www.sfei.org/projects/regional-watershed-spreadsheet-model#sthash.kOKnKvF2.dpbs.

Wu, J., Gilbreath, A.N., McKee, L.J., 2017. Regional Watershed Spreadsheet Model (RWSM): Year 6 Progress Report. A technical report prepared for the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP), Sources, Pathways and Loadings Workgroup (SPLWG), Small Tributaries Loading Strategy (STLS). Contribution No. 811. San Francisco Estuary Institute, Richmond, California.

Wu, J., Gilbreath, A.N., McKee, L.J., 2016. Regional Watershed Spreadsheet Model (RWSM): Year 5 Progress Report. A technical report prepared for the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP), Sources, Pathways and Loadings Workgroup (SPLWG), Small Tributaries Loading Strategy (STLS). Contribution No. 788. San Francisco Estuary Institute, Richmond, California.

APPENDIX B
Urban Sediment Concentration Statistics

B.1 Descriptive Statistics

Tables B-1 and B-2, and Figures B-1 and B-2 presents descriptive statistics for the PCBs and mercury street and storm drain sediment dataset that has been compiled by BASMAA to-date. This dataset includes 1,535 PCBs samples and 1,350 mercury samples taken within the street right-of-way, storm drain conveyance system, and private properties from 1999 through 2019. Data are summarized by the predominant land use within the vicinity of where the sediment was collected.

Table B-1: PCBs concentrations in sediment (mg/kg) collected from streets, stormwater conveyance systems, and private properties located in Alameda, Contra Costa, Santa Clara, San Mateo, and Solano Counties between 1999 and 2019.

Statistic	Old Industrial	Old Urban (Not Residential/Parks)	Old Urban (Residential /Parks)	New Urban	Open Space	All Samples
Maximum	193	17	5.7	0.72	1.1	193
90th Percentile	1.1	0.18	0.30	0.27	0.19	0.77
75th Percentile	0.21	0.08	0.10	0.047	0.054	0.16
Mean	0.79	0.22	0.20	0.066	0.067	0.65
Geometric Mean	0.26	0.09	0.12	0.059	0.058	0.22
Median	0.05	0.03	0.023	0.016	0.009	0.041
25th Percentile	0.01	0.01	0.006	0.001	0.002	0.009
10th Percentile	ND	ND	ND	ND	ND	ND
Minimum	ND	ND	ND	ND	ND	ND
n	1,205	110	98	69	53	1,535

Table B-2: Mercury concentrations in sediment (mg/kg) collected from streets, stormwater conveyance systems, and private properties located in Alameda, Contra Costa, Santa Clara, San Mateo, and Solano Counties between 1999 and 2015.

Statistic	Old Industrial	Old Urban Not Res/Parks	Old Urban Res/Parks	New Urban	Open Space	All Samples
Maximum	21	1.7	4.5	13	4.3	21
90th Percentile	0.80	0.41	0.78	0.63	0.35	0.74
75th Percentile	0.30	0.22	0.40	0.27	0.20	0.29
Mean	0.43	0.20	0.43	0.46	0.29	0.41
Geometric Mean	0.29	0.13	0.19	0.27	0.11	0.28
Median	0.15	0.11	0.18	0.14	0.11	0.15
25th Percentile	0.088	0.071	0.082	0.100	0.046	0.086
10th Percentile	0.057	0.051	0.045	0.056	0.030	0.054
Minimum	ND	0.015	0.015	ND	0.020	ND
n	1,069	80	91	62	48	1,350

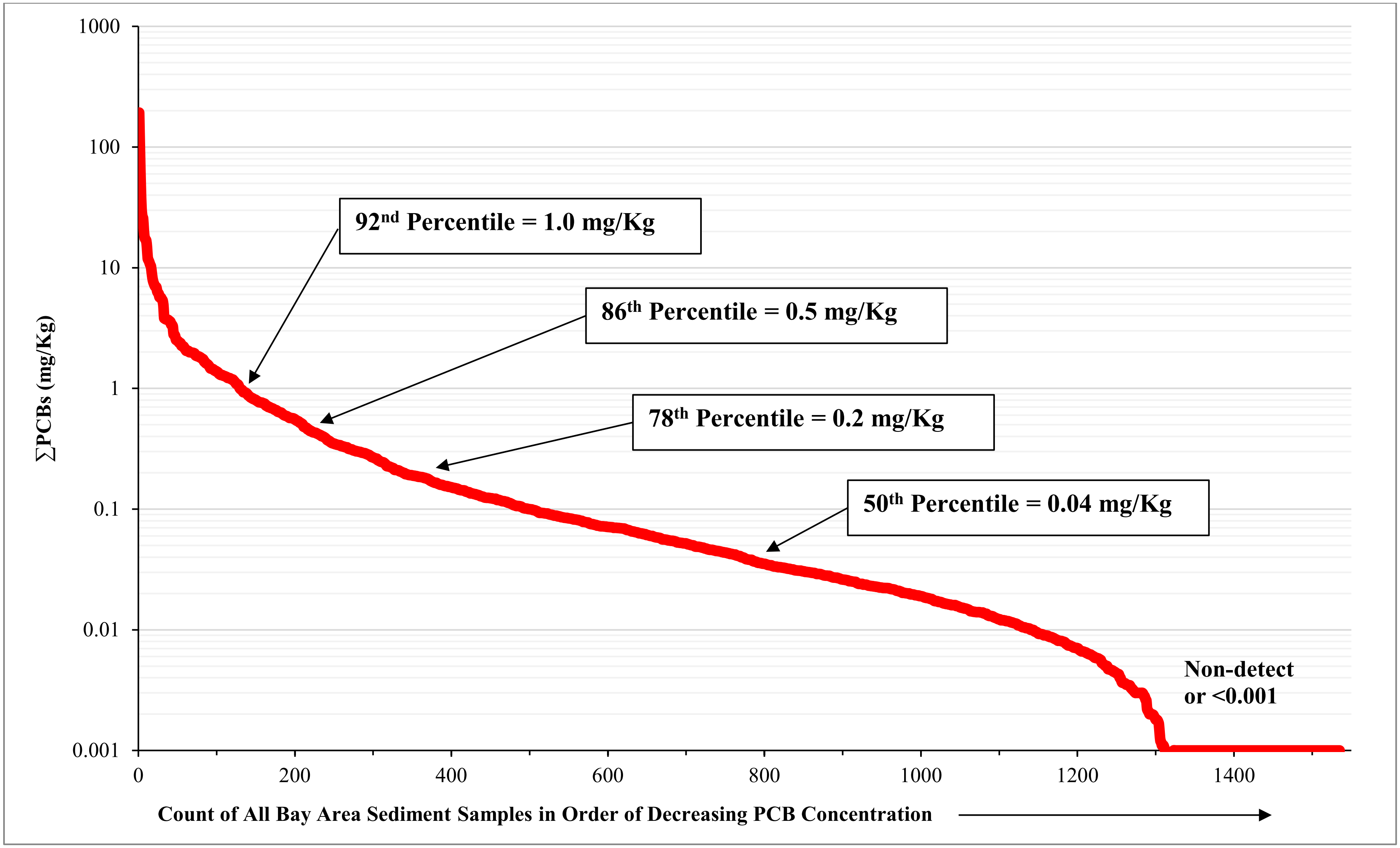

Figure B.1: Total PCB concentrations in sediment collected from streets, stormwater conveyance systems, and private properties located in Alameda, Contra Costa, Santa Clara, San Mateo, and Solano Counties between 1999 and 2019.

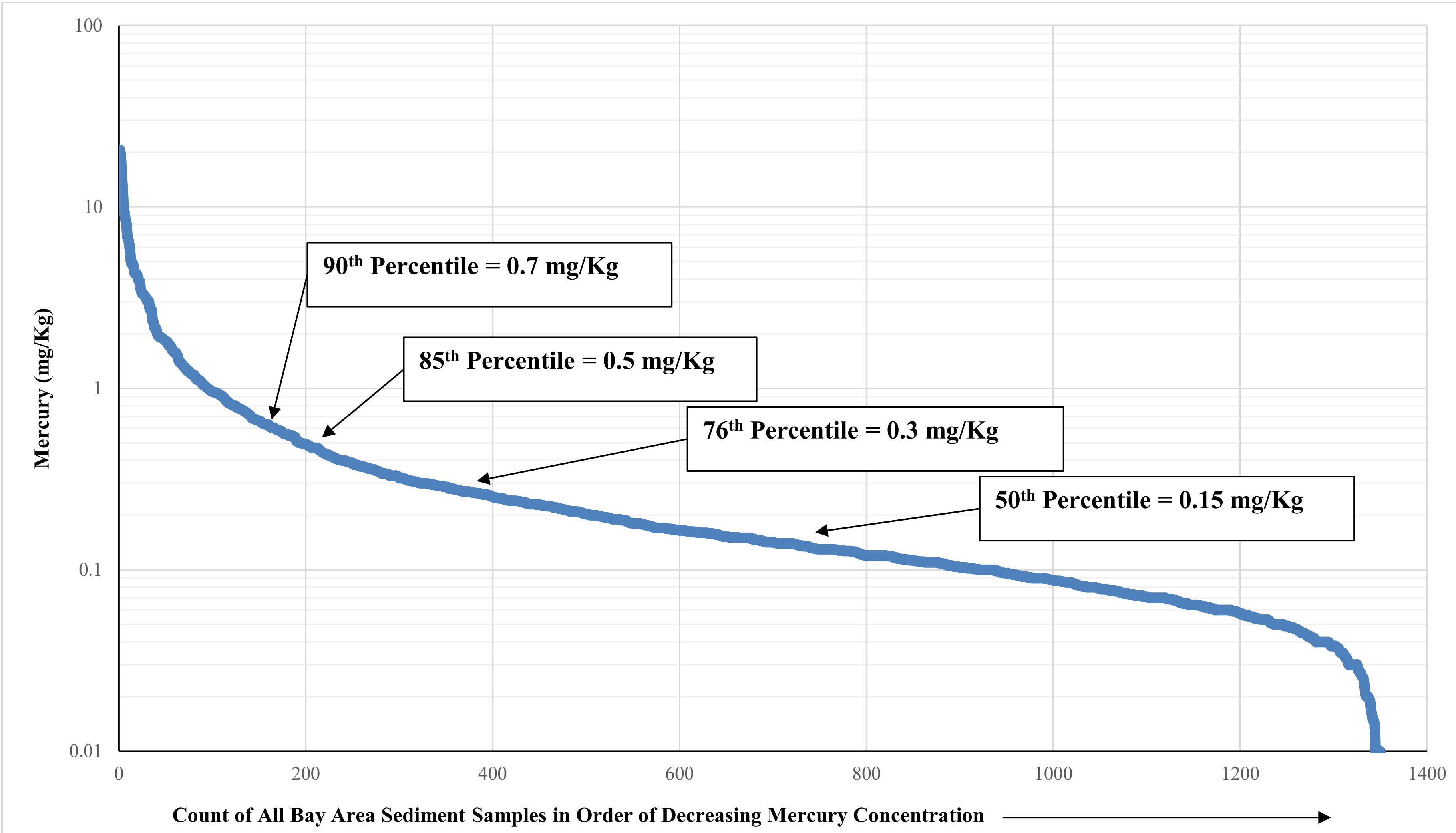

Figure B.2: Total mercury concentrations in sediment collected from streets, stormwater conveyance systems and private properties located in Alameda, Contra Costa, Santa Clara, San Mateo, and Solano Counties between 1999 and 2019.

APPENDIX C
Source Area Investigation and Abatement Guidance

C.1 BACKGROUND

Since 2000, Bay Area stormwater programs have conducted investigations on behalf of MRP Permittees to identify land areas or properties that contribute substantial amounts of PCBs to Bay Area municipal separate storm sewer systems (MS4s). These investigations have largely focused on land areas where industrial land use activities occurred prior to 1980 and continue today (i.e., old industrial land use areas). The *Interim Accounting Methodology for TMDL Loads Reduced Report* (BASMAA, March 2017) described this control measure and defined the methodology that was used for PCBs load reduction accounting during the MRP 2.0 permit term.

The pollutant reduction benefits and costs of conducting source property investigations were examined, along with other stormwater control measures, via the *Clean Watersheds for Clean Bay* (CW4CB) project. The CW4CB project concluded that PCBs source property investigations are much more cost-effective at reducing loads of PCBs than retrofitting old industrial areas with green stormwater infrastructure (GSI). This finding and the pollutant reductions achieved during the MRP 2.0 permit term via this control measure provide an impetus for MRP Permittees to continue source property investigations as a viable control measure for PCBs during MRP 3.0.

The process for conducting source area investigations that would be followed by each stormwater program during MRP 3.0 is presented below.

C.2 SOURCE AREA INVESTIGATION PROCESS

The source area investigation process consists of the four steps outlined below:

1. Identify areas that should be considered for source area investigations;
2. Conduct screening-level investigations in the areas identified in (1) to prioritize these areas as high, moderate, or low-likelihood source areas;
3. Conduct targeted source area investigations in areas prioritized as high or moderate-likelihood source areas in (2) to identify and confirm source areas; and
4. Determine next steps for confirmed source areas.

Each of these steps is described in more detail below.

C.2.1 Step 1: Identify Areas Considered for Source Area Investigations

Identify areas that should be considered for source area investigations as follows:

A. Identify the extent of old industrial land use areas that were present in 2002, the starting date for accounting for POC load reductions;

B. Remove those old industrial land use areas that have already been investigated, referred, and/or abated since 2002;

C. Remove those old industrial land use areas that have undergone redevelopment or GSI retrofit since 2002;

D. Remove those old industrial land use areas that do not drain to an MS4, rather drain directly to the Bay shoreline; and

E. Identify the remaining old industrial land use areas that should be considered for source property investigations by subtracting B, C, and D from A above.

Each countywide stormwater program has implemented this process to identify the total area that will be considered for investigation within each of the five MRP counties.

C.2.2 Step 2: Conduct Screening-level Source Area Investigations

The purpose of screening-level source area investigations is to identify both (1) areas that are likely to contain sources of PCBs, and (2) areas that are unlikely to contain sources of PCBs. This effort will assist Permittees in narrowing the focus for more in-depth, targeted source investigations to those areas that are most likely to contain sources. The screening methods described below are designed to categorize areas at the watershed, MS4 catchment, or individual parcel-scale as high-, moderate-, or low-likelihood source areas according to the following criteria:

- Low-likelihood source areas:
    - No evidence of current or historical use of PCBs; and,
    - all MS4 sediment concentrations and stormwater particle ratios are below 0.5 mg/kg.
- Moderate-likelihood source areas
    - There may be evidence of current or historical use of PCBs; and/or
    - At least one MS4 sediment or stormwater particle ratio between 0.5 and 1.0 mg/kg.
- High-likelihood source areas:
    - There is evidence of current or historical use of PCBs; and/or
    - At least one MS4 sediment or stormwater particle ratio is greater than 1.0 mg/kg.

Screening-level investigation methods may involve any of the following:

- Desktop Analysis. Desktop analysis conducted to gather available information on potential sources of PCBs in a given area or on a specific parcel can also be used to screen areas for further investigation or to remove them from further consideration. This type of screening may include review of current and historic land uses, historical parcel records, contaminated properties databases (e.g., Geotracker and EnviroStor), and aerial photography to identify past and current activities that may be associated with PCBs (e.g., recycling facilities, parcels with large electrical equipment, PCBs manufacturing sites, industrial activities that used PCBs, etc.). Any stormwater or MS4 sediment data collected in the past may also be used as an indicator of likely PCBs sources that warrant further investigation.
- Stormwater Monitoring. Stormwater samples collected at the outlet of a defined drainage area (watershed, MS4 catchment, or individual parcel scale) can be used to screen the entire area that drains to the sampling location; if the PCBs particle ratio in all

stormwater samples is less than 500 ng/g[10], then the entire area draining to that sampling location can be identified as a low-likelihood source area.

- Sediment Monitoring. Suspended sediment samples collected from storm drain infrastructure or a channel that drains a defined area (e.g., a watershed, MS4 catchment, or one or more individual parcels) can be also be used to screen potential source areas. If the PCBs particle ratio in samples collected are less than 0.5 mg/kg, then the area or parcels that drain to the sampling location can be identified as low-likelihood area/parcels.

C.2.3 Step 3: Conduct Targeted Source Area Investigations

Select parcels or smaller areas within areas that are identified in Step 2 as high- and moderate-likelihood source areas may be targeted for more in-depth source investigation. The purpose of a targeted source area investigation is to identify and confirm specific source properties that contribute elevated PCBs to MS4s. Once a source property has been confirmed, Permittees may refer the property to the Regional Water Board for abatement, or the Permittee can oversee property abatement directly. The targeted source area investigation steps are modeled after the CW4CB Source Property Identification and Referral Pilot Projects (BASMAA, 2017). The targeted source area investigation process proceeds through the following four tasks:

1. Records Review. The purpose of the records review is to evaluate available information on specific parcels of interest within an investigation area to identify sources of PCBs. The types of information reviewed may include the following:

    - Site history, cleanup records, or monitoring data available through online databases (i.e., Geotracker and EnviroStor);
    - Cal OES records of PCBs releases from electrical utility equipment;
    - Changes in aerial photos from prior to 1980 and present condition;
    - Outdoor storage, suspected waste areas or ponds;
    - Available stormwater inspection history, including occurrence of PCBs, spills, and stormwater violations on prior inspection reports; and
    - Industrial General Permit (IGP) facility data.

2. Public ROW Surveys / Facility Site Visits. The purpose of public ROW surveys / facility site visits is to verify information obtained during records review, document possible sources, observe sediment migration and flow patterns from parcels of interest to the public ROW, document existing stormwater control measures, and identify potential sample locations. Information documented during public ROW surveys / site visits may include the following:

[10] This value may be adjusted in the future based on the results of the Advanced Data Analysis under development by the Regional Monitoring Program Sources, Pathways, and Loadings workgroup or equivalent analyses conducted by the Permittees.

- Electrical equipment associated with PCBs (e.g., transformers and capacitors);
- Old equipment with hydraulic fluids;
- Outdoor hazardous material/waste storage areas (e.g., tanks, drums), especially with poor housekeeping;
- Signs related to hazardous materials and wastes;
- Recycling/scrap yards (e.g., for automobiles);
- Building demolition activities;
- Unidentified puddles or stains;
- Flow patterns and storm drain structures;
- Existing and potential stormwater control measures;
- Sediment erosion from a property and migration to the street or storm drains;
- Properties that have been redeveloped or are in the process of redevelopment; and
- Redeveloped areas where older exposed soils are available for tracking off site.

The combined results of the records reviews, public ROW surveys / facility site visits are then used to prioritize sampling and develop the sampling plan.

3. Sampling. The purpose of sampling is to confirm if the suspected source area is an actual source of elevated PCBs to the MS4 or is not. Sampling methods may include the collection of sediment in the ROW, and inlet, or the storm drain; and/or stormwater sampling.

4. Identification of Source Areas. This task will review the information gathered throughout the investigation process in order to identify and confirm any source areas. Pollutant concentrations provide the primary means of confirming the identification of source areas. Elevated soil/sediment or stormwater concentrations from samples collected onsite, at the border of a parcel, or at the junction of an onsite underground drainage pipe (lateral) and the MS4 provide the best definitive evidence of whether a property is a source of PCBs to the MS4 or is not. Parcels or areas with PCBs concentrations ≥ 1.0 mg/kg are considered *confirmed source areas* and need no further investigation.

C.2.4 Step 4: Determine Next Steps for Confirmed Source Areas

The options Permittees may pursue for confirmed source areas include the following:

- Submit a referral to the Regional Water Board (and/or other regulatory agency) for follow-up investigation and abatement. The referral process and standard referral form are more fully described in the *Source Control Load Reduction Accounting for Reasonable Assurance Analysis* report (BASMAA, 2020).

- Abate or cause the area to be abated directly, without referral to a regulatory agency. For this option, the City will work directly with the property owner to ensure the property is fully abated and a self-abatement report will be submitted to the Regional

Water Board according to the process outlined in the *Source Control Load Reduction Accounting for Reasonable Assurance Analysis* report (BASMAA, 2020).

- If the investigation conducted in Step 3 does not identify a specific source area for the observed elevated concentrations, then the source area will be considered for the application of other types of control measures.

APPENDIX D
Source Property Referral Form
Source Property Self Abatement Report

PCBs SOURCE PROPERTY REFERRAL FORM

The purpose of this form is to provide the Department of Toxic Substances Control, the United States Environmental Protection Agency (USEPA) or the Regional Water Quality Control Board with sufficient information to require site owner/operators to conduct follow-up investigations and/or PCB cleanup actions.

Referring Agency:

Staff Contact Name:

Phone:

Email Address:

Date of Report:

1. Name of Site:

2. Address City County ZIP:

3. APN(s):

4. Provide a Site Location Map and a Site Diagram showing significant features.
Parcel Area (acres):

5. Current Owner

   Name:

   Address:

   City, County & Zip Code:

   Phone:

   E-mail Address:

   Contact:

   Title:

6. Background: Current Business Operations

   Name:

   Period of Operation:

   Type:

7. Background: Previous Business Operations (if known)

   Name:

   Period of Operation:

   Type:

8. Summarize any available information that may indicate hazardous substances, pollutants, or contaminants OTHER than PCBs have been associated with the site.

9. Describe the known and suspected sources of PCBs at the site.

10. Has sampling or other investigation been conducted in the vicinity of the property to identify it as a source property? Yes No

Specify. For samples collected in the public right-of-way, show the nexus to the subject property as clearly as possible. Attach maps or pictures and coordinates (if applicable).

11. Is the site subject to the industrial general stormwater permit? Yes No

If yes, describe the findings of recent and past stormwater inspections conducted on the site, especially in regard to potential PCB sources.

12. Is there currently a potential for exposure of the community or workers to hazardous substances, pollutants, or contaminants at the site? Yes No

If yes, explain:

13. Are any Federal, State, or Local regulatory agencies involved with the site? Yes No

If yes, provide as much of the information below as known:

Agency	Involvement	Contact Name	Phone Number

14. Provide any other pertinent site information not covered above.

15. Describe enhanced control measures or downstream treatment control measures that will be implemented at the site. The selected enhanced O&M control measure(s) or stormwater treatment must be implemented and maintained during the source property abatement process and should be sufficient to intercept historically deposited sediment in the public right-of-way and prevent additional contaminated sediment from being discharged from the MS4.

Attach: Site Location Map, Site Diagram, and any pertinent sampling & analyses data

SOURCE PROPERTY ABATEMENT REPORT

The purpose of this form is to provide the Regional Water Quality Control Board with sufficient documentation that source property abatement has effectively eliminated the transport of PCBs or mercury offsite and from entering the municipal separate storm sewer system (MS4) infrastructure for all transport mechanisms that apply to the site (e.g., stormwater runoff, wind, vehicle tracking). This documentation shall include information on the type and extent of abatement that has occurred (e.g., have the sources of PCBs to the MS4 been eliminated via capping, paving, walls, plugging/removal of internal storm drains, etc.) and any available water or sediment monitoring data that demonstrates the effective elimination of transport of PCBs offsite into the MS4.

Responsible Agency:

Staff Contact Name:

Phone:

Email Address:

Date of Report:

1. Name of Site:

2. Address City County ZIP:

3. APN(s):

4. Provide a Site Location Map and a Site Diagram showing significant features. Parcel Area (acres):

5. Current Owner

   Name:

   Address

   City, County & Zip Code:

   Phone:

   E-mail Address:

6. Describe Current (Post-Abatement) Site Operations/Land Use.

7. Describe Previous Business Operations / Sources of PCBs or Mercury (if known).

8. Summarize any available information that may indicate hazardous substances, pollutants, or contaminants OTHER than PCBs have been associated with the site.

9. Has sampling or other investigation been conducted in the vicinity of the property to identify it as a source property? Yes No

Specify. For samples collected in the public right-of-way, show the nexus to the subject property as clearly as possible. Attach maps or pictures and coordinates (if applicable).

13. Were any Federal, State, or Local regulatory agencies involved with the site abatement?

Yes No

If yes, provide as much of the information below as known:

Agency	Involvement	Contact Name	Phone Number

14. Describe the type and extent of abatement that has occurred.

15. Describe how the property abatement has effectively eliminated the transport of PCBs offsite and from entering the MS4 infrastructure for all transport mechanisms that apply to the site (e.g., stormwater runoff via sheet flow or through a storm drain, wind, or vehicle tracking).

16. Describe any available water or sediment monitoring data that demonstrates the effective elimination of transport of PCBs offsite into the MS4.

Attach: Site Location Map, Site Diagram, and any pertinent sampling & analyses data

APPENDIX E

BASMAA Regional Stressor/Source Identification (SSID) Project Final Report PCBs from Electrical Utilities in San Francisco Bay Area Watersheds

PCBs from Electrical Utilities in San Francisco Bay Area Watersheds Stressor/Source Identification (SSID) Project

Prepared in support of provision C.8.e.iii of

NPDES Permit # CAS612008

Project Report

BASMAA

Bay Area Stormwater Management Agencies Association

Prepared for:

Bay Area Stormwater Management Agencies Association (BASMAA)

Prepared by:

EOA inc.

FINAL June 30, 2020

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List of Acronyms

ACCWP	Alameda Countywide Clean Water Program
Bay	San Francisco Bay
Bay Area	San Francisco Bay Area
Basin Plan	San Francisco Bay Basin (Region 2) Water Quality Control Plan
BASMAA	Bay Area Stormwater Management Agencies Association
BMPs	Best Management Practices
BOD	BASMAA Board of Directors
Cal OES	California Office of Emergency Services
CCCWP	Contra Costa Clean Water Program
CCR	California Code of Regulations
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CPUC	California Public Utilities Commission
CPAU	City of Palo Alto Utilities
CWA	Clean Water Act
dba	Doing Business As
DTSC	California Department of Toxic Substances Control
FERC	Federal Energy Regulatory Commission
FSURMP	Fairfield-Suisun Urban Runoff Management Program
kg/yr	kilogram per year
lb.	Pound
MRP	Municipal Regional Permit
MS4	Municipal Separate Storm Sewer System
MT	Metric Tons
NOI	Notice of Intent
NPDES	National Pollution Discharge Elimination System

PCBs	Polychlorinated Biphenyls
RMC	Regional Monitoring Coalition
ROW	right-of-way
SCVURPPP	Santa Clara Valley Urban Runoff Pollution Prevention Program
SVP	Silicon Valley Power
OFEE	Oil-filled Electrical Equipment
PG&E	Pacifica Gas and Electric Company
ppm	parts per million
PMT	BASMAA Project Management Team
RQ	reportable quantity
RCRA	Resource Conservation and Recovery Act
Regional Water Board	San Francisco Bay Regional Water Quality Control Board
SMCWPPP	San Mateo Countywide Water Pollution Prevention Program
SOP	Standard Operating Procedure
SOW	Scope of Work
SPCC Plan	Spill Prevention Control and Countermeasure Plan
SSID	Stressor/Source Identification
TMDL	Total Maximum Daily Load
TSCA	Toxic Substances Control Act
UCMR	Urban Creeks Monitoring Report
US EPA	United States Environmental Protection Agency
VFWD	Vallejo Flood and Wastewater District
WQOs	Water Quality Objectives
WQS	Water Quality Standard

1.0 Introduction

This project report supports the requirement to implement a Stressor/Source Identification (SSID) Project as required by Provision C.8.e.iii of the San Francisco Bay (Bay) Region Municipal Regional Stormwater National Pollutant Discharge Elimination System (NPDES) Stormwater Permit (MRP) (Order No. R2-2015-0049, SFRWQCB 2015). Per MRP Provision C.8.e.ii, the Bay Area Stormwater Management Agencies Association (BASMAA) Regional Monitoring Coalition (RMC)[1] members are working to initiate eight SSID projects during the five-year term of the MRP (i.e., 2016 – 2020). The RMC programs have agreed that seven SSID projects will be conducted to address local needs (for Santa Clara, Alameda, San Mateo, Contra Costa, Fairfield/Suisun and Vallejo counties), and one project (this project) will be conducted regionally (on behalf of all RMC members). SSID projects follow-up on monitoring conducted in compliance with MRP Provision C.8 (or monitoring conducted through other programs) with results that exceed trigger thresholds identified in the MRP. Trigger thresholds are not necessarily equivalent to Water Quality Objectives (WQOs) established in the San Francisco Bay Basin (Region 2) Water Quality Control Plan (Basin Plan) (SFRWQCB, 2017) by the San Francisco Bay Regional Water Quality Control Board (Regional Water Board); however, sites where triggers are exceeded may indicate potential impacts to aquatic life or other beneficial uses.

BASMAA submitted a Regional SSID Work Plan to the Regional Water Board in March 2019. The SSID work plan described the steps that would be taken to investigate sources of polychlorinated biphenyls (PCBs) from electrical utility equipment in watersheds draining to the San Francisco Bay Basin. The Work Plan focused on Pacific Gas and Electric Company (PG&E), the largest electrical utility operating in the MRP area, and the only utility that is not owned by a municipality. The project team developed a letter requesting assistance from the Regional Water Board and outlining the specific data that are needed from PG&E to complete this project. The letter was ultimately approved by the BASMAA Board of Directors (BOD) and sent to the Regional Water Board in June 2019. The letter specifically asked the Regional Water Board to use their regulatory authority under Section 13267 of the Clean Water Act to compel PG&E to provide the needed data. However, PG&E is currently in bankruptcy proceedings, and the outcomes of that process have not yet been determined. As such, the Regional Water Board has delayed sending a “13267 letter” to PG&E, and is currently considering other options for moving forward with PG&E on this issue.

The BASMAA MRP 3.0 C.11/12 workgroup met with and discussed the issue of PCBs in electrical utility equipment with representatives of several municipally-owned electrical utilities in the permit area. Based on the information gained during these discussions, and given the current situation with PG&E, BASMAA requested the project team develop a revised scope of work (SOW) for Task 2 of the Regional SSID Work Plan.

BASMAA submitted a Regional SSID Revised Scope of Work to address PCBs in electrical utility applications in March 2020 to the Regional Water Board. The revised SOW would

[1] The BASMAA RMC is a consortium of San Francisco Bay Area municipal stormwater programs that joined together to coordinate and oversee water quality monitoring and several other requirements of the MRP. Participating BASMAA members include the Alameda Countywide Clean Water Program (ACCWP), Contra Costa Clean Water Program (CCCWP), Fairfield-Suisun Urban Runoff Management Program (FSURMP), San Mateo Countywide Water Pollution Prevention Program (SMCWPPP), Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP), and City of Vallejo and Vallejo Flood and Wastewater District (VFWD).

implement the Regional SSID work plan, but would focus on municipally-owned electrical utilities in the San Francisco Bay Area (Bay Area), rather than PG&E. The Regional Water Board staff agreed[2] to a revised approach which focused on data gathering from municipally-owned electrical utilities. The Regional Water Board staff further acknowledged that revision of the work plan submitted in March 2019 is not needed to satisfy SSID project requirements. They also agreed the Regional SSID project will be considered complete based on the outcomes of the work described in this report, which focuses on data from municipally-owned electrical utilities instead of PG&E.

BASMAA retained EOA, Inc., of Oakland, CA to develop the work plan and implement the SSID project under the direction of a BASMAA Project Management Team (PMT). All work on this project is supported by funding provided by BASMAA.

1.1 Overview of SSID Project Requirements

SSID projects focus on taking action(s) to identify and reduce sources of pollutants, alleviate stressors, and address water quality problems. MRP Provision C.8.e.iii requires SSID projects to be conducted in a stepwise process, as described below.

Step 1: Develop a work plan that includes the following elements:

- Define the water quality problem (e.g., magnitude, temporal extent, and geographic extent) to the extent known;
- Describe the SSID project objectives, including the management context within which the results of the investigation will be used;
- Consider the problem within a watershed context and examine multiple types of related indicators, where possible (e.g., basic water quality data and biological assessment results);
- List potential causes of the problem (e.g., biological stressors, pollutant sources, and physical stressors);
- Establish a schedule for investigating the cause(s) of the trigger stressor/source which begins upon completion of the work plan. Investigations may include evaluation of existing data, desktop analyses of land uses and management actions, and/or collection of new data; and
- Establish the methods and plan for conducting a site-specific study (or non-site specific if the problem is widespread) in a stepwise process to identify and isolate the cause(s) of the trigger stressor/source.

Step 2: Conduct SSID investigations according to the schedule in the work plan and report on the status of the SSID investigation annually in the Urban Creeks Monitoring Report (UCMR) that is submitted to the Regional Water Board on March 31 of each year.

[2] Per Jan O'Hara at the BASMAA Monitoring and Pollutants of Concern Committee meeting held on March 3, 2020

Step 3: Follow-up actions:

- If it is determined that discharges to the municipal separate storm sewer system (MS4) contribute to an exceedance of a water quality standard (WQS) or an exceedance of a trigger threshold such that the water body's beneficial uses are not supported, submit a report in the UCMR that describes Best Management Practices (BMPs) that are currently being implemented and additional BMPs that will be implemented to prevent or reduce the discharge of pollutants that are causing or contributing to the exceedance of WQS. The report must include an implementation schedule.

- If it is determined that MS4 discharges are not contributing to an exceedance of a WQS, the SSID project may end. The Executive Officer must concur in writing before an SSID project is determined to be completed.

- If the SSID investigation is inconclusive (e.g., the trigger threshold exceedance is episodic or reasonable investigations do not reveal a stressor/source), the Permittee may request that the Executive Officer consider the SSID project complete.

1.2 SSID Project Report Organization

Step 1 of the SSID process described above in Section 1.1 was completed with the submittal of the BASMAA Regional SSID Work Plan in March 2019 and subsequent Revised Scope of Work (SOW) in March 2020.

The Work Plan and revised SOW identified the following tasks:

1. Conduct desktop analysis of data from Bay Area electrical utilities;
2. Develop Source Control Framework that summarizes the results of the desktop analysis and recommends approach to manage and control releases;
3. Develop data inputs that can be used to account for load reductions from new source control measures;
4. Develop Report that addresses management questions.

As described above, the revised SOW would implement the Regional SSID work plan, but would focus on municipally-owned electrical utilities in the Bay Area, rather than PG&E.

This Regional SSID Project Report provides background information, describes the work conducted in the desktop analysis, and proposes a source control framework to account for past load reductions and to further reduce ongoing loads of PCBs from electrical utility practices.

2.0 Problem Definition, Study Objectives, and Regulatory Background

2.1 Background

PCBs are commercially synthesized oily compounds consisting of carbon, hydrogen, and chlorine atoms. There are 209 possible arrangements of the atoms in PCB compounds. These are referred to as the 209 PCB congeners. PCBs were first manufactured in the United States (US) in 1929 and US production peaked in 1970. PCBs are non-flammable, chemically stable, have a high boiling point, and have electrical insulating properties. Therefore, they were used in hundreds of industrial and commercial applications. Most PCBs were manufactured as a mixture of several individual PCB congeners. The most common name for these mixtures in the US was the Aroclor series produced by Monsanto Company. There were more than ten common Aroclor mixtures.

Due to concern about their persistence in the environment, toxicity, and potential to cause cancer, the US Environmental Protection Agency (US EPA) banned the production and new use of PCBs in 1979. However, PCBs continue to be found in water and sediment collected from the San Francisco Bay, and urban stormwater runoff has been identified as a major source of PCBs to the Bay. Thus, PCBs are considered a legacy pollutant.

2.2 Problem Definition

Fish tissue monitoring in the Bay has revealed the bioaccumulation of PCBs in Bay sportfish at levels thought to pose a health risk to people consuming these fish. As a result, in 1994, the state of California issued a sport fish consumption advisory cautioning people to limit their consumption of fish caught in the Bay. The advisory led to the Bay being designated as an impaired water body on the Clean Water Act (CWA) "Section 303(d) list" due to elevated levels of PCBs. In response, in 2008, the Regional Water Board adopted a Total Maximum Daily Load (TMDL) water quality restoration program targeting PCBs in the Bay[3]. The general goals of the TMDL are to identify sources of PCBs to the Bay, implement actions to control the sources, restore water quality, and protect beneficial uses.

The PCBs TMDL estimates baseline loads to the Bay from various source categories. The largest source category, at 20 kilograms (kg) per year, was estimated to be stormwater runoff. This category includes all sources to small tributaries draining to the Bay. The PCBs TMDL indicates that a 90% reduction in PCBs from stormwater runoff to the Bay is needed to achieve water quality standards and restore beneficial uses. The TMDL states that the wasteload allocation for stormwater runoff of 2 kg per year shall be achieved within 20 years (i.e., by March 2030). The PCBs TMDL is being implemented through NPDES permits to discharge stormwater issued to municipalities and industrial facilities in the Bay Area (e.g. the MRP).

This SSID project was triggered by monitoring conducted over the past 15+ years by BASMAA members that demonstrates municipal stormwater runoff is a source of PCBs to the Bay. PCBs were historically used in many applications, including electrical utility equipment and caulks and sealants used in building materials. However, the greatest use by far was in electrical

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[3] The PCBs TMDL was approved by the US Environmental Protection Agency (US EPA) on March 29, 2010 and became effective on March 1, 2010.

equipment such as transformers and capacitors (McKee et al. 2006). Existing electrical utility equipment, which is often located in the public right-of-way (ROW), may still contain PCBs that can be released to the MS4 when spills and leaks occur. Due to past leaks or spills of PCBs oil from electrical equipment, properties owned and operated by electrical utilities may potentially have elevated concentrations of PCBs in surrounding surface soils that can be released to the MS4. Because the cumulative releases of PCBs-laden soils from these properties, and spills or leaks of PCBs oils from electrical equipment to MS4s across the Bay Area may occur at levels that exceed the 2 kg per year TMDL waste load allocation, this potential source of PCBs may limit the ability of municipalities to meet the goals of the PCBs TMDL for the Bay. Therefore, this potential source warrants further investigation.

2.3 SSID Project Objectives

The overall goal of this SSID project is to investigate electrical utility equipment as a source of PCBs to urban stormwater runoff and identify appropriate actions and control measures to reduce this source. Building on the information presented by SCVURPPP (2018), this project is designed to achieve the following three objectives:

1. Gather information from Bay Area municipally-owned utility companies to improve estimates of current PCBs loadings to MS4s from electrical utility equipment, and document current actions conducted by utility companies to reduce or prevent release of PCBs from their equipment;

2. Identify opportunities to improve municipal spill response, cleanup protocols, or other programs designed to reduce or prevent releases of PCBs from electrical utility equipment to MS4s;

3. Develop an appropriate mechanism for municipalities to ensure adequate clean-up, reporting and control measure implementation to reduce urban stormwater loadings of PCBs from municipally-owned electrical utility equipment.

In addition, an outcome of the project was to provide data inputs that could be used in the accounting methodology presented in the BASMAA Source Control Load Reduction Accounting Methodology and Reasonable Assurance Analysis (RAA) (BASMAA, 2020). The methodology was developed to account for PCBs load reductions that may be achieved due to source control measures implemented through a regional control measure program for electrical utilities.

2.4 Management Questions

This SSID project work plan identified a number of key management questions regarding electrical utility applications as sources of PCBs to MS4s to address, including:

1. What is the current magnitude and extent of PCBs stormwater loadings from electrical utility equipment and operations in the San Francisco Bay Area region?

2. What aspects of equipment or operational procedures should electrical utilities be required to report to the Regional Water Board?

3. Are improvements to spill and cleanup control measures needed to reduce water quality impacts from the release of PCBs in electrical utility equipment?

4. Are additional proactive management practices needed to reduce releases of PCBs from electrical utility equipment?
5. What are the PCBs load reductions that can be achieved through implementation of a regional reporting and control measure program?

This SSID project was implemented to provide the information needed to address these management questions.

3.0 Background

3.1 Study Area

The study area for this SSID project is the portion of the San Francisco Bay Area region subject to the MRP. This section provides an overview of electrical utility systems and companies currently operating in the study area, and describes how and where PCBs are used within those systems.

Electrical utilities produce or buy electricity from generating sources, and then distribute that electricity to users through two networks: the transmission system and the distribution system. The **transmission system** carries bulk electricity at high voltages, often across long distances, directly from generation sources to substations via high voltage power lines. Substations connect the transmission and distribution systems. Substations may increase the voltage from nearby generating facilities for more efficient transmission over long distances or lower the voltage for transfer to the distribution system. Electricity at a typical substation flows from incoming transmission lines, to circuit breakers, to transformers (which step down the voltage), to voltage regulators and cut out switches (which protect the system from overvoltage), and finally to outgoing distribution lines.

The **distribution system** delivers lower voltage electricity from substations directly to homes and businesses over shorter distances. This system includes pole-mounted equipment, equipment in underground vaults, and aboveground equipment on cement pads that are often in green boxes in the public ROW. This equipment is smaller, but more numerous in terms of the number of units.

Electrical utility equipment and facilities in both the transmission and distribution systems are distributed across the entire Bay Area region. In the past, PCBs were routinely used in electrical utility equipment that contained dielectric fluid as an insulator. This is because prior to the 1979 PCBs ban, dielectric fluid was typically formulated with PCBs due to a number of desirable properties they have (e.g., high dielectric strength, thermal stability, chemical inertness, and non-flammability). Electrical equipment containing dielectric fluid is typically identified as Oil-Filled Electrical Equipment (OFEE). Any OFEE that contained PCBs in the past could still potentially be in use and contain PCBs today. The most common types of OFEE that may contain PCBs are transformers, capacitors, circuit breakers, reclosers, switches in vaults, substation insulators, voltage regulators, load tap changers, and synchronous condensers (PG&E 2000).

In the Bay Area, there are eight electric utility companies operating as of February 2015 (State Energy Commission 2015):

<u>Investor-Owned Utilities (IOUs)</u>

1. Pacific Gas and Electric Company (PG&E)
   77 Beale Street
   San Francisco, CA 94105
   (415) 973-7000 (tel)

<u>Publicly Owned Load Serving Entities (LSEs) and Publicly Owned Utilities (POUs)</u>

2. Alameda Municipal Power
   2000 Grand Street

Alameda, CA 94501-0263
510.748.3905 (tel)

3. CCSF (also called the Power Enterprise of the San Francisco Public Utilities Commission)
   1155 Market Street, 4th Floor
   San Francisco, CA 94103
   209.989.2063 (tel)
4. City of Palo Alto, Utilities Department
   P.O. Box 10250
   Palo Alto, CA 94303
   650.329.2161 (tel)
5. Pittsburg Power Company Island Energy-City of Pittsburg,
   65 Civic Drive
   Pittsburg, CA 94565-3814
   925.252.4180 (tel)
6. Port of Oakland
   530 Water Street, Ste 3
   Oakland, CA 94607-3814
   510.627.1100 (tel)
7. Silicon Valley Power (SVP) - City of Santa Clara
   1500 Warburton Avenue
   Santa Clara, CA 95050
   408.615.2300 (tel)

Community Choice Aggregators

8. Marin Clean Energy (MCE)
   781 Lincoln Ave Ste 320
   San Rafael, CA 94901-3379
   888.632.3674 (tel)

PG&E is by far the largest electrical utility company in the Bay Area. PG&E is an investor-owned company that is not under the jurisdiction of any Bay Area municipality[4]. Three small publicly-owned utilities in the Bay Area (Alameda Municipal Power, City of Palo Alto Utilities Department, and Silicon Valley Power owned by the City of Santa Clara) maintain their own substations and distribution lines. The other public utilities partner with PG&E to deliver energy through PG&E's equipment. PG&E owns and operates several hundred electrical substations in the Bay Area, in addition to the smaller electrical utility equipment that is widely disbursed throughout urbanized areas and along rural corridors (e.g., small transformers on utility poles or in utility boxes). The total number of pieces of equipment that is in use across the Bay Area and that contains PCBs is not known but is likely in the range of tens to hundreds of thousands (see Section 3.3).

[4] PG&E is regulated by the California Public Utilities Commission (CPUC) and the Federal Energy Regulatory Commission (FERC).

3.2 Regulatory Controls on PCBs in Electrical Utility Equipment

In California, both federal and state laws regulate in-use PCBs, PCB wastes, and PCB clean-up. At the federal level, the Toxic Substances Control Act (TSCA) and the Resource Conservation and Recovery Act (RCRA) are used to regulate PCBs and PCB wastes. PCB cleanup sites may also be subject to regulation by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). In addition, discharges from electrical utility applications are regulated under the NPDES program authorized by the CWA and implemented through the State and Regional Water Quality Control Boards. State PCB regulations are primarily implemented under the California Health and Safety Code.

TSCA is the primary regulatory tool that addresses most aspects of PCB management and cleanup. Passed into law in 1976, TSCA banned the continued manufacture and commercial distribution of PCBs in the US after July 2, 1979, and prohibited the continued use of PCBs outside of totally enclosed systems. TSCA also governs the ongoing management of PCBs that remain in use that are present at 50 ppm or greater, including labeling, handling, distribution, storage, cleanup of contaminated properties, spill response and disposal (Title 40 CFR Part 761). The federal TSCA regulations are enforced by the US EPA.

In addition to the TSCA regulations, other federal regulations under authority of the Clean Water Act are in place to prevent oil spills from reaching navigable waters, and provide for appropriate and efficient cleanup of any oil spills that do occur (40 CFC part 112). These regulations require Spill Prevention Control and Countermeasure (SPCC) Plans for facilities that could potentially discharge oils to navigable waters (including storm drains and drainage ditches) if the facility also meets one or more of the following criteria: aboveground oil storage > 1,230 gallons; and/or underground oil storage > 42,000 gallons; and/or storage of containerized PCB-contaminated liquid wastes for disposal between 50 and 500 ppm. Electrical utility substations may fall into the category of facilities that require such SPCC plans.

In California, hazardous waste regulations detailed in the California Code of Regulations (CCR) Title 22 are more stringent for PCBs than federal rules. CCR Title 22 designates oils or other liquids containing PCBs concentrations ≥ 5 ppm as non-RCRA hazardous waste requiring special handling and disposal. The California Department of Toxic Substances Control (DTSC) enforces the additional hazardous waste rules that apply to PCBs less than 50 ppm, including spill cleanup, disposal and reporting requirements. DTSC also regulates closure requirements for PCB sites under CERCLA.

3.2.1 PCB Classification and Labeling Requirements

Under both federal and state regulations, all required management of in-use PCBs and PCB-containing equipment, including labeling, disposal, site cleanup, spill response, and reporting is based on classifications of PCB concentrations. Table 3.1 defines the federal and state PCB classifications.

- TSCA regulations apply to PCBs 50 ppm or greater, while California regulations apply to PCBs between 5 and 50 ppm. Under TSCA, PCB concentrations greater than 500 ppm are classified as high PCBs, while PCB concentrations between 50 ppm and 500 ppm are classified as low PCBs. PCB concentrations below 50 ppm are classified by TSCA as non-PCB.

- In California, PCB concentrations in liquids between 5 ppm and < 50 ppm are classified as non-RCRA hazardous waste and governed by state regulations.
- If PCB concentrations are not known, neither federal nor state regulations require testing of in-use equipment or materials for PCB concentrations to determine the appropriate classification. Instead, a number of assumptions are applied to determine the appropriate PCBs classification.

Table 3.1 Current Federal and State Regulatory Classifications of PCBs Concentrations.

PCBs Concentration (known or assumed)	Label	Classification	Regulatory Requirements
Federal Requirements			
≥ 500 ppm (in original source)	PCB	TSCA - High PCB Concentration	Waste remediation required by federal law
50 to < 500 ppm (in original source)	PCB-Contaminated	TSCA - Low PCB Concentration	Waste remediation required by federal law
> 0 to < 50 ppm	Non-PCB	Non-PCB	No waste remediation required
0 ppm	No PCBs	Contains no PCBs, and was manufactured after July 1, 1978	No waste remediation required
State Requirements			
≥ 5 ppm (liquid) ≥ 50 ppm (solids)	PCB-Contaminated	California Hazardous Waste	Waste remediation required by State Law
< 5 ppm (liquid) < 50 ppm (solid)	Non-PCB	California Non-PCB	No waste remediation required

PCB-containing equipment is required to be labeled according to its PCB classification. When removed from service, all transformers, large capacitors (high and low voltage), and voltage regulators that are known or assumed to have PCB concentrations equal to or greater than 500 ppm at the time of manufacture require a "PCB" label. Other electrical equipment known or assumed to contain PCBs between 50 and <500 ppm are labeled according to the federal regulations as "PCB-Contaminated". In California, equipment determined to have PCBs < 5 ppm can be labeled as "Non-PCB"; however, because federal regulations were enacted prior to state regulations, some "Non-PCB" labels may have been applied to equipment that fit the non-PCB category for federal regulations (< 50 ppm). This lends uncertainty to the "Non-PCB" label if other information is not also available. Electrical equipment that was manufactured after July 1, 1978, and that does not contain any concentration of PCBs can be labeled as "No PCBs".

3.2.2 Spill Response and Site Cleanup

Both state and federal regulations require cleanup of releases of hazardous materials. As required under both federal and state regulations, the appropriate response to a PCB release is dictated by the known or assumed PCB classification of the equipment responsible for the release. Concentrations are determined based on the source of the release, not on the spilled concentration. For PCBs and PCB-contaminated materials that are 50 ppm PCBs or greater, federal regulations under TSCA govern spill response and cleanup. TSCA requires spill cleanup for releases from equipment or materials that are classified as low or high PCBs (i.e., ≥ 50 ppm PCBs). California hazardous waste regulations require spill cleanup and reporting for releases of PCB-contaminated liquids that fall below the federal regulations (i.e., ≥ 5 ppm but < 50 ppm). Equipment labels are used to identify PCBs and PCB-containing equipment. However, if equipment labels are not present and/or do not provide full information, assumptions about PCB concentrations are often necessary during the initial spill response. For example, any release of untested mineral oil from electrical equipment is assumed to be PCB-contaminated per federal regulations (i.e., ≥ 50 ppm but < 500 ppm).

The first step when a hazardous material release occurs is notification. Under both federal and state rules, the responsible party is required to immediately notify the California Office of Emergency Services (Cal OES) state warning center hotline, and/or 911 when a hazardous material release occurs. This initial reporting is typically a verbal notification (i.e., by telephone). Materials that are 50 ppm PCBs or greater are considered hazardous per federal regulations and liquids that are 5 ppm PCBs or greater are considered hazardous per state regulations. Therefore, any released liquids that are 5 ppm PCBs or greater should be reported to Cal OES.

TSCA hazardous materials spill cleanup requirements (i.e., for releases of PCBs ≥ 50 ppm) are summarized here:

- Low PCB Concentrations (< 500 ppm): excavate all soil within the spill area and backfill with clean soil. Double wash/rinse solid surfaces.
- High PCB Concentration (≥ 500 ppm): notify National Response Center; cordon off the area with a minimum 3-ft buffer and post warning signs; document and record area of visible contamination; excavate all soil within the spill area and backfill with clean soil. Remove all contaminated porous surfaces (e.g., wood asphalt, cement, concrete, etc.). Double wash/rinse non-porous solid surfaces; properly dispose of all PCBs or PCB-contaminated materials from the cleanup site (e.g., soils, solvents, rags, etc.);
- Soils must be remediated to background levels (i.e., detection limits) where practicable.

Federal and state regulations also restrict the allowable concentrations of PCBs remaining in any post-cleanup soils and/or materials, based on the risk categories identified in Table 3.2. For example, in low occupancy areas (i.e., restricted access areas such as electrical substations), PCBs must be below 25 ppm, or the area can have up to 50 ppm PCBs if the appropriate notification is posted at the site. In high occupancy areas (e.g., unrestricted access areas), PCBs must be below 10 ppm. Clean fill used to replace soil removed during the cleanup process must contain less than 1 ppm PCBs. (Note that all of these allowable remaining concentrations are potentially above the thresholds required to meet TMDL goals.) Post cleanup verification sampling is required only for high concentration spills and low-concentration spills involving 1 pound (lb.) or more of PCBs by weight (>270 gallons of untested mineral oil)[5].

Table.3.2 Federal and State Regulatory Classifications of PCB Concentrations and Cleanup Levels.

Risk Category	Allowable PCBs Concentration
PCB waste remediation required	≥ 50 ppm in original source
Low Human health risk from direct exposure	< 50 ppm
High occupancy areas (i.e., non-restricted access areas)	≤ 10 ppm in remaining material
Low occupancy areas (i.e., restricted access areas, such as electrical substations) Low occupancy areas IF the area contains a label or other visible notification of the contamination Low occupancy areas with a cap	≤ 25 ppm in remaining material ≤ 50 ppm in remaining material 25 to < 100 ppm in remaining material
Clean fill	< 1 ppm

In addition, as required by US EPA regulations to prevent oil pollution (40 CFR, Part 112 and 761), utilities must prepare Spill Prevention Control and Countermeasure (SPCC) Plans for facilities that could potentially discharge oils to navigable waters (including storm drains and drainage ditches). SPCC plans are prepared if the facility also meets one or more of the following criteria: aboveground oil storage > 1,230 gallons; and/or underground oil storage > 42,000 gallons; and/or storage of containerized PCB-contaminated liquid wastes for disposal between 50 and 500 ppm. The purpose of the SPCC Plan is to ensure oil spills are minimized, and if any oil spills do occur, to prevent spilled oils from leaving the property and provide maximum cleanup efficiency.

3.2.3 Spill Reporting

In addition to the initial verbal notification, both state and federal regulations may also require submission of follow-up written reports for releases of hazardous materials that are at or above the federal reportable quantities (RQs), or for discharges of oil to navigable waters. For PCBs, the federal RQ is 1 lb. (0.454 kg), while for oil spills, the federal RQ is 42 gallons. Thus, under federal regulations, a follow-up written report must be submitted for any release of 1 lb. or more of PCBs at concentrations ≥ 50 ppm, or for “Non-PCBs” mineral oil spills of 42 gallons or more.

[5] See 40 CFR 761 Subpart G PCB Spill Cleanup Policy for post cleanup verification sampling requirements. EPA provides guidance for sampling in *Verification of PCB Spill Cleanup by Sampling and Analysis* (EPA 560/5-85-026 August 1987), *Field Manual for Grid Sampling of PCB Spill Sites to Verify Cleanup* (EPA-560/5-86-017 May 1986), and *Wipe Sampling and Double Wash and Rinse Cleanup as Recommended by the Environmental Protection Agency PCB Spill* Cleanup Policy (EPA Revised and Clarified on April 18, 1991).

In California, state regulations only require submission of follow-up written reports if the amount of the hazardous material released is at or above the federal RQ.

Spill reporting requirements for releases of 1 lb. or more of PCBs ≥ 50 ppm are detailed here:

- Identification of the source
- Spill date and time (actual or estimated)
- Clean-up date and time completed or terminated
- Identification of spill locations and contaminated material/surfaces, including identification of restricted access or non-restricted access location
- Pre-clean-up sampling data used to establish spill boundaries, if required
- Description of solid surfaces cleaned
- Depth of soil excavation and quantity of soil removed
- Post-clean-up sampling data
- Estimated cost of clean-up (not required)

3.2.4 Regulation of Utility Vault Discharges

There are additional regulatory requirements for short-term intermittent discharges from electrical utility vaults to surface waters of the U.S. An electrical utility vault is an underground room that provides access to subterranean electrical equipment, which may include PCB transformers or other PCB-containing equipment. These are commonly found throughout the electrical system across the Bay Area. Water may collect in these vaults, requiring utility companies to dewater subsurface vaults and underground structures to protect equipment, and provide safe worker conditions for installation, maintenance, or repair of equipment. Compliance with a general NPDES permit is required for these discharges. In California, the General NPDES permit is issued by the California State Water Resources Control Board (Order WQ 2014-0174-DWQ). To be covered under the general permit, a utility company must submit an application to both the State Water Board and their Regional Water Quality Control Board. The permit application includes a Notice of Intent (NOI) and a Pollution Prevention Plan. PG&E has applied for coverage under the General Permit and PG&E's most recent Pollution Prevention Plan submitted to the San Francisco Bay Regional Water Quality Control Board (Region 2) in compliance with the general permit requirements is available on the State Water Board website (https://www.waterboards.ca.gov/water_issues/programs/npdes/docs/utilityvaults/ppplans/pger2_noi_ppp.pdf). It is estimated that approximately 150 to 200 utility vaults are dewatered in the San Francisco Bay Region each year. The State Water Board's website showing utilities that have applied for coverage under the General Permit did not identify any other electrical utilities, other than PG&E, in the San Francisco Bay Region (Region 2).

Regulation of utility vault discharges is included in this section because unplanned spills or releases from PCBs equipment within a vault may occur due to equipment failure. However, although utility vault discharges could potentially result in release of PCBs, chemical analysis of the liquid in the vault is only required at vaults discharging > 10,000 gallons. Instead, if the vault contains equipment from prior to January 1, 1985 and there is any noticeable oil or sheen, the water is containerized and hauled offsite for analysis and disposal. At all other vaults, liquid samples are collected in a jar, allowed to sit for 5 minutes, and then the appearance (color/opacity) of the liquid in the jar is compared to pictures of three example sample jars that vary in the levels of contamination from green (low contamination) to red (high contamination). The appropriate disposal method for the liquid from the vault is determined by the appearance of the sample. If the sample collected looks similar to the green zone samples, then the liquid from the vault can be discharged through a filter sock into the storm drain or waterway. If the sample collected looks similar to the red zone sample, then the liquid from the vault must be collected and disposed of off-site. This qualitative evaluation provides no information on PCB concentrations that may be present in the liquid.

During the first year of coverage under the general NPDES permit, in compliance with the Notice of Applicability (dated September 22, 2016), PG&E collected samples at fifteen of their utility vault dewatering projects. Samples were analyzed for PCBs using EPA Method 1668. The monitoring results were summarized in an email from Regional Water Board staff. PCBs were detected in 11 out of 15 samples. In samples with detections, PCBs concentrations ranged from 0.5 ng/L to 3.4 ng/L.

3.2.5 Chemical Analysis Methods for PCBs

For compliance purposes, TSCA regulations recommend the use of EPA Method 8082 (i.e., the "Aroclor Method") to determine PCB concentrations with a quantifiable level of detection at 2 ppm. Aroclors are the most common PCB formulations that were produced and used commercially in the US. Aroclors are composed of 1 to 7 primary congeners, plus trace levels of other congeners. EPA Method 8082 identifies and quantifies total PCB concentrations based on comparison with the gas chromatograph patterns (referred to as fingerprints) for known Aroclor formulations. Although widely used for determination of PCB concentrations since the 1970's, this method has a number of limitations.

- First, PCBs in a given sample may not match up well with the Aroclor standards that are used for comparison in the analysis. Typically, a group of five to seven Aroclors are used as technical standards. While these are selected to represent the most commonly used formulations, there were many more Aroclor formulations that were produced and used over the years, including slight variations in the formulations produced from year to year. While Aroclors represent the largest mass of PCBs used commercially in the US, they do not represent all PCB products.
- Second, samples that contain mixed Aroclors or that have undergone weathering are not expected to have the same fingerprint as Aroclor standards. Fitting these samples to a set of standard Aroclor fingerprints may not provide accurate information.
- Third, this method does not detect certain PCB congeners, including some of the most toxic.
- Finally, the Aroclor Method has relatively high method detection limits compared with concentrations of concern for water quality.

TSCA regulations allow the use of an alternative analytical method for PCB determination if it is validated as described in 40 CFR 761, Subpart Q. Alternative analytical methods for PCBs, such as EPA Method 1668, or a revised version of Method 8082 that allows for individual congener analysis provide lower detection and reporting limits, and can be used to detect all 209 individual PCB congeners. However, these methods require more specialized laboratory equipment and expertise to perform, and are therefore considerably more expensive than the "Aroclor" method. Although these improved methods are more appropriate for stormwater control purposes because they are not required, they are unlikely to be used in place of the easier and less expensive "Aroclor" method when responding to mineral oil spills.

3.3 PCBs Remaining in Electrical Utility Equipment

Although use of PCBs is highly restricted currently, McKee et al. (2006) estimated that 12.3 million kilograms of PCBs were used in the San Francisco Bay Area between 1950 and 1990. Roughly 65% (8 million kg) was used in electrical transformers and large capacitors (McKee et al. 2006). How much of this mass was released to the environment and how much remains in electrical equipment distributed across the Bay Area today is unknown. While the 1979 ban of PCBs did not require the immediate removal of PCBs from current applications, electrical utilities have made substantial efforts over the past 35+ years to reduce the amount of PCBs still used in their applications in the Bay Area. According to PG&E, the majority of OFEE containing PCBs in the Bay Area has already been removed or refurbished with dielectric fluids that do not contain PCBs through the following actions:

- Voluntary replacement programs;
- Ongoing removal of PCBs from OFEE as units are serviced or replaced due to routine maintenance programs; and
- OFEE replacement due to unplanned actions (e.g., transformer leaks and fires).

Voluntary actions conducted by PG&E, primarily in the mid-1980s, included the PCBs Distribution Capacitor Replacement Program and the PCBs Network Transformer Replacement Program (PG&E 2000). In addition, in the 1990s, PG&E implemented a program to remove oil-filled circuit breakers and replace them with equipment that contains sulfur hexafluoride gas (PG&E 2000). Current ongoing PG&E efforts to remove PCBs-containing equipment are conducted primarily through maintenance programs. Past maintenance of older equipment may have included draining PCBs-containing oils and refilling the equipment with oils that did not contain PCBs. These refurbished OFEE may still contain PCBs at levels of concern to municipalities due to residual contamination from the original PCB-oil. Currently, as maintenance staff identify older equipment in-use, it is scheduled for replacement. However, PG&E has provided limited documentation of their past and current PCBs removal efforts. There remains much uncertainty on where PCBs transformers, PCBs capacitors, oil-filled circuit breakers, and PCBs-containing distribution system equipment were originally located, and which ones have already been removed or replaced.

Despite the removal efforts described above, PCBs may still be found in older and refurbished OFEE, and particularly OFEE located throughout the distribution system. In a recent meeting with Regional Water Board Staff, PG&E noted that any equipment installed prior to 1985 could contain PCBs, as it would have come from equipment stockpiled prior to the 1979 ban and was installed prior to the voluntary replacement programs (*personal communication*, Sanchez 2016). Because OFEE are not typically tested for PCBs until the fluid is removed during servicing or disposal, or in the event of a spill, the total number of PCBs-containing OFEE that remain in use is unknown. However, in a letter to the Regional Water Board in 2000, PG&E provided information that can be used to make some preliminary estimates, including the following (PG&E 2000):

- There are over 900,000 pieces of OFEE in service in the distribution system;

- In 1999, 22,000 pieces of equipment were serviced at the main PCBs-handling facilities in Emeryville;
- Approximately 10 percent of the units serviced and tested annually contain PCBs at concentrations of 50 parts per million (ppm) or greater, and fewer than 1 percent contained PCBs at concentrations of 500 ppm or greater; and
- The number of pieces of equipment containing PCBs concentrations > 50 ppm has declined over time.

The information above was used to calculate the following:

- Assuming the count of equipment processed in 1999 in Emeryville represents an average annual processing rate throughout the region and that there are at least 900,000 pieces of equipment in PG&E's distribution system it would take over 40 years at a minimum for all of this equipment to be replaced;
- Assuming the 1999 processing rate and 900,000 pieces of equipment in PG&E's distribution system in 1985, approximately 175,000 pieces would not yet have been serviced or replaced as of 2018; and
- Of the approximately 175,000 pieces of equipment remaining in-use in 2018, approximately 17,500 (10%) may contain PCBs concentrations > 50 ppm.

Although based on limited information, the above estimates demonstrate that a potentially large number of pieces of equipment containing PCBs over 50 ppm (i.e., 17,500 as of 2018) may remain in-use in PG&E's electrical utility distribution system. And the remaining 90% (roughly 157,000 pieces of equipment) may contain lower concentrations of PCBs that could still be of concern to Permittees in their efforts to meet TMDL requirements.

3.4 Estimated PCBs Loads from Electrical Utility Equipment to MS4s

McKee et al. (2006) developed a PCBs mass balance model that estimated the total loads to stormwater from all major sources during the peak period of PCBs production and use (i.e., 1950 – 1990), and in the period of the study (i.e., 2005). The mass balance model started with the total mass of PCBs that was used in the region between 1950 and 1990 and apportioned that mass to the major source categories. The largest PCBs-use category was transformers and large capacitors (i.e., oil-filled electrical equipment, OFEE). The total mass used in transformers and large capacitors between 1950 and 1990 was estimated at 7,600 metric tons (MT). Although most of this PCBs mass remains contained within the equipment, a small percentage of PCBs are released each year due to spills and leaks. These releases are the primary source of PCBs to stormwater conveyances from OFEE. Using literature values and the assumptions outlined below, McKee et al. (2006) estimated the following:

- Between 1950 and 1990 (the peak period of production and use of PCBs in the U.S.) 120 – 520 kg of PCBs entered stormwater conveyances due to releases from transformers and large capacitors. On average, this equated to a stormwater load of 8 kg/yr to the San Francisco Bay from electrical utility equipment during that time period.
- In 2005, the mass of PCBs entering stormwater conveyances due to releases from transformers and large capacitors was 1.2 to 4.3 kg/year (average = 2.8 kg/yr). The assumptions and literature data that were used to calculate the 2005 load included the following:

  - 0.05% was estimated to leak from transformers and 0.35% from large capacitors each year over an assumed 30-year service life (Harrad 1994, EIP Associates 1997).
  - When spills occur, 99% of the spilled PCBs are cleaned up and only 1% of the remaining PCBs are left on erodible surfaces and available for wash off;
  - Assumed runoff coefficients based on land-use classifications were used to approximate the fraction of PCBs on erodible surfaces that can enter local storm drains each year; and
  - A small fraction (0.3%) of PCBs released to the environment enter the atmosphere (Keeler et al. 1993); McKee et al. (2006) estimated 2% to 6% of these PCBs are subsequently captured in stormwater through wet deposition.

McKee et al. (2006) estimated a stormwater load of 2.8 kg/yr to the Bay from transformers and large capacitors in 2005.

4.0 Desktop Analysis

The purpose of the desktop analysis is to better understand the extent and magnitude of municipally-owned electrical utility equipment as a source of PCBs to urban stormwater runoff, document past and current efforts to reduce PCBs releases from electrical utility equipment during spills or other accidental releases, and document measures already taken or underway to remove PCBs-containing oils and electrical equipment from active service across the Bay Area.

PG&E, the largest electric utility company in the Bay Area, was likely the largest single user of PCBs in the Bay Area, and as such, likely remains the largest current source of PCBs releases to MS4s from electrical utility equipment. However, the project was revised in early 2020 to focus the desktop analysis on information provided by municipally-owned electrical utilities in the Bay Area on their OFEE inventories, and any other readily available data, such as the data provided previously by PG&E on voluntary replacement programs for PCBs-containing OFEE and spill reporting records presented in Sections 3.3 and 3.4, respectively.

The BASMAA project team identified representatives from municipally-owned electrical utilities in the Bay Area and discussed the project information needs with those representatives. The Project team sent the identified representatives a *Request for Information from Municipal Electrical Utilities*. The requested information included a description of the agency's electrical utility transmission and distribution systems, description of OFEE in the systems and PCBs-containing OFEE in the systems, past and current replacement and maintenance programs for OFEE and current and past protocols for OFEE spill response and cleanup.

4.1 Overview of Participating Municipally-Owned Electrical Utilities

In the MRP Area, there are five municipally-owned (public) electrical utilities, including:

1. Alameda Municipal Power
2. City of Palo Alto Utilities
3. Pittsburg Power Company, doing business as (dba) Island Energy – City of Pittsburg
4. Port of Oakland
5. Silicon Valley Power - City of Santa Clara

Three of these public utilities participated in this project and submitted data on their OFEE inventories and spill response protocols for evaluation, including: City of Palo Alto Utilities (CPAU), Pittsburg Power Company dba Island Energy (Island Energy) – City of Pittsburg, and Silicon Valley Power (SVP) – City of Santa Clara.

Additional information about each of the three participating municipally-owned electrical utilities and the information provided on OFEE in their systems is presented below.

4.1.1 City of Palo Alto Utilities

The City of Palo Alto Utilities (CPAU) have been operating a municipal electric power system in that city for over 100 years. CPAU serves the City of Palo Alto with an area of approximately 16,640 acres (including ~11,000 acres of urban area and ~5,500 acres of open space) and a population of approximately 67,082 people.

CPAU provided data on their inventory of OFEE through December 2019, including counts of equipment that are currently active in the system and equipment that have been removed from the system. OFEE counts were provided by the following equipment types:

- Poletop transformers
- Padmount single phase transformers
- Padmount three phase transformers
- Padmount substation transformers
- Underground commercial and residential distribution transformers
- Regulators
- Padmount switches
- Vault/box switches

For each type of equipment, CPAU provided an average volume of oil in each piece of equipment. The OFEE counts were further divided into the following categories:

- All active OFEE (equipment that are currently in active service within electrical transmission or distribution systems);
- Active OFEE that were purchased or installed prior to 1985 (pre-1985 OFEE);
- All inactive OFEE (equipment that have been removed from service);
- Inactive pre-1985 OFEE that were removed from service prior to 2002;
- Inactive pre-1985 OFEE that were removed from service in 2002 or later.

CPAU did not provide any data on measured PCBs concentrations in their OFEE inventory. However, they did identify OFEE that were labeled as “Non-PCBs” by the manufacturer.

4.1.2 Silicon Valley Power

Silicon Valley Power (SVP) has been operating in the City of Santa Clara for more than 100 years. As of December 2019, SVP includes 25 substations, 55 miles of transmissions lines, and 186 miles of overhead distribution lines. The total coverage area is 11,782 acres, and the population served is 129,488 people.

SVP provided data on their inventory of OFEE through December 2019, including counts of equipment that are currently active in the system and equipment that have been removed from the system. OFEE counts were provided by the following equipment types:

- Poletop transformers
- Padmount single phase transformers
- Padmount three phase transformers
- Padmount substation transformers
- Underground commercial and residential distribution transformers
- Regulators
- Padmount switches
- Vault/box switches

For each type of equipment, SVP provided an average volume of oil in each piece of equipment. The OFEE counts were further divided into the following categories:

- All active OFEE (equipment that are currently in active service within the electrical transmission or distribution systems);
- Active OFEE that were purchased or installed prior to 1985 (pre-1985 OFEE);
- All inactive OFEE (equipment that have been removed from service);
- Inactive pre-1985 OFEE that were removed from service prior to 2002;
- Inactive pre-1985 OFEE that were removed from service in 2002 or later.

SVP also provided equipment counts and oil volumes for a number of OFEE that comprised approximately 12% of the oil mass in their inventory, for which no information on equipment status (active or inactive) and no information on equipment age (pre-1985 or post-1985) were available at the time this report was prepared. These data were excluded from the main analysis presented in Section 4.2. However, a sensitivity analysis was conducted in order to understand potential implications of excluding these data. The results of the sensitivity analysis are presented in Section 4.2.3. Based on those results, the unknown data were included in the estimated ranges of PCBs mass and stormwater loads as described further in Section 4.2.3 and Table 4.4.

SVP did not provide any data on measured PCBs concentrations in their OFEE inventory.

4.1.3 Pittsburg Power Company, Island Energy

Pittsburg Power Company is a joint powers authority and department within the City of Pittsburg, California. Since 1997, Pittsburg Power has been operating an electric utility distribution system at Mare Island in Vallejo under the name “Island Energy”. Mare Island was formerly the location of a US Naval shipyard that was decommissioned in 1996. Following decommissioning, the Pittsburg Power Company acquired the electrical utility distribution rights on Mare Island from the US Navy. The distribution system on Mare Island that is operated by Island Energy consists of one substation and approximately 11 miles of distribution lines that serve an area of ~1,200 acres. The Mare Island zip code has a population of approximately 900 people.

Island Energy provided detailed inventories for the transformers that were part of both the historic (US Navy) inventory and the current (Island Energy) inventory of OFEE on Mare Island. The historic inventory documents each piece of OFEE that was part of the US Naval shipyard on Mare Island until 1996. At that time, the US Navy removed the bulk of pre-1985 OFEE and sent them to hazardous waste facilities for proper disposal. However, some pre-1985 OFEE remained on the island. The current inventory identifies each piece of OFEE on Mare Island that has been operated by Island Energy since 1997 through December 2019. The data provided in both the current and historic inventories includes the volume of oil, installation date, and (if applicable) removal date for each transformer in the historic or current system on Mare Island. In addition, measured concentrations of PCBs were provided for most OFEE in these inventories. Island Energy noted that there are gaps in the historic records, and the data provided may be incomplete. The current inventory identifies all OFEE that have been or are currently active and operated by Island Energy on Mare Island between 1997 and 2019 (i.e., since Island Energy began operating the electrical distribution system on Mare Island). The data analysis focused on the PCBs-containing OFEE in the historic and current inventories.

4.2 Analysis of Municipally-Owned Electrical Utility Data

The overall goal of the analysis of municipally-owned electrical utility OFEE inventories was to develop improved estimates of both the load of PCBs to stormwater from OFEE, and the load reductions that have been achieved over time due to ongoing equipment maintenance and replacement programs. The data analysis was also intended to provide data inputs that could be used in the accounting methodology presented in the BASMAA Source Control Load Reduction Accounting for RAA (BASMAA 2020) to calculate the PCBs load reductions achieved since the start of the PCBs TMDL, and the expected PCBs load reductions in the future due to the ongoing removal and proper disposal of PCBs-containing OFEE. To accomplish these goals, the project evaluated the OFEE inventories provided by participating municipally-owned electrical utilities to characterize the magnitude of PCBs-containing OFEE in these systems and document the rate of removal of PCBs-containing OFEE over time. The data were used to calculate the annual average removal rates of PCBs-containing OFEE from participating municipally-owned electrical utility systems since the start of the PCBs TMDL (i.e., 2002). This information was then scaled-up to the larger MRP area in order to provide a rough, first-order estimate of the potential magnitude of the current OFEE load of PCBs to stormwater across the area.

4.2.1 OFEE Inventory Data Analysis Approach and Assumptions

The OFEE inventory data were analyzed to generate estimates of the following:

- The potential mass of PCBs in active OFEE within each municipally-owned electrical utility system at the start of the PCBs TMDL (i.e., 2002) and currently (i.e. 2020).
- The potential mass of PCBs in OFEE that has been removed from each of these systems due to ongoing maintenance and replacement programs before and after 2002.
- The annual average reduction rate achieved since the start of the PCBs TMDL due to removal of PCBs-containing OFEE from these systems.
- The potential PCBs stormwater load from OFEE in these systems at the start of the PCBs TMDL and currently.
- The expected PCBs stormwater load reductions in the future due to continued removal of PCBs-containing OFEE from these systems.

Because information on measured PCBs in these OFEE was limited, the mass of oil in OFEE was used as the primary metric to characterize OFEE within each system, to estimate the magnitude of potentially PCBs-containing OFEE in each system, and to calculate equipment removal rates. The age of the OFEE, based on the purchase or installation date provided, was used as the primary metric to identify potentially PCBs-containing equipment as follows:

- Pre-1985 OFEE. All equipment that was installed prior to 1985 (i.e., pre-1985 OFEE) were assumed to potentially contain PCBs. 1985 was selected as the appropriate cut-off date to identify equipment that may contain PCBs because the installation of PCBs-

containing equipment that had been stockpiled prior to the 1979 PCBs ban continued for several years after the ban[6].
- Post-1985 OFEE. All equipment installed after 1985 (i.e., post-1985 OFEE) were assumed to contain zero PCBs.

The potential mass of PCBs in pre-1985 OFEE was calculated from the mass of oil in these OFEE multiplied by a range of assumed PCBs concentrations in that oil. The PCBs concentrations in all pre-1985 OFEE were based on the following assumptions:

- Measured PCBs concentrations were used, if available.
- If no PCBs measurement data were provided, the range of PCBs concentrations was estimated as follows:
  - Pre-1985 OFEE with "PCBs" labels are assumed to have PCBs concentrations ≥ 500 ppm (i.e., PCBs Transformers). However, because PCBs transformers must be registered with the US EPA transformer registry, and none of the participating municipally-owned utilities have registered any PCBs transformers in this database, all PCBs concentrations in any equipment in the current OFEE inventories were assumed to be less than 500 ppm.
  - Pre-1985 OFEE with "Non-PCBs" on the label have PCBs concentrations < 50 ppm. All OFEE with these labels were assumed to have PCBs between 1 and 49 ppm, unless otherwise noted.
  - Pre-1985 OFEE that were not labeled, or that did not have measured PCBs concentrations were assumed to contain PCBs between 50 and 499 ppm.

Because this report is focused on OFEE that contain or may contain PCBs, the data analysis focused primarily on pre-1985 OFEE.

4.2.2 Data Analysis Methods

Analysis of the OFEE inventory data proceeded through the following seven steps:

1. Calculate the total mass of oil in all active OFEE within each system and the total mass of oil in active pre-1985 OFEE. Use this information to estimate the mass of oil and current abundance of potentially PCBs-containing OFEE within each system.

The total mass of oil in all active OFEE was calculated from the volume of oil in each piece of equipment multiplied by the density of the oil. The OFEE inventories provided by the participating municipally-owned electrical utilities provided either the actual volume of oil in each piece of equipment in their inventory, or the average volume of oil per piece of equipment for each type of equipment and the total counts of active equipment of that type. The density of the

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[6] Personal communication, Sanchez 2016. This assumption is based on statements made to Regional Water Board staff at a meeting with PG&E representatives that equipment stockpiled prior to the 1979 ban continued to be put into service after the ban until voluntary replacement programs were instituted around 1985.

oil in all OFEE was based on the density of highly refined mineral oil used as a dielectric fluid in transformers of 0.9 mg/l[7].

Pre-1985 OFEE were identified based on information provided by the municipally-owned electrical utilities on either the installation date for each piece of equipment in their inventory, or the counts of all equipment within each category that were installed before 1985 and are currently active in their system.

2. Calculate the mass of oil in pre-1985 OFEE that has been removed from active service since the start of the PCBs TMDL in 2002.

Only pre-1985 OFEE were included in this calculation because this category comprises all OFEE that may contain PCBs. Each participating municipally-owned electrical utility provided slightly different data on equipment removal dates. Both CPAU and SVP provided direct counts of pre-1985 OFEE within each equipment category that were removed from service in 2002 or later. Island Energy identified all pre-1985 OFEE in their current inventory as either active or inactive as of 2019 but did not provide removal dates for inactive equipment. However, Island Energy's current OFEE inventory only includes OFEE that were active in 1997. At this step in the process, in order to simply this calculation and provide information needed for Step #3, this calculation assumed all equipment in Island Energy's current inventory were active until at least 2002 (i.e., all inactive OFEE were removed from service in 2002 or later).

3. Calculate the overall equipment removal rate and annual average equipment removal rate for pre-1985 OFEE since the start of the PCBs TMDL in 2002. Use this estimate to calculate the future date by which all pre-1985 OFEE will be removed from each participating municipally-owned electrical utility system.

The overall equipment removal rates for pre-1985 OFEE that were achieved between 2002 and 2019 were calculated based on the total mass of oil in pre-1985 OFEE that were removed from each system during that time period, divided by the total mass of oil in all pre-1985 OFEE that were active in 2002. The annual average removal rates were then calculated by dividing the overall removal rate by the number of years between 2002 and 2019 (17 years).

For CPAU and SVP, the overall removal rates since the start of the PCBs TMDL in 2002 were calculated directly from the data provided on removals between 2002 and 2019. However, because of the way the data were provided for Island Energy, an additional step was needed to estimate the overall removal rate since 2002. Island Energy identified all equipment in their current inventory, which spans the time period between 1997 and 2019, as active or inactive in 2019. However, specific removal dates for inactive equipment in the current inventory were not provided. Therefore, in order to estimate the overall removal rate since 2002, first, the annual average removal rate between 1997 and 2019 was calculated by dividing the overall removal rate for this period by the number of years between 1997 and 2019 (22 years). This annual average removal rate was then multiplied by the number of years between 2002 and 2019 (17 years) to estimate the overall removal rate since the start of the PCBs TMDL in 2002.

[7] Based on the reported density of Shell Diala Oil AX manufactured by SOPUS Products. Island Energy identified this as the dielectric oil used in the large transformers at their substation and provided a Material Safety Data Sheet (MSDS) for this product in their Spill Prevention, Control and Countermeasure (SPCC) plan.

Both the annual average removal rates and the overall removal rates since 2002 were compared across participating municipally-owned utilities. These data were also compared with the rates proposed in the accounting methodology for calculating the load reductions due to ongoing removal of PCBs-containing OFEE since the start of the PCBs TMDL and into the future. These removal rates were also used to estimate the future date by which all pre-1985 OFEE will be removed from each system. This calculation assumes the annual average removal rate for each system that has been achieved since 2002 will continue until all pre-1985 OFEE have been removed from each system. The starting point for this calculation was the mass of oil in all pre-1985 OFEE that were active in each system in 2020 (calculated in step #1). This 2020 value was then multiplied by the annual average removal rate for each system to estimate the total mass of pre-1985 OFEE oil removed each year. The number of years to reduce this mass to zero was then estimated by dividing the total mass of oil in active pre-1985 OFEE in 2020 by the mass of oil that would be removed each year.

4. Calculate the potential range of PCBs mass in active OFEE in 2020.

The potential range of PCBs mass (kg) in currently active pre-1985 OFEE was estimated for each system based on the total mass of oil in active pre-1985 OFEE in 2020 multiplied by the measured or assumed PCBs concentrations based on previously described assumptions (see Section 4.2.1).

5. Calculate the 2002 and 2020 loads of PCBs to stormwater from OFEE in the participating municipally-owned electrical utility systems and load reductions achieved over time due to equipment removals.

The starting point for this calculation was the current PCBs mass in active OFEE (step #5 above) for each participating municipally-owned electrical utility system. The following assumptions used by McKee et al., (2006) were then applied to estimate the fraction of PCBs in OFEE that are released to MS4s annually.

- 0.05% was estimated to leak from transformers and 0.35% from large capacitors each year (Harrad 1994, EIP Associates 1997); For this analysis, the value for transformers was used for all OFEE;
- When leaks occur, 99% of the materials leaked are cleaned up and only 1% remain on erodible surfaces and available for wash off.

6. Estimate the stormwater loads from OFEE across the larger MRP area and the potential load reductions that can be achieved through continued equipment removal.

This calculation extrapolated the stormwater loads estimated for the participating municipally-owned electrical utility system OFEE (developed in step #5) to the larger Bay Area.

4.2.3 Data Analysis Results

Summary of Municipally-Owned Electrical Utility Data

Figure 4.1 presents a summary of the distribution of OFEE in each of the participating municipally-owned electrical utility systems' inventories. Additional information about these distributions is provided in the following sections.

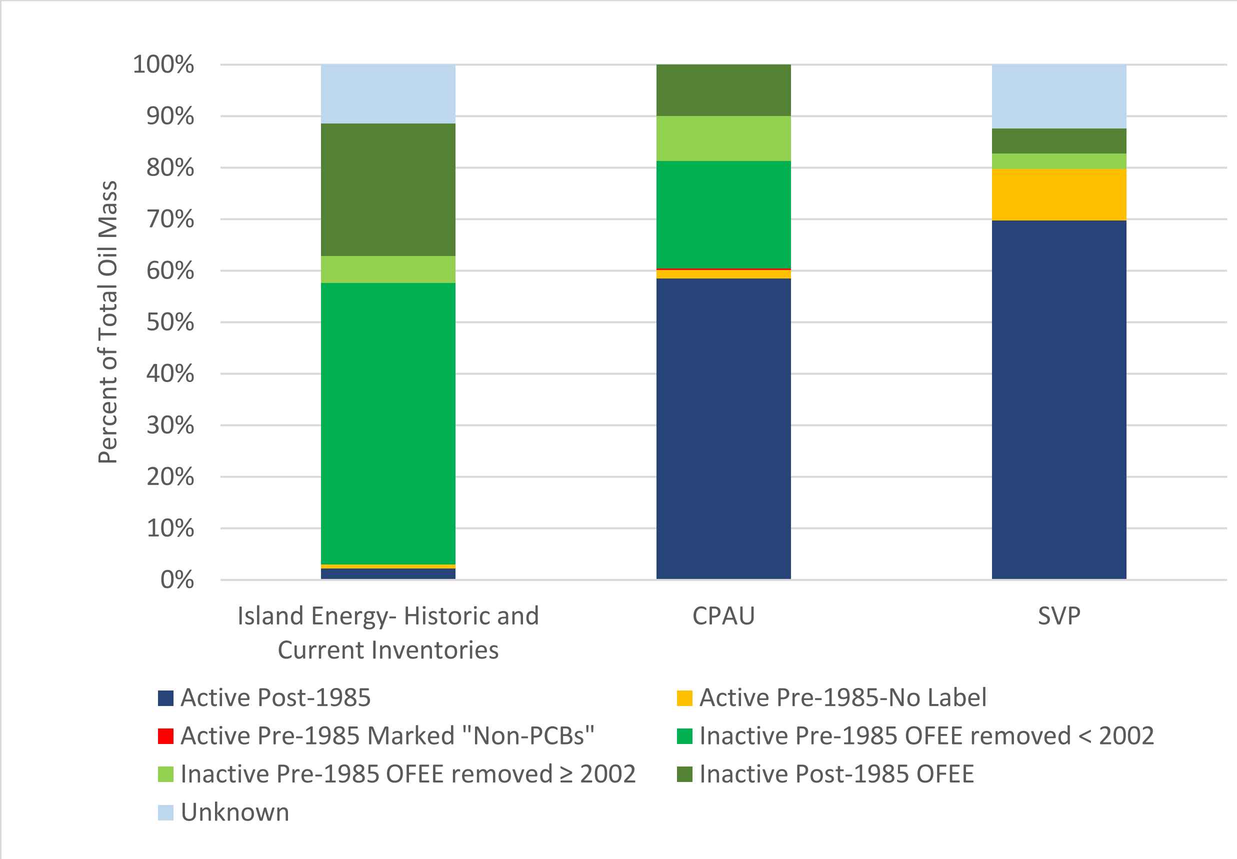

Figure 4.1 Distribution of the mass of oil in oil-filled electrical equipment (OFEE) in three municipally-owned electrical utility systems.

Active Equipment - including both Pre-1985 and Post-1985 OFEE

Table 4.1 presents the mass of oil in all OFEE that are currently active in each participating municipally-owned electrical utility system, divided between pre-1985 OFEE and post-1985 OFEE. Where available, the data are also presented by equipment type. Across all 3 systems, there are more than 4.8 million kilograms (kg) of oil in active OFEE.

Combined, there are nearly 500,000 kg of oil in active pre-1985 OFEE in these systems, which is 10% of the oil in active OFEE (Table 4.1). CPAU has the lowest abundance of active pre-1985 OFEE oil, which comprises 3.4% of their OFEE. Approximately 12% of SVP's active equipment, and 25% of Island Energy's active equipment are comprised of pre-1985 OFEE. Additional pre-1985 OFEE may be active in the system that cannot be verified at this time (see Section 4.1.2 on SVP OFEE identified as "unknown status and age"). Detailed equipment type was not provided by Island Energy, but for both CPAU and SVP, 64% of the pre-1985 OFEE oil is contained in padmount transformers, and about 25% is contained within pole-top transformers. The remainder is either in underground transformers or switches.

Table 4.1 Mass of dielectric oil in oil-filled electrical equipment (OFEE) that are currently active in three municipally-owned electrical utility systems.

Utility System	Equipment Type	Oil in ACTIVE OFEE (kg) Pre-1985 OFEE	Post-1985 OFEE	TOTAL	Percent of Active OFEE that are pre-1985
City of Palo Alto Utilities (CPAU)	Padmount Single Phase Transformer	988	57,798	58,786	1.7%
	Padmount Three Phase Transformer	33,336	609,353	642,689	5.2%
	Poletop Transformer	4,923	121,608	126,531	3.9%
	Regulator	0	920	920	0%
	Underground Commercial Distribution Transformer	0	108,560	108,560	0%
	Underground Residential Distribution Transformer	204	62,584	62,789	0.3%
	Padmount Oil Switch	0	1,090	1,090	0%
	Padmount Vacuum Switch	0	99,038	99,038	0%
	Vault/Box Oil Switch	0	0	0	0%
	Vault/Box Vacuum Switches	0	63,027	63,027	0%
	Subtotal - CPAU	**39,452**	**1,123,977**	**1,163,429**	**3.4%**
Silicon Valley Power (SVP) – City of Santa Clara[1]	Padmount Single Phase Transformer	2,044	23,201	25,245	8.1%
	Padmount Three Phase Transformer	189,333	1,147,357	1,336,690	14%
	Poletop Transformer	111,551	139,338	250,889	44%
	Underground Residential Distribution Transformer	0	1,635	1,635	0%
	Padmount Oil Switch	7,645	9,444	17,089	45%
	Padmount Vacuum Switch	51,880	154,999	206,879	25%
	Padmount Vacuum-Disconnect Switch	0	249,764	249,764	0%
	Padmount Substation Transformer	91,985	1,460,593	1,552,578	6%
	Subtotal - SVP	**454,439**	**3,186,330**	**3,640,76**	**12%**
Island Energy[2]	**Current Inventory of Transformers**	**3,669**	**10,882**	**14,551**	**25%**
	TOTAL (All Systems Combined)	**497,560**	**4,321,189**	**4,818,749**	**10%**

[1]SVP identified incomplete records for OFEE that contain approximately 566,000 kg or oil. The current status of these OFEE (active or removed) and the installation dates were unavailable at the time of this report. Therefore, these OFEE were not included in any of the totals above. See Section 4.1.2 for additional information.

[2]Since 1997, Pittsburg Power Company has been operating the electrical distribution system on Mare Island in the City of Vallejo under the name Island Energy.

Pre-1985 OFEE Removed from Active Service

Table 4.2 presents the total mass of oil in all pre-1985 OFEE that have been removed from service since they were originally installed, divided between the pre-1985 OFEE that were removed before 2002, and those that were removed in 2002 or later (i.e., since the start of the PCBs TMDL). Across the three systems, nearly 1 million kilograms of oil in pre-1985 OFEE have been removed from active service due to ongoing equipment removal and maintenance programs. This represents approximately 67% of the oil from all pre-1985 OFEE in these inventories.

Both CPAU and Island Energy have already removed the bulk of their pre-1985 OFEE from active service (94% and 88%, respectively). When the pre-1985 OFEE in the historic inventory on Mare Island were factored into the calculation, the removal rate on Mare Island increased to over 99% removal of all pre-1985 OFEE. SVP has removed at least 23% of their documented pre-1985 OFEE from active service. Additional removals from the SVP system may have occurred that cannot be verified at this time (see Section 4.1.2 on SVP OFEE identified as "unknown status and age").

In addition, since the start of the PCBs TMDL in 2002, more than 320,000 kg of oil in pre-1985 OFEE have been removed from service across all three systems (Table 4.2). This represents an overall 39% removal rate, and an average removal rate of 2.3% per year. The overall removal rates for each individual system over this same time period were 81% (CPAU), 68% (Island Energy) and 23% (SVP). These overall removal rates equate to average removals of 4.8% (CPAU), 4.0% (Island Energy), and 1.3% (SVP) per year. Based on these annual average removal rates, the project estimates it will take between 21 and 75 years for all pre-1985 OFEE to be removed from these systems due to continued equipment maintenance and removal programs.

Table 4.2 Mass of dielectric oil in oil-filled electrical equipment (OFEE) that have been removed from active service in three municipally-owned electrical utility systems.

Utility System	Equipment Type or	Pre-1985 OFEE Oil in Inactive/Removed OFEE (kg)			Pre-1985 OFEE Removed Between 2002 and 2019		Pre-1985 OFEE removed since installation	Estimated time to remove all pre-1985 OFEE (years)
		Removed prior to 2002	Removed in 2002 or Later	TOTAL REMOVED	Overall Removal Rate	Annual Average Removal Rate		
City of Palo Alto Utilities	Padmount Single Phase Transformer	2,998	3,475	6,473	**81%**	**4.8%**	**94%**	**21**
	Padmount Three Phase Transformer	98,953	79,431	178,384				
	Poletop Transformer	204,165	47,100	251,265				
	Regulator	0	0	0				
	Underground Commercial Dist.Transformer	39,162	19,879	59,041				
	Underground Residential Dist. Transformer	54,374	17,971	72,345				
	Padmount Oil Switch	0	0	0				
	Padmount Vacuum Switch	0	0	0				
	Vault/Box Oil Switch	0	0	0				
	Vault/Box Vacuum Switches	0	0	0				
	Subtotal - CPAU	**399,651**	**167,856**	**567,508**				
Silicon Valley Power - City of Santa Clara[1]	Padmount Single Phase Transformer	0	1,635	1,635	**23%**	**1.3%**	**23%**	**75**
	Padmount Three Phase Transformer	944	108,642	109,585				
	Poletop Transformer	327	21,801	22,128				
	Underground Residential Dist. Transformer	0	664	664				
	Padmount Oil Switch	0	0	0				
	Padmount Vacuum Switch	0	0	0				
	Padmount Vacuum-Disconnect Switch	0	0	0				
	Padmount Substation Transformer	0	0	0				
	Subtotal - SVP	**1,271**	**132,742**	**134,013**				
Island Energy[2]	**Current Inventory**	**5,276**	**21,161**	**26,437**	**68%**	**4.0%**	**88%**	**25**
	Historic Inventory	**266,192**	**NA[3]**	**266,192**	**NA[3]**		**100%**	
TOTALS (All Systems Combined)		**672,391**	**321,759**	**994,150**	**39%**	**2.3%**	**67%**	**43**

[1]SVP identified incomplete records for OFEE that contain approximately 566,000 kg or oil. The current status of these OFEE (active or removed) and the installation dates were unavailable at the time of this report. Therefore, these OFEE were not included in any of the totals above. See Section 4.1.2 for additional information.
[2]Since 1997, Pittsburg Power Company has been operating the electrical distribution system on Mare Island in the City of Vallejo under the name Island Energy.
[3]NA=not applicable; the historic inventory only covers the period up to 1996.

Sensitivity Analysis – SVP Data

As described in Section 4.1.2, about 12% of the equipment in the SVP inventory did not have information on the status (active or inactive) or age (pre- or post-1985) of the OFEE. In order to evaluate the potential impact of excluding these unknown data, additional analyses were conducted to account for the following three scenarios:

1- All "unknown" OFEE are assumed to be active, pre-1985 OFEE;
2- All "unknown" OFEE are assumed to be pre-1985 OFEE that were removed from service after the start of the PCBs TMDL in 2002;
3- All "unknown" OFEE are assumed to be pre-1985 OFEE that were removed from service prior to 2002.

The results of the sensitivity analysis conducted under each of these three scenarios are shown in Table 4.3. The default scenario excluded all "unknown" oil from all calculations. For each alternative scenario, the mass of "unknown" oil was added to the value for the cell highlighted in blue in the table. The minimum and maximum values calculated for each of the percentage columns are bolded in the table.

This analysis indicates that under Scenario 1, the percent of active OFEE that are pre-1985 increases from 12% to 24%, and the percent of pre-1985 OFEE that have been removed since installation decrease from 23% to 12%.

Under Scenarios 2 and 3, the percent of active pre-1985 OFEE remain the same, but the percent of pre-1985 OFEE that have been removed since installation increases from 23% to 61%, which is more in line with the rates observed for the other two systems. Scenario 3 also increases the annual average removal rate since the start of the TMDL from 1.3% to 3.6% per year.

The primary impacts of these alternative scenarios include the following:

- Under Scenario 1, the pre-1985 OFEE currently in the system more than doubled, which would result in an increase in the current PCBs loads to stormwater from this source;
- Under Scenario 3, the mass of pre-1985 OFEE removed since the start of the TMDL was nearly tripled, which would result in an increase in the PCBs stormwater loads reduced during this time period accordingly. Also under Scenario 3, because of the increased annual removal rate, all pre-1985 OFEE would be removed within 28 years (compared to 75 years in the default scenario).

Because these impacts are potentially large, the results for SVP presented in the next section used the ranges presented in Table 4.3 for Scenario 1 and Scenario 2. The results for these two scenarios provide the upper and lower limits for all values across the default and alternative scenarios.

Table 4.3 Sensitivity analysis conducted to evaluate the impacts of unknown status and age of oil-filled electrical equipment (OFEE) identified in the Silicon Valley Power (SVP) OFEE inventory on the evaluation of pre-1985 as a source of PCBs to urban stormwater.

Scenario	Oil in Active OFEE (kg)		Oil in Inactive/Removed OFEE (kg)			Oil in OFEE with Unknown Status and Age (kg)	Total Oil in OFEE Inventory (kg)	Percent of all Active OFEE that are Pre-1985	Percent of Pre-1985 OFEE Removed Since Installation	Pre-1985 OFEE Removed Between 2002 and 2019	
	Post-1985 OFEE	Pre-1985 OFEE	Pre-1985 OFEE removed before 2002	Pre-1985 OFEE removed in 2002 or later	Post-1985 OFEE					Overall Removal Rate	Annual Average Removal Rate
Default: "Unknown" not included in calculations	3,186,330	454,439	1,271	132,742	221,460	566,026	4,562,268	**12%**	23%	23%	1.3%
1. All "unknown" = Active, Pre-1985 OFEE	3,186,330	1,020,465	1,271	132,742	221,460		4,562,268	**24%**	**12%**	**12%**	**0.7%**
2. All "unknown" = Pre-1985 OFEE Removed in 2002 or Later	3,186,330	454,439	1,271	698,768	221,460		4,562,268	12%	**61%**	**61%**	**3.6%**
3. All "unknown" = Pre-1985 OFEE Removed Prior to 2002	3,186,330	454,439	567,296	132,742	221,460		4,562,268	12%	61%	23%	1.3%

Potential PCBs Mass in Active OFEE and Estimated Stormwater Loads

Table 4.4 provides the calculated PCBs mass in the Island Energy historic and current OFEE inventories, and estimates of the potential PCBs mass in the CPAU and SVP OFEE inventories. Only Island Energy provided data on measured PCBs concentrations in their OFEE oil. Concentrations of PCBs in Island Energy's current inventory of OFEE ranged from 1 to 37 ppm. Concentrations in the historic inventory ranged from <1 up to nearly 900 ppm. About 20% of the OFEE in the historic inventory had PCBs concentrations > 500 ppm. Based on these measured PCBs concentrations and the volumes of oil in each piece of equipment, the historic inventory documents OFEE containing more than 70 kg of PCBs. By comparison, Island Energy's current inventory of both active and inactive OFEE had 0.088 kg of PCBs. Of that total, 0.040 kg of PCBs remain in active OFEE, and 0.048 kg of PCBs were from OFEE that have been removed from active service. This represents a three-order of magnitude decrease in PCBs mass from the historic inventory. One interesting detail about the PCBs concentration data was that nearly one-third of the PCBs in the current inventory were contained in post-1985 equipment. All of these equipment were from 1986 or 1987. PCBs concentrations were generally low in these OFEE, ranging from 1 to 4 ppm. However, the potential contribution from these OFEE could still be important. For example, in the Island Energy current inventory, there is one piece of equipment from 1987 that contains 600 gallons of oil at 1 ppm PCBs, or 2 g of PCBs in total. If this quantity of PCBs were released to the environment, this could have a detrimental impact on stormwater quality.

Because CPAU and SVP did not provide measured PCBs concentrations for OFEE in their inventories, the potential PCBs mass in pre-1985 OFEE was estimated based on the assumptions described in Section 4.2.1. For CPAU, these estimates suggest active pre-1985 OFEE may contain between 1.7 and 17 kg of PCBs, while pre-1985 OFEE that have been removed potentially contained between 28 kg and 284 kg. These estimates suggest an order of magnitude reduction in PCBs mass in the active OFEE inventory. For SVP, active pre-1985 OFEE may contain between 23 kg and 227 kg. If the "unknown" OFEE were assumed to be active pre-1985 OFEE, then the total estimated mass of PCBs in active OFEE doubles to 51 kg to 510 kg. PCBs in pre-1985 OFEE that have been removed were estimated to range from 6.7 to 67 kg, which would increase up to 35 kg to 350 kg if the "unknown" OFEE were assumed to be pre-1985 OFEE that have been removed from service. Across all three systems, the total potential mass of PCBs in active OFEE ranged from 24 kg up to 527 kg. The upper value assumes the "unknown" mass is contained within active, pre-1985 OFEE.

Table 4.4 Estimated potential mass of PCBs in municipally-owned electrical utilities oil-filled electrical equipment (OFEE) inventories

OFEE Category	PCBs (kg)				
	CPAU	SVP	Island Energy - Current	Island Energy - Historic	TOTAL (All Systems)
All Active	1.7 - 17	23 - 227	0.040		24 - 244
All Removed	28 - 284	6.7 - 67	0.048	70	105 - 421
Removed since 2002	8.4 - 84	6.6 - 66	0.048		15 - 150
Removed prior to 2002	20 - 200	0.1 - 0.6		70	90 - 271
Unknown		28 - 283			28 - 283

Based on the approximate population of the MRP area of ~6 million people, if the active OFEE in all the participating municipally-owned electrical utility systems were representative of the PCBs contained in OFEE across the larger MRP area (i.e., 24 to 527 kg), the estimated mass of PCBs would range from roughly 730 kg up to 16,000 kg of PCBs. Based on acres, the estimated mass of PCBs across the larger MRP area of nearly 3 million acres would range from 2,400 kg up to 53,000 kg of PCBs in active OFEE.

Table 4.5 presents the estimated loads of PCBs to stormwater from active OFEE in the three participating municipally-owned electrical utility systems. Across all three systems, the estimated PCBs stormwater load in 2002 from active OFEE was between 197 mg/yr to 3,390 mg/yr. The low end of this range is the sum of the minimum values for all active OFEE and all OFEE removed since 2002. The upper end of this range is the sum of the maximum values for all active OFEE, all OFEE removed since 2002, and all unknown OFEE. In 2020, the total estimated PCBs stormwater loads from active OFEE were estimated to range from 122 mg/yr up to 2,640 mg/yr. The low end of this range is the sum of the minimum value for all active OFEE. The upper end of this range is the sum of the maximum values for all active OFEE and all unknown OFEE. Scaling these estimates up to the MRP area of roughly 3 million acres gives a stormwater load of between 20,000 mg/yr up to 340,000 mg/yr in 2002, and 12,000 mg/yr up to 260,000 mg/yr in 2020. These estimates are highly uncertain due to all the assumptions that were used in the calculations.

Table 4.5 Estimated range of PCBs loads to stormwater from oil-filled electrical equipment within three municipally-owned electrical utility systems.

OFEE Category	PCBs Stormwater Loads (mg/yr)				
	CPAU	SVP	Island Energy - Current	Island Energy - Historic	TOTAL
All Active OFEE	8.3 - 84	114 - 1,136	0.199	0	122 - 1,220
All Active OFEE - assume "unknown" = active	8.3 - 84	255 - 2,551	0.199	0	264 - 2,636
All Removed OFEE	142 - 1,419	34 - 335	0.241	352	527 - 2,106
Removed since 2002	42 - 420	33 - 332	0.241	0	75 - 752
Removed prior to 2002	100 - 999	0.3 - 3.2		352	452 - 1,354
All Removed OFEE - assume "unknown" = removed	142 - 1,419	175 - 1,750	0.241	352	317 - 3,169
Unknown		142 - 1,415			142 - 1,415

4.3 Spill Response and Cleanup

Although the bulk of PCBs remain contained within OFEE until the equipment is removed from use and transported to proper hazardous waste disposal facilities, releases of PCBs to the environment can and do occur.

4.3.1 Summary of OFEE Release Data for Bay Area

In order to document spills, publicly available data in the California Office of Emergency Services (Cal OES) spill report database (Cal OES 2017), as well as internal spill records (PG&E 2000) supplied by PG&E to the Regional Water Board in September 2000 (that were provided pursuant to a California Water Code §13267 request for information) were reviewed. The Cal OES database and available PG&E spill records were searched for reports of spill releases related to OFEE in the Bay Area between 1994 and 2017. Over 1,200[8] reported release incidents from OFEE in the Bay Area were identified. The information provided by these records and a summary of the important issues identified for water quality concerns are summarized in the remainder of this section. It is important to note that current regulations do not require reporting of all releases from OFEE. The information provided below is based only on the reported releases for which records were available, and likely represents an underestimate of actual OFEE releases during the time period of review. However, these reports clearly demonstrate that PCBs may still be present in the electrical transmission and distribution systems in the Bay Area, and that releases from these systems can and do continue to occur.

Generally, the publicly available spill release records provide information about the spill release date, time, location, chemical, quantity released, actions taken, known or anticipated risks posed by the release, and additional comments. Other information that is sometimes reported for OFEE releases includes a description of the causes of the release and the equipment affected, and the concentrations of PCBs in that equipment (if known). Concentration information reported is likely assumed from equipment labels, as ranges are most often provided rather than specific values. Typically, the reports are limited to the information that was available at the time the spill was initially reported. In some cases, follow-up information such as the results of analytical testing of the spilled materials is also provided, but this is not typical.

Number of Reported OFEE Releases

Between 1994 and 2017, over 1,000 spills from electrical equipment were reported to Cal OES. PG&E records contain information about 200 additional releases that were not reported to Cal OES between 1994 and 2000. A count of these reports by year is presented in Figure 4.2.

[8] The records span 24 years of spill reports, and include PG&E's own record of releases from 1994 thru 1999 and a portion of 2000. The number of reports PG&E submitted in 2000 represents less than half the number of reports for that year. Records did not include all the districts in the Bay Area. District documents submitted reported releases prior to June of 2000, with the exception of one district that submitted a June report. As a result, the number of additional reports from PG&E's records are assumed to be less than half the number of incidents for 2000.

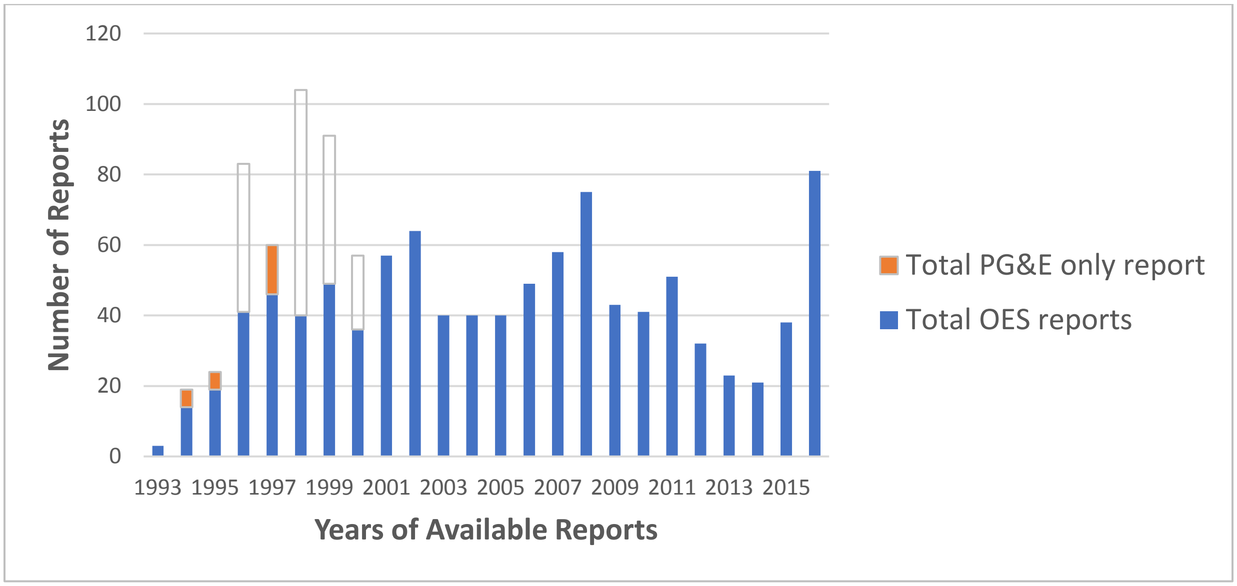

Figure 4.2 Oil-filled electric equipment spills reported to the California Office of Emergency Services (Cal OES) and/or identified through internal Pacific Gas & Electric (PG&E) reports between 1993 and 2017.

Volume of OFEE Releases

The total volume of material released from all reported OFEE spills in a given year in the Bay Area is presented in Figure 4.3. Mineral oil or transformer oil are the substances identified in over 99% of reported releases from OFEE in the Cal OES spill report database. In a phone conference with Regional Water Board staff in 2012, PG&E said they submit written reports to Cal OES for all PCBs spills that meet or exceed the mineral oil federal reportable quantities (RQ) of 42 gallons (*personal communication*, Jan O'Hara 2012). However, the reports reviewed indicate written reports are sometimes submitted for spills that are much less than 42 gallons.

The reported volumes of oil released during a single incident range from less than one gallon up to 5,000 gallons. Nearly half of all OFEE spill reports identify the volume of oil spilled as 5 gallons or less, and more than 90% of all spill reports identify the volume of fluid spilled as less than 100 gallons. Releases as large as 500 gallons from the distribution system and 5,000 gallons from the transmission system have been reported. Only five incidents reported releases that exceeded 1,000 gallons of oil. Nearly all (~99%) of reports provided information on the volume of oil released.

The reported volumes released do not necessarily equate to the volume of the oil that may have reached storm drains or local creeks. Estimates of those volumes were not available.

Location of OFEE Releases

Cal OES and PG&E records show releases occurred in all Bay Area counties. Leaks and spills of PCBs from electrical equipment have occurred onto roads, sidewalks, pervious areas, vegetation, structures, vehicles, and even people (Cal OES 2017). Most releases occurred in the distribution system, often from equipment installed in the public ROW such as pole-mounted transformers installed along roadways.

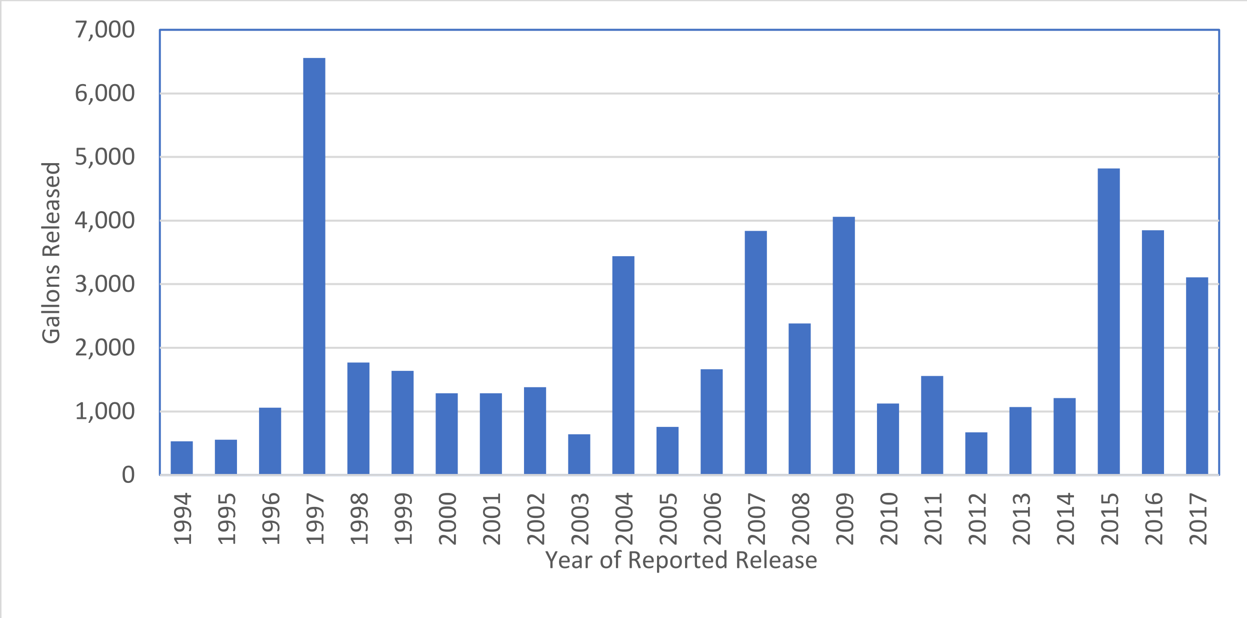

Figure 4.3 Total reported gallons of oil released each year (1994 – 2017) from spills from PG&E electrical utility equipment in the Bay Area.

A number of reports document direct releases from OFEE to the MS4, and potentially a downstream waterbody (e.g., creek). There are at least 17 incidents identified during the past 15 years that involved direct releases from OFEE directly to a waterbody or to storm drains that discharge to local creeks (Table 4.6). The majority of these releases were reported as having unknown PCBs concentrations, and no reports provide any follow-up information on the concentration of PCBs in the spilled materials based on chemical analysis.

It is important to note that in addition to the incidents identified in Table 4.6, materials spilled during any of the numerous other incidents may (or may not) have entered the MS4 and/or receiving waters such as local creeks directly or been washed into the MS4 and/or creeks by stormwater or irrigation runoff. Generally, the spill reports lack any details regarding this type of information.

Table 4.6 Examples of Information Reported on Releases of PCBs to Bay Area Storm Drains and Creeks.

Date	Gallons	Reported Concentration	Water Body	Municipality
1/24/2016	Unknown	<50 ppm	Coyote Creek	San José
2/17/2016	Up to 18	Unknown	Los Gatos Creek	Los Gatos
3/7/2016	10	Unknown	Culvert	Concord
8/16/2016	Unknown	<50 ppm	Guadalupe River	San José
11/17/2015	Unknown	Unknown	Cerrito Creek	Richmond
10/4/2015	5	Unknown	Creek	Los Gatos
5/3/2015	30	<2 ppm	Cerrito Creek	Richmond
3/2/2011	30	Unknown	Unknown Marsh	Menlo Park
6/2/2007	40	Unknown	Pond, Marsh Area	Vallejo
2/28/2006	20	<50 ppm	Calara Creek	Pacifica
5/27/2006	1	Unknown	Unknown Creek	Orinda
10/10/2005	Unknown	Unknown	Coyote Creek	San José
7/23/2005	<15	Unknown	Nearby Creek	Walnut Creek
12/8/2004	Small amount	<50 ppm	Moraga Creek	Orinda
3/7/2004	Unknown	Unknown	Blossom Creek	Calistoga
7/14/2003	8	< 50 ppm	Coyote Creek	San José
2/16/2002	15	Unknown	Napa River	Napa

Causes of OFEE Releases

Cal OES release reports and PG&E records document a number of causes of PCBs releases from OFEE. Most releases can be attributed to one of the following:

- **Equipment Failure**. This is the cause of the majority of the reported releases. Equipment failure in utility vaults has additional potential as an important source of PCBs because OFEE in these vaults may contain more than 100 gallons of oil. More than 50 release incidents were reported for equipment contained in electrical utility vaults during the time period reviewed. A number of these reports noted the presence of water in the vaults in addition to the PCBs oil released. Releases from equipment failure in utility vaults are mostly contained, but Cal OES spill reports document releases of PCBs oil that breached containment, including discharges that reached water bodies.

- **Accidents**. Approximately 20% of reported releases resulted from equipment knocked over by accident. In the distribution system, reports document 50 to 500 gallons released from poles knocked over during car accidents, by construction equipment, and during tree trimming. On rare occasion PCBs releases have occurred during accidents while equipment is in transport.

- **Storms, Fires, and Overheating from High Summer Temperatures**. These factors are the reported cause of more than 10% of the releases from the distribution system.

- **Field Repairs and Fluid Replacement**. The Cal OES database contains records that indicate draining fluids in the field may have been ongoing as recently as 2007, when a report documented that a valve left open from draining a transformer in the field caused a release. In 2016, Daniel Sanchez, who at the time was PG&E's Manager of Hazardous Materials and Water Quality Environmental Management Programs, informed Regional Water Board staff that PG&E does not drain and refill pole mounted PCB transformers in the field any longer; however, it is unclear when this practice ceased, and/or if it still occurs with equipment not mounted on poles.

- **Vandalism**. Between 1997 and 2015, there were at least 25 separate reported incidents of vandalism that resulted in PCBs releases. For example:
  - In 1997, gunshot damage caused the release of 5,000 gallons of oil from a substation transformer and regulators in San Mateo County;
  - In 2011, copper theft at a substation released 750 gallons of oil in Contra Costa County;
  - In 2013, vandalism of pad-mounted transformers resulted in the release of possibly 1,000s of gallons of oil before discovery in San José.

PCBs Concentrations in OFEE Releases

Of the more than 1,200 spill reports that were reviewed, approximately one-third identified the PCBs concentration as unknown or did not provide any information on the PCBs concentration of the spilled material (Figure 4.4). Releases with high PCBs concentrations (> 500 ppm) were infrequently reported, accounting for only 1% of reported spills. Concentrations above 50 ppm represent about 8% of the reported spills. As recently as 2016, failure of a pole-mounted transformer resulted in release of mineral oil with 280 ppm PCBs to surrounding soils and brick structures. For approximately 44% of the reported releases, the PCBs concentration was identified as less than 50 ppm, based primarily on assumptions associated with a "Non-PCB" label. For these 44% of reports, no additional information was provided on PCBs concentrations other than a designation of "< 50 ppm". According to labeling requirements, a "Non-PCB" label indicates the PCBs concentrations in the oil are assumed to be below hazardous waste thresholds of 50 ppm (federal regulations, see Section 3.2.1). However, in most cases, no additional information was provided in the spill reports to indicate how the "Non-PCB" category was arrived at, or whether the federal (> 50 ppm) or state (> 5 ppm in liquid) "Non-PCB" category was assumed.

For the vast majority of these reports, no follow-up chemical analysis results were provided that confirmed the "Non-PCB" designations. In a limited number of reports, follow-up PCBs analysis results were provided for materials that were identified as "Non-PCB" during initial reporting. Generally, these results found PCBs concentrations between 5 and 49 ppm, suggesting that the labels were correctly applied. However, any concentration of PCBs in electrical equipment oils is potentially significant in terms of water quality impacts and implementation of the PCBs TMDL. These results clearly demonstrate that the "Non-PCB" designation represents a threshold that is far too high to necessarily be protective of water quality.

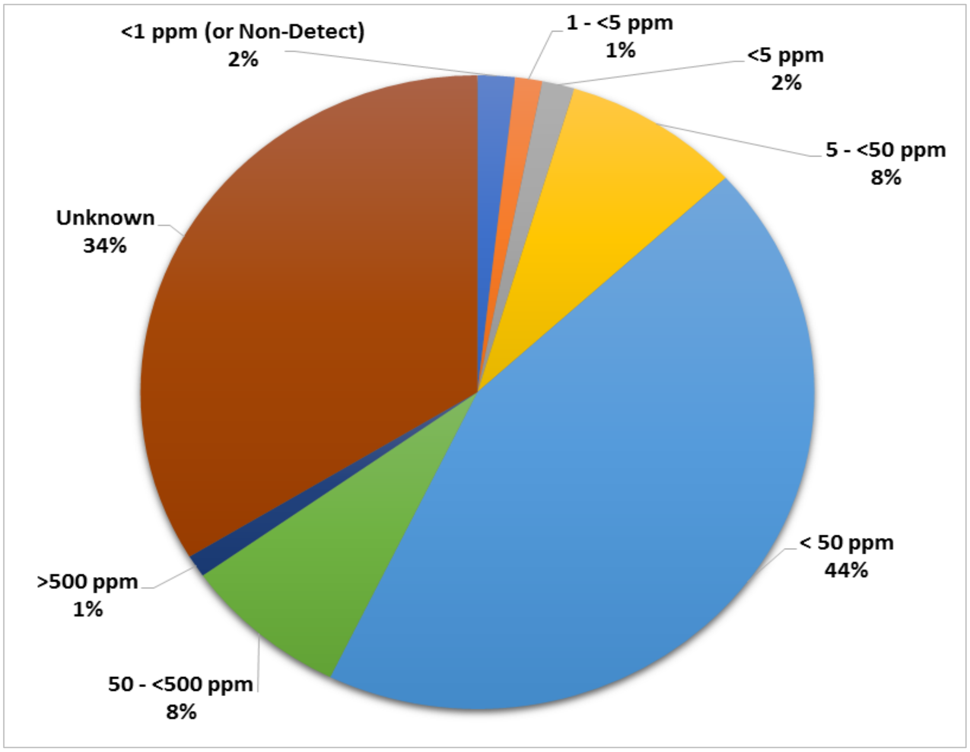

Figure 4.4 PCB Concentration data reported for releases from PG&E electrical equipment between 1993 and 2016. Each category identified above is independent (e.g., the "< 50 ppm category" does not include reports that provided more specific concentration data that was < 50 ppm).

Only 1% of the reported releases identified the PCBs concentrations as either below 1 ppm, or below detection limits. Although the quality of the PCBs concentration data in the release reports varies widely, these results clearly demonstrate that electrical equipment in the Bay Area can still contain PCBs at concentrations of concern for water quality protection programs.

Recommendations

Based on review of reports in the Cal OES database, while they meet the current regulatory notification requirements, the current spill notification and reporting procedures are not adequate to address TMDL goals, and do not provide the Regional Water Board or Bay Area MS4s with the information needed to better quantify and control releases to the MS4.

Review of two municipally-owned utilities' procedures for spill response indicates that all spills, even those of a low PCBs concentration or low volume release, are internally documented even if there is no OES notification requirements. Given that PG&E provided spill reports (pursuant to a 2000 California Water Code §13267 request for information) that were not submitted to OES indicates PG&E also internally documents spills even if they do not need to be reported. Therefore, it is likely that the municipally-owned utilities already have procedures for documenting and recording all spills.

More stringent requirements to address PCBs TMDL goals should include spill response and reporting for all spills/releases from municipally-owned utility OFEE unless there is clear and sufficient evidence available when the spill is initially discovered that unequivocally identifies the equipment involved as having been installed after 1985. This more stringent requirement will ensure that all releases from equipment that could potentially contain PCBs will be reported.

In addition, the information reported in Cal OES database typically captures only the data that were available at the time the spill occurred. Although these reports may provide some preliminary information on the mass of PCBs released (i.e., volume and concentration spilled), these reports rarely provide any corroborating measurement data or any follow-up information on the effectiveness of cleanup activities. This information is needed to quantify PCBs from OFEE releases, or to track where PCBs remain in use in the system. As discussed in Section 3.2.5, any chemical analysis methods should follow the recommendations of the Regional Water Board for congener analysis at sufficiently low reporting levels to capture all concentrations of concern and congeners of concern to address water quality issues (SFBRWQCB 2016).

Bay Area MS4s do not receive timely notification of releases from OFEE. Even for releases that must be reported to Cal OES, electrical utilities do not typically notify local agencies directly. Instead, Bay Area MS4s are responsible for reviewing Cal OES reports in order to identify spills or releases that have occurred in their jurisdictions. This delay is problematic because clean-up actions have likely been completed by the time reports are submitted to Cal OES. Bay Area MS4s should be notified of releases within their jurisdiction as soon as possible so they can provide oversight during initial cleanup efforts, as well as any follow-up that is needed to ensure cleanup was completed to the desired levels. The appropriate local agency staff understand their municipal storm drain systems and how storm drain inlets connect to creeks and water bodies in their jurisdictions. Better communication between utilities and municipal stormwater programs can result in more efficient responses and less impact to waterways.

In summary, to better quantify the amount of PCBs released from OFEE spills, and to help ensure that adequate cleanup actions are being implemented, the following improvements to current reporting and notification requirements could be made:

- Notify Bay Area MS4s of releases within their jurisdiction as soon as possible so they can provide oversight during initial cleanup efforts, as well as any follow-up that is needed to ensure cleanup was completed to the desired levels.
- Respond and report to Bay Area MS4s for all spills/releases from OFEE unless there is clear and sufficient evidence available when the spill is initially discovered that the equipment involved was installed after 1985.
- Any chemical analysis methods should follow the recommendations of the Regional Water Board for congener analysis at sufficiently low reporting levels to capture all concentrations of concern and congeners of concern to address water quality issues.

4.3.2 Spill Response Protocols

Electrical utility companies typically address spills or leaks from their OFEE with Standard Operating Procedures (SOPs) that should conform to both TSCA requirements and the more stringent California hazardous waste rules. The SOPs describe the steps to be taken by field crews in the event of an OFEE leak or spill, which should generally include the following:

- Notify Supervisor or compliance Manager
- Stop and contain the leak
- Determine the spill area (i.e., the area with visible traces of oil plus 1 foot beyond)

- Determine the PCB classification
- Notify property owner
- Notify Cal OES when required

Response to a specific release incident is determined by the PCBs classification of the responsible equipment. The state response level (5 to <50 ppm PCBs) requires immediate clean-up by next business day. The federal response level requires immediate clean-up until clean for spills of 50 to < 500 ppm, and the additional use of all resources to clean the spill immediately for spills > 500 ppm.

The disposal of all materials removed from a cleanup site or used to clean the site are handled according to the TSCA hazardous waste classifications (50 to <500 ppm; and ≥500 ppm in solids or liquids), or the state non-RCRA hazardous waste classification (5 to <50 ppm PCBs in liquids). The allowable post-cleanup concentrations of remaining soils and other surface materials typically range from 10 to 25 ppm, depending on site-specific evaluations of human health risk. As a result, current efforts to control and cleanup PCBs releases from electrical utility equipment are focused on these thresholds.

By comparison, Bay Area municipalities are concerned with much lower concentrations of PCBs. For example, currently Bay Area municipalities generally designate a site as a *potential* PCBs source to stormwater runoff if soil or sediment concentrations are ≥0.5 ppm and designate a site as a *confirmed* PCBs source to stormwater runoff if soil or sediment concentrations are ≥1.0 ppm. Control of PCBs sources at these substantially lower concentrations has been deemed necessary to make progress towards meeting the stringent stormwater runoff wasteload allocations called for in the PCBs TMDL. In addition, post cleanup verification sampling is only required for high concentration spills or high volume spills.

The Cal OES reports provide almost no information on actions taken to stop active spills, or the methods used to cleanup spilled materials from surrounding surfaces, storm drain infrastructure, or creeks. Municipalities need this type of information to better understand any potential risks that remain following initial cleanup. Because of the challenges with achieving the stormwater runoff wasteload allocation in the PCBs TMDL, additional remedial actions may be warranted in some cases.

According to information supplied to the Regional Water Board (PG&E 2000), PG&E spill response is guided by internal documents, including:

- ***Utility Operations Standard D-2320*** - for PCB spills in the distribution system;
- ***PCB Management at Substations -*** for PCB spills in the transmission system.

These documents were not available for review. However, PG&E staff presented the basic elements of their spill response protocol during a public presentation to CCCWP in 2013. PG&E's spill response protocol, as described during this presentation, is summarized here. First, PG&E's spill response is based on the following three guiding principles:

1. Personnel and public safety: isolate or barricade the area from the public; do not do anything to put yourself and others in harm's way.
2. Reporting: report the incident to electric operations.
3. Containment: prevent the spill from spreading using diking or applying absorbents.

Two municipally-owned utilities provided spill response procedures for review. The procedures followed the general guidelines discussed above. In one procedure the cleanup activities included double wash/rinse affected area of the pole and associated equipment. The other procedure expanded this to all solid surfaces such as walls, sidewalks, streets, cars, etc. One procedure called for removing all *visibly* contaminated soil plus one foot buffer zone or to a depth where there are no detectible PCBs. The other procedure called for removing all visibly contaminated soil but only included a one foot buffer for Federal low concentration PCB spills (50-499 ppm). One procedure called for collecting a sample after cleanup activities were completed for all categories of spills but there were no guidelines provided for the sample methods or results. The other procedure only called for cleanup sampling of Federal high concentration PCBs spills (>500 ppm) for comparison with the regulatory cleanup levels. The procedures do discuss containing spills, however, there was no discussion about specific procedures when the spill enters a storm drain system.

Recommendations

Bay Area MS4s need access to all electrical utility spill cleanup procedures to review and provide suggested revisions to ensure all necessary measures and precautions are included to achieve consistency across spill cleanups. Additional spill cleanup procedures suggested by MS4s may also depend on the location and type of spill (e.g., impervious surface vs soil; public right of way vs utility property; proximity to storm drain). Clean-up investigations should not only determine the spill area but determine if soils may have migrated off-site. In addition, samples for cleanup sites should be required for all spills unless there is clear and sufficient evidence available when the spill is initially discovered that the equipment involved was installed after 1985. The samples collected should be compared to thresholds identified by MS4s for *confirmed* PCBs source to stormwater runoff (e.g., soil or sediment concentrations are ≥ 1.0 ppm) in addition to the federal and state post cleanup levels required.

Improved notification of spills/releases to Bay Area MS4s discussed in Section 4.3.1 would also allow municipal stormwater program staff to field verify appropriate spill cleanup procedures as needed.

5.0 Source Control Framework

The overall approach for this SSID Investigation was to conduct a desktop analysis to evaluate electrical utility equipment in municipally-owned electrical utility systems in the Bay Area and propose a source control framework for electrical utility equipment to reduce ongoing PCBs loads to the Bay in stormwater runoff. The elements of the proposed source control framework include development of a new regional Electrical Utilities Management Program which identifies specific actions to reduce the release of PCBs to MS4s, estimates of PCBs loads to stormwater from electrical utility equipment, and development of data inputs that can be used to calculate the PCBs loads reduced through implementation of the new program. This section describes each element of the proposed source control framework for electrical utility equipment. This framework is consistent with MRP Provision C.8.e.iii.(3)(a) requirements for SSID project closure. Implementation of this source control framework will prevent or reduce the discharge of PCBs from electrical utility equipment in the Bay Area.

5.1 Electrical Utilities Management Program

Electrical utility applications present special challenges for source identification and abatement[9] due to the quantity of equipment and facilities, their dispersed nature, and difficulty in sampling discharges when they occur. In addition, municipalities lack control over the vast majority of these properties and equipment. Permittees have no jurisdiction over many large electrical utilities, including PG&E, and therefore no control over the cleanup of PCBs-containing spills (e.g., dielectric fluids from transformers), or prompt notification when they happen. To date, neither Permittees nor the Regional Water Board have been able to verify that a sound and transparent cleanup protocol is used consistently by all electrical utilities for PCBs spills from their electrical equipment across Bay Area cities. Moreover, current state and federal regulatory levels for reporting and cleanup of PCBs spills (e.g., cleanup goals for soils) are higher than cleanup levels recommended by the Regional Water Board to meet the objectives of the PCBs TMDL (SFBRWQCB 2016). There are currently potential missed opportunities to account for load reductions that have been and continue to occur due to the removal of PCBs-containing OFEE through ongoing equipment removal and replacement programs. Furthermore, there are missed opportunities to cleanup spills to the stringent levels that would be more consistent with the PCBs TMDL requirements, and to reduce the loads of PCBs from MS4s to the Bay. Given these constraints and the potential opportunities to reduce PCBs loads from electrical utility equipment, a new regional control measure program is proposed to manage the release of PCBs from OFEE. The Electrical Utilities Management Program described here identifies actions that address OFEE as a source of PCBs to stormwater at a regional level. The Program includes components that can address both municipally-owned and non-municipally-owned electrical utility OFEE in the Bay Area. However, the Regional Water Board will need to use their authority to compel non-municipally-owned electrical utilities (i.e., PG&E) to participate in the Program.

[9] Source identification and abatement is one type of stormwater control measure that Permittees use to reduce loads of PCBs in urban runoff. This control measure involves investigations of properties with elevated PCBs in stormwater or sediment to identify sources that contribute a disproportionate amount of PCBs to the MS4, and cause the properties to be abated, or refer the properties to the San Francisco Bay Water Board or other regulatory authority for follow-up investigation and abatement. This control measure is described in more detail in the BASMAA Source Control Load Reduction Accounting for RAA (BASMAA 2020).

Actions under the new Electrical Utilities Management Program would include the following:

- Action 1: Electrical utilities will document the removal of PCBs-containing OFEE since the start of the TMDL and in the future until all PCBs-containing OFEE have been removed from active service. The documentation should include data to support calculations of the associated stormwater load reductions due to these efforts;
- Action 2: Electrical utilities will implement enhanced spill response and reporting protocols, as needed, to further reduce the mass of PCBs released to stormwater due to accidental releases from PCBs-containing OFEE. The enhanced spill response and reporting protocols should include data gathering requirements that will support calculations of the associated stormwater load reductions due to these efforts.

Implementation of these actions would provide the following benefits: (1) document PCBs loads that have already been avoided due to removal of PCBs-containing OFEE, (2) reduce PCBs loads released to stormwater when spills do occur, and (3) provide information that can be used to determine when this potential source of PCBs to stormwater has been eliminated due to removal of all PCBs-containing equipment from service.

5.2 Estimated PCBs Loads to Stormwater from Electrical Utility Equipment

The starting point for documenting the load reductions that have been and will continue to be achieved through implementation of the new program is an estimate of the PCBs loads to stormwater from electrical utility equipment at the start of the PCBs TMDL. As described in more detail in Section 3.4, McKee et al. (2006) developed a PCBs mass balance model that estimated the total loads to stormwater from all major sources during the peak period of PCBs production and use (i.e., 1950 – 1990), and in the period of the study (i.e., 2005).

The estimated stormwater load of 2.8 kg/yr to the Bay from transformers and large capacitors in 2005, developed by McKee et al. (2006) as part of their PCBs mass balance model described in detail in Section 3.4, is the starting point for estimating load reductions that have been achieved since the PCBs TMDL was established. As shown in Table 5.1, the McKee et al. (2006) mass balance model presents the best estimate for the total PCBs stormwater load from all sources in 2005 as 52 kg/yr. The PCBs TMDL for the San Francisco Bay identifies the total stormwater load at that time as 20 kg/yr (SFBRWQCB 2008). For consistency with the TMDL, the McKee et al. (2006) best estimate for stormwater loads from various sources were normalized to a total stormwater load of 20 kg/yr (Table 5.1). As shown in Table 5.1, the TMDL-normalized PCBs load to stormwater conveyances in 2005 from electrical utility equipment is assumed to be 1.1 kg/yr. This value is one to two orders of magnitude larger than the estimated stormwater loads that were developed in this project based on extrapolation of the municipally-owned electrical utility data presented in Section 4.0 to the larger Bay Area (0.02 – 0.34 kg/yr). However, the stormwater load estimates extrapolated from the participating municipally-owned electrical utility data have some important limitations. There is currently no information available to determine if these estimates, representative of electrical utilities operating across small service areas, would be appropriate as representative of the OFEE and associated PCBs mass across the much larger MRP area. These utility systems service a population of less than 200,000 people, again a tiny fraction (about 3%) of the larger MRP area population of nearly 6 million people. These utility systems also serve an area of less than 30,000 acres, which is (1%) of the entire MRP area of nearly 3 million acres. Almost all of the remaining area is served by PG&E, a large private company that may not be well-represented by data from the three small municipally-owned electrical utilities that participated in this project. There are likely substantial differences between PG&E equipment, operations, and practices, especially in the past, that preclude extrapolating the municipally-owned utility data from this project to PG&E service areas across the Bay Area. The number, type and range of transmission and distribution OFEE that make up a small service area system may not be representative or scalable to the number, type and range of transmission and distribution OFEE that make up a large service area system where electricity must be delivered over larger distances.

There was also considerable variability in the quality and quantity of the OFEE inventory data provided across the three participating municipally-owned utility systems that was used to develop the load estimates in Section 4.0. Island Energy provided complete information on their current inventory but acknowledged there were gaps in the historic data and they could not verify the accuracy or completeness of those data. Neither CPAU nor SVP had information on measured PCBs concentrations in any of their OFEE. SVP, the largest among the three participating utilities, had large uncertainty in their data because of the “unknown” OFEE category. SVP indicated it may be possible in the future to resolve some of these uncertainties. However, within the time frame of this project, SVP provided the data they were able to access. One of the limitations was that compiling these data, especially during the COVID-19 pandemic and shelter-in-place orders, was extremely challenging for the utility staff. This was especially true for data that were limited to hard copies or available only on computer servers located at the electrical utility offices. Under these conditions, SVP was still able to provide useful data on a large portion of their OFEE inventory.

Given the limitations described here, the use of the municipally-owned electrical utility OFEE inventory data to represent OFEE beyond the boundaries of each of the participating systems may not be appropriate. The McKee et al. (2006) TMDL-normalized stormwater load estimate of 1.1 kg/yr remains the best currently available estimate of the PCBs load from electrical utility equipment to the Bay at the start of the PCBs TMDL.

Table 5.1 PCBs mass input to stormwater conveyances in the San Francisco Bay Area from all sources based on the mass balance model presented in McKee et al. (2006). Transformers and Large Capacitors represent the oil-filled electrical utility equipment source.

Source	McKee et al., (2006) PCBs Load (kg/yr)	PCBs Load Normalized to TMDL Stormwater Load (kg/yr)
Watershed Surface Sediment Erosion	30	12
Building Demolition and Remodeling	4.1	1.6
PCBs Still in Use	4	1.5
Bed and Bank Erosion	2.9	1.1
Transformers and Large Capacitors	**2.8**	**1.1**
Atmospheric Deposition	2.8	1.1
Identified Industrial Contaminated Areas	2	0.77
Plasticizers	1.1	0.43
Railway Lines	1.1	0.43
Small Capacitors	0.5	0.19
Auto-Recycling	0.4	0.15
Other Dissipative Uses	0.06	0.023
Lubricants	0	0
Landfills	0	0
Total Stormwater Load (kg/yr)	**52**	**20**

5.3 Data Inputs to Calculate PCBs Loads Reduced

The proposed new Electrical Utilities Management Program identifies actions to document PCBs load reductions that have occurred since the start of the TMDL and will continue to occur in the future due to removal of PCBs-containing OFEE, until all of these equipment have been removed from active service in electrical utility systems in the Bay Area (Action 1). The new Program also identifies actions to document PCBs load reductions due to implementation of enhanced spill response and reporting procedures (Action 2). One of the objectives of the analysis of the municipally-owned electrical utility system OFEE inventory data was to provide information and data inputs that could be used to calculate PCBs loads reduced due to implementation of the Electrical Utilities Management Program. These data inputs are presented below.

5.3.1 Data Inputs to Calculate PCBs Loads Reduced for Action 1

For Action 1 (PCBs-containing equipment removal), the accounting methodology described in the BASMAA Accounting (2020) calculates the PCBs loads reduced by multiplying the PCBs load to stormwater from electric utility equipment by the assumed rate of load reduction achieved over a given period of time due to equipment removals. The data inputs needed for this calculation include the following two terms:

Term 1.1 (L_0) = Estimated annual load of PCBs that enters MS4 from OFEE in the starting year of the time period of interest (i.e., the year that accounting begins, kg/yr).

Term 1.2 (R_1) = Estimated annual average percent of PCBs loads prevented from entering the MS4 due to OFEE removal (percent per year).

Term 1.3 (Y_i) = Number of years in the time period of interest.

The values that are recommended for each of these terms are presented in Table 5.2.

Table 5.2 Recommended values for each of the terms required to account for the PCBs load reductions achieved through implementation of Action 1, removal of PCBs-containing equipment from active service, between 2005 and 2020..

Term	Description	Value	Units	Source
1.1	Annual PCBs Stormwater Load in 2005 (i.e., the assumed load at the start of the PCBs TMDL)	1.1	kg/yr	McKee et. al. (2006)
1.2	Annual average % of loads prevented from entering MS4 due to equipment removals.	1.3 to 4.8 (average = 2.3)	%	Section 4.2.3 (this report)
1.3	Number of years in the time period of interest.	varies	years	N/A

For Term 1.1 the estimated PCBs load of 1.1 kg/yr in 2005 (described in Section 5.2) is the recommended starting value for the annual load of PCBs to stormwater at the start of the PCBs TMDL. This value is currently the best available estimate of PCBs loads to the Bay from electrical utility equipment at that time.

For Term 1.2, the recommended value for the annual average percent of PCBs prevented from entering the MS4 due to OFEE removal ranges from 1.3 % to 4.8 % per year, with an average value of 2.3 % per year (Table 5.2). These values represent the annual average equipment removal rates for the participating municipally-owned electrical utilities presented in Section 4.2.3. These annual average equipment removal rates were calculated based on the mass of oil in pre-1985 OFEE that was removed from service between 2002 and 2019. Use of these values for Term 1.2 assumes the rate of load reduction achieved over the time period of interest is approximately equivalent to the equipment removal rate achieved during that same time period. Further, these values also assume the equipment removal rates for the municipally-owned electrical utilities (Section 4.2.3) reasonably represent the equipment removal rates at other Bay Area electrical utilities (i.e., PG&E). As a check on these assumptions, the load reduction rate between 1990 and 2005 based on the estimate in the McKee et al (2006) mass balance models presented in section 3.4 was compared with the equipment removal rates calculated for municipally-owned electrical utilities that were reported in Section 4.2.3.

The McKee et al. (2006) mass balance models provide PCBs stormwater load estimates for electrical utilities in 2005, and during the peak period of PCBs production and use (1950 – 1990). Based on these estimates, the PCBs load to stormwater from OFEE in 2005 was 65% lower than the average annual load in1990. That equates to a PCBs load reduction of 4.33%

per year during the fifteen-year period between 1990 and 2005. This annual average PCBs load reduction rate compares well with the equipment removal rates at the participating municipally-owned electrical utilities reported in Section 4.2.3. This finding supports the assumption that the equipment removal rates at the participating municipally-owned electrical utilities reasonably approximate the load reduction rates over time. This finding further supports the assumption that most of this load reduction was likely the result of the removal and proper disposal of PCBs-containing OFEE. As described in Section 3.3, during the late 1980s and 1990s, electrical utilities implemented voluntary equipment replacement programs specifically designed to remove PCBs-containing OFEE. Past statements provided to the Regional Water Board by PG&E support the assertion that the majority of PCBs-filled equipment had been replaced by the early 2000's (PG&E 2000). Additional removals have continued to occur, albeit at a slower pace, due to routine maintenance programs that replace older electrical equipment that is more likely to contain PCBs with newer equipment that does not contain PCBs. Information provided to the Regional Water Board by PG&E on maintenance records from their Emeryville processing facility supports this assertion (PG&E 2000). Those data indicate that in 1999, approximately 10% of the 22,000 pieces of OFEE that were dismantled and disposed of at the Emeryville site had PCBs at concentrations at or above 50 ppm. This information further supports the assertion that a large mass of PCBs that were in use during the peak period have since been removed. However, this information also indicates there are still large numbers of equipment that contain PCBs at high concentrations in active service across the Bay Area. Although no information was provided on the percent of equipment that contained PCBs at lower concentrations (i.e., below 50 ppm), equipment with these lower concentrations are also potential sources to stormwater. Current spill reports in Cal OES records further corroborate that PCBs-containing equipment are still in use across the Bay Area, both at concentrations above and below 50 ppm (see Section 3.4.1).

The value for Term 1.3 will vary, depending on the number of years during the time period of interest. For example, to calculate the PCBs loads that have already been reduced due to equipment removals since the start of the PCBs TMDL and the current date (i.e., between 2005 and 2020), the value for Term 1.3 is 15 years.

Assuming the annual average PCBs-containing equipment removal rate remains constant over time, then the current (2020) and future stormwater loads of PCBs from electrical equipment can be estimated along with the associated timeframe to achieve removal of all PCBs-containing equipment. The results are presented in Table 5.3. The calculation starts with the assumed TMDL baseline load of 1.1 kg/yr, multiplied by the annual average load reduction rates presented in Table 5.2 and the 15-year period since the TMDL baseline load estimates in 2005. The results of this calculation demonstrate PCBs loads to stormwater have been reduced by **0.215 kg/yr to 0.792 kg/yr (average = 0.380 kg/yr)**. The resulting Bay Area PCBs stormwater loads from electrical equipment in 2020 ranges from 0.308 kg/yr to 0.886 kg/yr (average = 0.721 kg/yr). Based on these current loading estimates, it will take between 20 and 80 years before all of the PCBs-containing OFEE in the Bay Area have been removed from service.

Table 5.3 Estimated PCBs loads to Stormwater from PCBs-containing oil-filled electrical equipment (OFEE) in the San Francisco Bay Area in 2005 and 2020, based on assumed load reduction rates, and the additional time before all PCBs-containing OFEE are removed from active service.

Equipment Removal Scenario	Estimated PCBs Load to Stormwater in 2005 (kg/yr)	Average Load Reduction Rate per Year (%/year)	Estimated PCBs Loads Reduced since 2005 (kg/yr)	Estimated PCBs Load to Stormwater in 2020 (kg/yr)	Time to Remove all PCBs-containing OFEE from active service (Years)
Low Reduction Rate	1.1	1.3%	0.215	0.886	77
Average Reduction Rate	1.1	2.3%	0.380	0.721	43
High Reduction Rate	1.1	4.8%	0.792	0.308	21

5.3.2 Data Inputs to Calculate PCBs Loads Reduced for Action 2

PCBs loads reduced due to enhanced spill cleanup and reporting (Action 2) can be calculated by multiplying the current annual mass of PCBs released to MS4s due to spills by an enhanced cleanup efficiency rate. The data inputs needed for this calculation include the following 3 terms:

Term 2.1(M_{sp}) = Average annual mass of PCBs released in spills (kg/yr).

Term 2.2 (SW_i) = Estimated percent of spilled PCBs mass that enters the MS4 without the enhanced spill cleanup and reporting protocols.

Term 2.3 (E_f) = Efficiency of the enhanced spill cleanup and reporting protocols to reduce spilled PCBs released to MS4s (percent).

The recommended values for each of the terms above are presented in Table 5.4.

Table 5.4 Recommended values for each of the terms required to account for the PCBs load reductions achieved through implementation of Action 2, enhanced spill cleanup and reporting.

Term	Value	Units	Source
2.1	2.3	kg/yr	Section 5.3.2 (this report)
2.2	1	%	McKee et. al. (2006)
2.3	10	%	Section 5.3.2 (this report)
	25		
	50		

The values in Table 5.4 were developed as described here. First, the ten most recent years of Cal OES spill reports for OFEE in the Bay Area from the 1993-2017 reports discussed in

Section 3.4.1 were reviewed. Between 2008 and 2017, a total of 507 spills of electrical equipment oils were reported. The reports document the total volume of oil spilled as approximately 24,300 gallons. However, most of the reports provided limited or no information on PCBs concentrations. Nearly 50% of the reports identified the PCBs concentration as unknown, and 40% of the reports identified PCBs concentrations as < 50 ppm based on equipment labels. Only 9% of the reports provided information on measured PCBs concentrations in the spilled oils. The reported concentrations spanned a range from 1 ppm up to 720 ppm, with an average of 110 ppm. Given the limited data on concentrations of PCBs in the spilled oils, the mass of PCBs released in these spills is uncertain. Using the average measured PCBs concentration of 110 mg/kg, the average annual mass of PCBs released in spills was calculated as 0.9 kg/yr. However, not all spills are reported to Cal OES. Review of internal PG&E spill reports that were provided to the Regional Water Board for a 7-year period from 1994 to 2000 (PG&E 2000) showed that only 40% of the spills identified in internal records had also been reported to Cal OES during that time period. For the spills not reported to Cal OES, ~30% had measured PCBs concentrations ranging from 1 ppm to 700 ppm, with an average of 113 ppm. Based on this information, the Cal OES reports between 2008 and 2017 represent only 40% of spills, and accordingly increase the estimated total mass of PCBs released during spills to 2.3 kg/yr.

Applying the McKee et al. (2006) assumption that 99% of PCBs released during spills are successfully cleaned, and 1% remain in the environment, then 0.023 kg/yr of spilled PCBs remain in the environment and available for removal in stormwater. Enhanced cleanup protocols that increase the cleaning efficiency by 10%, 25%, and 50% would result in additional removal of between **0.002 and 0.012 kg/yr** of PCBs. These estimates are summarized in Table 5.5. This project did not identify any additional information that could be used to further refine or improve the data inputs shown in Table 5.4 that were used to calculate the potential load reductions due to implementation of enhanced cleanup protocols shown in Table 5.5.

Table 5.5 Estimated annual PCBs load reduction for implementing enhanced spill response and reporting for oil-filled electrical equipment (Action 2).

Scenario	Annual Mass of PCBs released in spills (kg/yr)	Current cleanup efficiency	Current PCBs Load to Stormwater due to spills (kg/yr)	Assumed Improved Cleanup Protocol Efficiency	Annual Load Reduction Due to Improved Cleanup Protocol (kg/yr)
Low	2.3	99%	0.023	10%	0.002
Mid	2.3	99%	0.023	25%	0.006
High	2.3	99%	0.023	50%	0.012

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APPENDIX F

Load Reduction Credit for PCBs in Roadway and Storm Drain Infrastructure Management Program

F.1 BACKGROUND

The BASMAA study *Evaluation of PCBs in Caulk and Sealants in Public Roadway and Storm Drain Infrastructure* (BASMAA, 2018) sampled caulk and sealant materials from public roadway and storm drain infrastructure around the Bay Area. The overall approach to the sampling program was to work cooperatively with multiple Bay Area municipal agencies to identify public right-of-way locations where PCBs were potentially used in caulk or sealant applications on roadway and storm drain infrastructure. These locations were identified primarily based on the time period that the infrastructure was originally constructed and/or repaired, with a focus on the 1970's - the most recent time period PCBs were still in widespread use. The project team collected 54 caulk or sealant samples from public infrastructure in these locations; 11 of these were collected from concrete bridges or overpasses. The Project Team then reviewed the information collected about each sample to determine how to group the samples for compositing prior to PCBs analysis. A total of 20 composite samples were then analyzed for PCBs concentrations. Ten of these composites were associated with concrete roadways, sidewalks, or bridges.

F.2 TOTAL ESTIMATED PCBS LOAD IN OLDER BRIDGES

The U.S. Department of Transportation Federal Highway Administration National Bridge Inventory (USDOT, 2019) was used to estimate the total potential PCBs load contained in older bridges located within the jurisdictions subject to the MRP.

F.2.1 Equations Used to Estimate PCBs Load

The equation used to estimate the total PCBs load contained in bridges built and/or reconstructed prior to 1981 within the jurisdictions subject to the MRP is as follows:

$$\text{Total Load}_{\text{PCBs, Bridges}} = \text{Density}_{\text{sealant}} * \text{Concentration}_{\text{PCBs}} * \sum \text{Volume}_{\text{sealant, bridges}}$$

Where:

$\text{Density}_{\text{sealant}}$ = average sealant density [kg/m^3]

$\text{Concentration}_{\text{PCBs}}$ = empirically derived concentration of PCBs [mg/kg]

$\sum \text{Volume}_{\text{sealant, bridges}}$ = Volume of sealant in all applicable bridges [m^3]

The volume of joint sealant was calculated using an assumed cross-section of sealant, multiplied by the assumed length of applied sealant:

$$\text{Volume}_{\text{sealant, bridges}} = \text{Cross-Section}_{\text{sealant}} * \text{Length}_{\text{sealant}}$$

Where:

$\text{Cross-Section}_{\text{sealant}}$ = Cross-section of applied sealant

$\text{Length}_{\text{sealant}}$ = Length of applied sealant

F.2.2 Data Used to Estimate Load

Data used to estimate load were obtained from BASMAA, 2018; a study of Bay Bridge sealant summarized by Hardeep Takhar of the California Department of Transportation (Caltrans) in 2013; and bridge dimensional information available from the National Bridge Inventory (USDOT, 2019). A summary of the data inputs is provided in Table F-1 below.

Table F-1: Bridge Load Calculation Data Inputs

Input	Result	Units	Source
Density of Sealant	1,100	kg/m^3	Takhar, 2013
Cross-Section of Sealant	1	square inch	Caltrans, 2007
PCBs Concentration	184	mg/kg	See Section 2.2.1

The derivation of the representative concentration of PCBs in sealant applied to bridges is described below.

F.2.2.1 PCBs Concentration

In order to compute a reasonable estimate of the expected PCBs concentration in caulking material in bridges in the MRP area, a data set consisting of 20 composite samples from BASMAA (2018) and four grab samples from the demolition of the Bay Bridge (Takhar, 2013) was analyzed.

Of the 20 BASMAA composite samples, 10 were identified as representative of caulking used on bridges based on the location from which the samples were taken (i.e., five of the composite samples were taken from bridges and five were from concrete roadway surfaces, sidewalks, and curbs and gutters). The remaining composite samples were judged to be non-representative, as they were taken from storm drain structures, asphalt roadways, metal pipes, and electrical utility poles and boxes. Table F-2 below summarizes the BASMAA study results for the concrete roadway, sidewalk, and bridge composite samples (BASMAA, 2018). Table F-3 summarizes the Bay Bridge caulk measurements (Takhar, 2013).

Table F-2: Sample Descriptions and PCBs Concentrations for Roadway and Bridge Composite Samples from the BASMAA Regional Infrastructure Caulk and Sealant Sampling Program (BASMAA, 2018)

<table>
<tr><th>Composite ID</th><th>Total PCBs (mg/kg)</th><th>Type of Structure(s) Sampled</th><th>Caulk/Sealant Application</th><th>Sample Appearance (Color/ Texture)</th><th># of samples in composite</th><th>Sample ID's in composite</th><th>Structure Construction Date</th></tr>
<tr><td rowspan="2">A</td><td rowspan="2">4,967</td><td rowspan="2">Concrete Bridge</td><td rowspan="2">Caulk between expansion joints</td><td rowspan="2">Black Pliable Foam</td><td rowspan="2">2</td><td>10</td><td>1960-70's</td></tr>
<tr><td>13</td><td><1960</td></tr>
<tr><td rowspan="3">B</td><td rowspan="3">4,150</td><td rowspan="3">Concrete Bridge</td><td rowspan="3">Caulk between expansion joints</td><td rowspan="3">Black Pliable</td><td rowspan="3">3</td><td>9</td><td>1960-70's</td></tr>
<tr><td>30</td><td>1960-70's</td></tr>
<tr><td>31</td><td><1960</td></tr>
</table>

Composite ID	Total PCBs (mg/kg)	Type of Structure(s) Sampled	Caulk/Sealant Application	Sample Appearance (Color/ Texture)	# of samples in composite	Sample ID's in composite	Structure Construction Date
C	0.78	Concrete Bridge	Caulk between expansion joints	Brown Fibrous	2	20	1960-70's
						26	1960-70's
D	0.70	Concrete Bridge	Sealant between concrete surfaces or between concrete and wood surface	Black Hard/Brittle	3	27	<1960
						29	1960-70's
						32	<1960
E	ND	Concrete Roadway Surface	Caulk between expansion joints	Black Hard/Brittle	5	35	<1980
						36	<1980
						37	<1980
						38	<1980
						39	<1980
F	ND	Concrete Sidewalk	Caulk between expansion joints	Black Hard/Brittle	3	2	<1960
						7	<1960
						46	<1980
G	ND	Concrete Sidewalk	Caulk between joints	Brown Fibrous	2	16	1960-70's
						17	1960-70's
H	ND	Concrete Sidewalk /Curb/Gutter	Caulk between joints	White/Gray Hard/Brittle or Pliable	3	1	<1980
						8	1960-70's
						18	1960-70's
I	0.06	Concrete Sidewalk /Curb/Gutter	Crack Sealant	White Hard/Brittle or White Pliable	2	23	<1980
						24	<1980
S	2.5	Concrete Bridge	Prefabricated joint filler	Black Pliable	1	12	<1960

A photo log of the samples taken from concrete bridges is provided in Attachment 1.

Table F-3: Concentrations of PCBs in Caulks Measured from the Bay Bridge

Description	Result (mg/kg)
PCBs Concentration (Bay Bridge Upper Roadway Sample)	1.01
PCBs Concentration (Bay Bridge Upper Roadway Sample)	1.65
PCBs Concentration (Bay Bridge Upper Roadway Sample)	0.705
PCBs Concentration (Bay Bridge Roadway Barrier Wall)	3.71
Bay Bridge Average Concentration	1.77

Source: Takhar, 2013

The complete dataset (i.e., results summarized in Table F-2 and F-3 and other non-representative samples) contains 10 non-detect (all in the BASMAA (2018) dataset) and 14 detected values.

After removing the 10 data points considered unrepresentative of bridges, the representative dataset contains 4 non-detect and 10 detected values (i.e., Table F-2 and Table F-3 summarized values). For the purposes of this analysis, both the complete and the presumed representative subset of the PCBs-in-caulk datasets were analyzed independently.

The non-detect values were imputed using a regression-on-order statistics method prior to estimating summary statistics using a maximum likelihood estimation approach as described in the sections below.

F.2.2.2 Handling Censored (Non-Detect) Results

Since estimation of common descriptive statistics of censored datasets can be heavily biased with simply substituted values, a robust regression-on-order statistics (ROS) method, as described by Helsel and Cohn (1988), was utilized to provide probabilistic estimates of non-detects (NDs). When applying the ROS method, ND values are imputed based on their plotting positions relative to the probability distribution estimated from the detected data. Imputed values are always less than their detection limits, but if the dataset includes multiple detection limits, some imputed values may be larger than some of the detected values. For the PCBs-in-caulk dataset, method detection limits (MDLs) for individual samples were not reported, but an overall MDL of 0.05 μg/kg was included in the BASMAA report and NDs are only reported for samples when every individual congener was not detected.

Maximum Likelihood Estimation

The lognormal probability distribution is often used to represent positively skewed contaminant concentrations (Singh et al., 1997). As such, the PCBs-in-caulking dataset has been assumed to arise from a population that is lognormally distributed, which implies that the standard deviation is proportional to the mean and the data are bounded by zero. A random variable, x, is said to be lognormally distributed if the distribution of $y = \ln(x)$ is normally distributed with a mean, μ_y, and variance, σ_y^2. The mathematical equation for lognormal distribution is:

$$f_x(x) = \frac{1}{\sqrt{2\pi}\sigma x} \exp\left[-\frac{1}{2}\left(\frac{lnx-\mu}{\sigma}\right)^2\right] \quad x > 0 \qquad \textbf{Equation 1}$$

Where:

- μ is mean of the untransformed random variable x,
- σ^2 is the variance of the untransformed random variable x, and
- x is the variable of interest.

The lognormal distribution parameters of x are related to the normal parameters of y with the following equations:

$$\mu_x = \exp\left(\mu_y + 0.5\sigma_y^2\right) \qquad \textbf{Equation 2}$$

$$\sigma_x{}^2 = \mu\sqrt{\exp(\sigma_y^2) - 1} \qquad \textbf{Equation 3}$$

When a dataset is a random sample from a lognormal distribution, the Maximum Likelihood Estimate (MLE) of the parameter, μ_y, is simply the sample mean of the log-transformed data

(Singh et al., 1997). Similarly, the MLE of the parameter, σ_y^2, is the sample variance of the log-transformed data. However, for small sample datasets with a few extreme values, such as the PCB-in-caulk dataset, severe transformation bias can occur when estimating the arithmetic mean, μ_x, and arithmetic standard deviation, σ_x. Because of this, an alternative method for computing the expected value is needed as described below.

Advancing the assumption that the sample data arise from a lognormal distribution, a probability weighted mean can be computed as:

$$\hat{\mu}_x = \frac{\sum_{i=1}^{n}(x_i * w_i)}{\sum_{i=1}^{n} w_i} \qquad \textbf{Equation 4}$$

Where:

- $\hat{\mu}_x$ is probability-weighted mean of the untransformed random variable x;
- x_i is the ith sample value; and
- w_i is weight of the ith sample value, which is assumed equal to the probability of occurrence, $p(x_i)$, and can be computed by fitting the data to a lognormal probability density function (PDF).

The lognormal PDF can be constructed by computing the theoretical percentiles and plotting against the probability of a standard lognormal PDF. Any percentile, P_k, of x can be computed using the parameters of y as follows:

$$P_k = \exp(\mu_y + z_k \sigma_y) \qquad \textbf{Equation 5}$$

Where:

- z_k is the kth percentiles of the standard normal distribution.

Results and Conclusions

As stated above, the available data was evaluated in two separate dataset configurations:

1. All data including the potentially unrepresentative values (*N = 24)*
2. Roadway and bridge-only data excluding the potentially unrepresentative values (*N = 14)*.

In both configurations, lognormal distributions were fit to datasets where the non-detect values had been imputed with ROS. Figure F-1 below shows lognormal probability plots along with a best-fit line demonstrating the lognormality of the data.

Table F-4 provides summary statistics after applying ROS to the datasets. As shown, the data mean and data median are significantly different, which again supports the lognormal distribution assumption. The arithmetic mean values computed from Equation 2, however, are unrealistic considering the values are larger than any of the sample values – this is a result of transformation bias. The probability weighted mean values are believed to be the most accurate representation of the central tendency of PCBs in caulk for bridges in the MRP area based on the two datasets because this adjusts for the likely probability of occurrence of the extreme values observed in the data while preserving all sample data in the calculation.

Figure F-2 and Figure F-3 show the PDFs of the best-fit lognormal distributions. Each observed or imputed value drawn along the PDF is used to indicate the probabilities of occurrence, which were used to determine the weights for the probability weighted mean values.

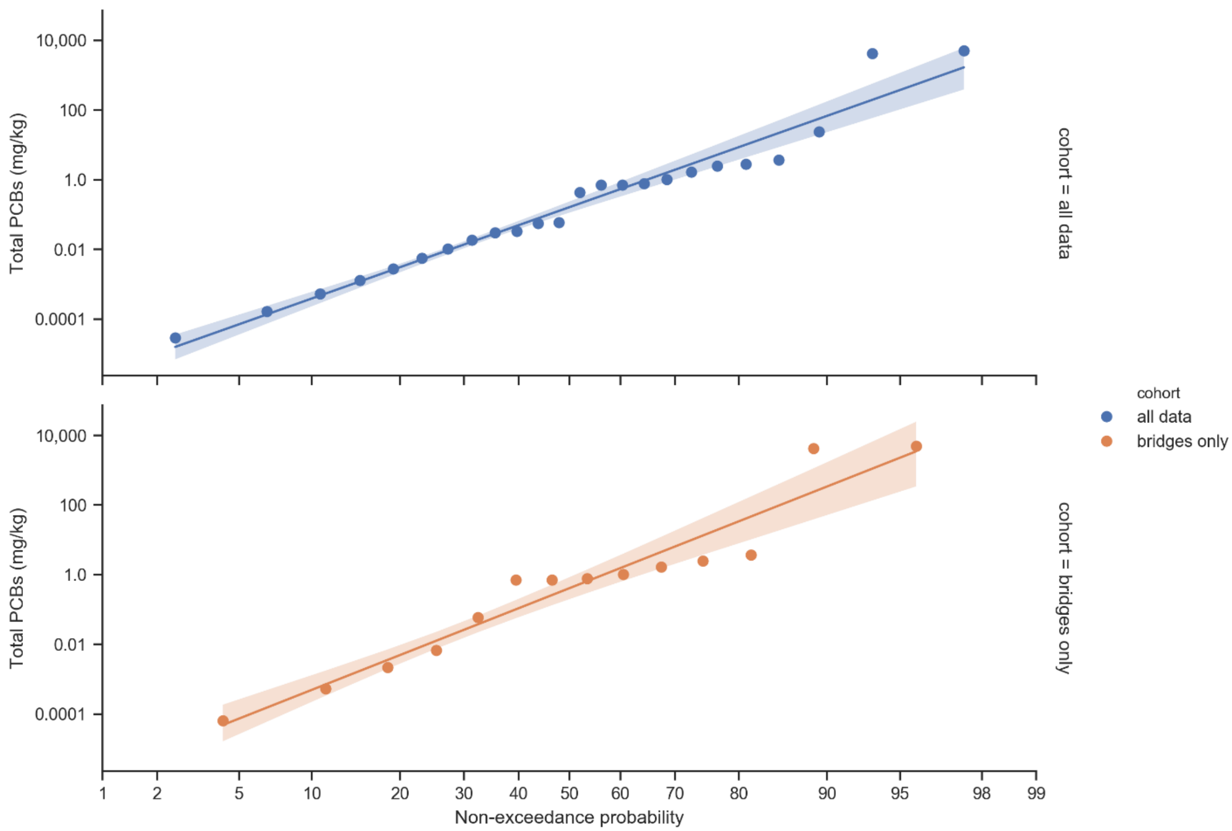

Figure F-1 - Lognormal probability plots. The shaded bands indicate the 95% confidence interval around the best-fit lines.

Table F-4: Summary Statistics

Statistic	Dataset	
	All Data	Roadway/Bridge Only
Sample Count (Total; NDs)	24; 10	14; 4
Data Mean, mg/kg	381	652
Data Standard Deviation, mg/kg	1292	1663
Data Median, mg/kg	0.25	0.74
Lognormal Mean (μy)	-1.82	-0.891
Lognormal Standard Deviation(σy)	4.57	5.02
Arithmetic Mean (μx), mg/kg	8,927	334,514
Probability Weighted Mean ($\hat{\mu}_x$), mg/kg	49.5	184

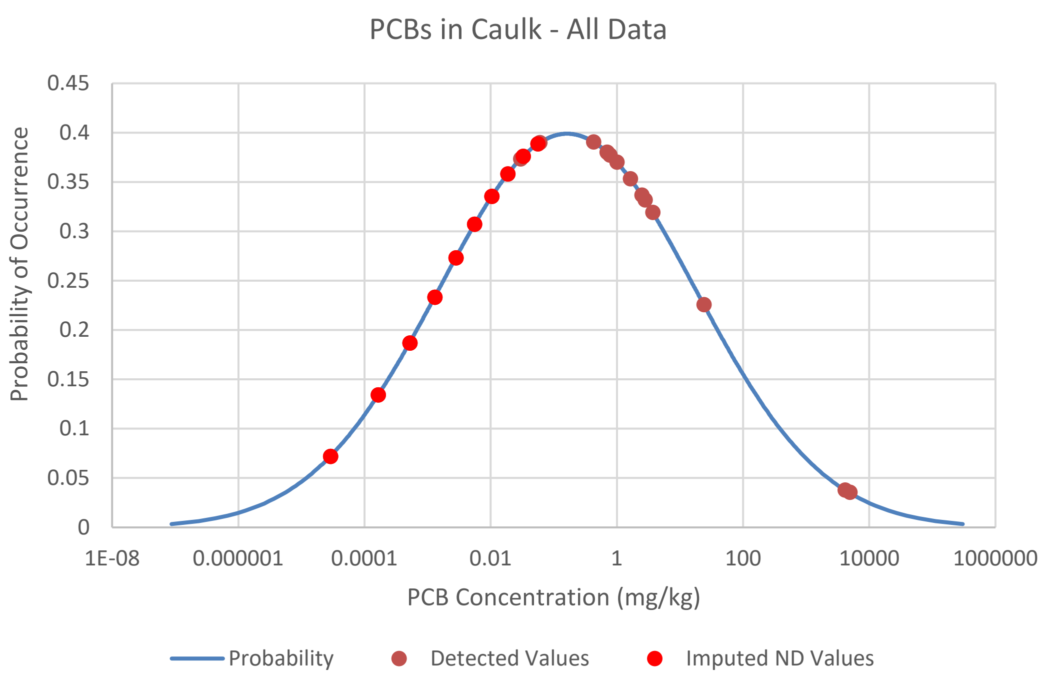

Figure F-2: Lognormal distribution plot for all available Total PCBs data, showing the weights of the detected and imputed values

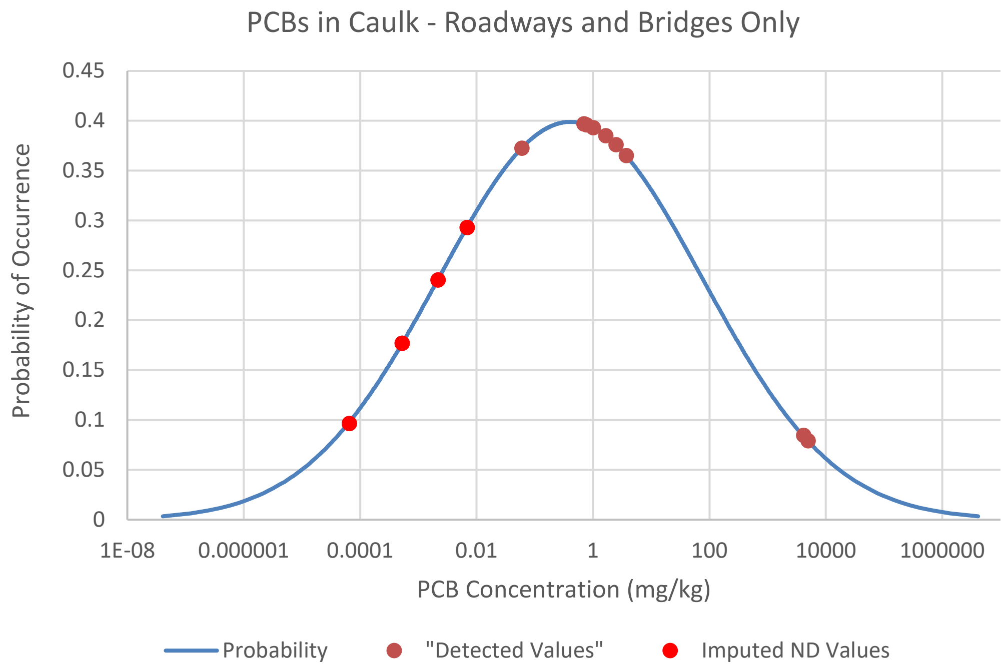

Figure 3: Lognormal distribution plot for Total PCBs data from roadways and bridges only, showing the weights of the detected and imputed values

F.2.2.2 Length of Applied Sealant

While it is evident from the BASMAA (2018) study photos that sealant may be applied to many concrete connections within any given bridge, this estimate focuses on the locations most exposed to weather and traffic and therefore most likely to leach into the environment. The sealant application locations of focus in this study include the bridge expansion joints (e.g., at connections between bridge spans), and the longitudinal seam between the bridge deck and the sidewalk and/or bridge side rail.

The federal bridge database used for this analysis contains information about dimensions of bridges located within the MRP jurisdictions. The length of sealant used to calculate total potential PCBs mass was estimated using database values as follows:

$$Length_{sealant,\ joints} = (N_{span} + 1) * Width_{deck}$$

Where:

N_{span} = The number of bridge spans

$Width_{deck}$ = Bridge deck width

Assuming there are seams along either side of the bridge at the sidewalk or wall, the longitudinal seam was calculated as:

$$Length_{sealant,\ longitudinal\ seam} = 2 * Length_{bridge}$$

F.2.3 Total Estimated PCBs Load in Bridges

A summary of the total calculated loads for bridges within the MRP coverage boundary, built and/or reconstructed prior to 1981, and specific bridge types[11], per the Nation Bridge Inventory, is provided in Table F-5.

Table F-5: Total Calculated Loads for Bridges within the MRP Area, Built and/or Reconstructed Prior to 1981

County	Total Sealant PCBs Mass - Joints Only (kg)	Total Sealant PCBs Mass - Joints and Longitudinal Seal (kg)	Number of Bridges
Alameda	3.8	11.2	340
Contra Costa	1.7	7.3	277
San Mateo	2.5	7.2	254
Santa Clara	3.7	10.1	473
Solano	0.9	3.2	133
Total	**12.6**	**39.0**	**1,477**

The average mass of PCBs in MRP bridges with the characteristics described, based on the calculation, is approximately 8.5 grams, accounting for joint sealant only, and 26 grams, accounting for both joint and longitudinal sealant.

F.3 LONG TERM LOAD REDUCTION ESTIMATE

F.3.1 Methodology

To estimate the load reduction associated with long-term bridge or expansion joint replacement, it is assumed that an ongoing PCBs release rate from bridge joints is mitigated through bridge joint maintenance and whole bridge replacement projects. The load reduction estimation is based on the assumption that PCBs in caulk are leaching from bridge joints and longitudinal seals over their lifetime. When that PCBs-containing caulk is replaced or removed through maintenance or replacement projects, the source of PCBs release is removed, and the associated annual released load is also removed. PCBs leaching from the material could occur through incremental wear or through larger damage (e.g., pieces of caulk torn out) over the lifetime of the caulk.

While volumetric or mass-based losses of joint seals over time were not found in literature, publications that describe joint maintenance and failure were reviewed to justify the assumption of leaching over time. Compression and strip seal type joints, which could potentially be expected to consist of PCBs-containing material, have an expected lifetime of 8 to 16 years, according to a survey conducted for an NCHRP study on bridge joints (NCHRP, 2016). Despite this recommended lifetime, an extrapolated rate of joint replacement in the Bay Area demonstrates that joints are being replaced at a much lower frequency. According to three

[11] 0 – Other; 01 – Slab; 02 – Stringer/Multi-beam or Girder; 03 – Girder and Floorbeam System; 04 – Tee Beam; 05 – Box Beam or Girders – Multiple; or 06 – Box Beam or Girders – Single or Spread.

Permittee preventative maintenance plans available on Caltrans' Highway Bridge Program funding website (Caltrans, 2019), approximately 3% of bridges meeting the characteristics described above are scheduled for joint replacement over the next five-year funding period. An additional 1.5% of bridges are scheduled for replacement over the same five-year period (presumptively replacing the joints). At this rate, replacing the joints via joint maintenance or bridge replacement projects in all 1,477 bridges would take over 110 years.

The concept that older, likely PCBs-containing joints persist in the older MRP bridges is borne out through the findings of the BASMAA (2018) study, which found very high PCBs concentrations in composite samples from a random selection of representative bridge infrastructure. This outcome is also consistent with a finding from a 2003 NCHRP report (NCHRP, 2003), which found through interviews with transportation agencies that "agencies indicated that they tend not to respond to joint problems unless there is a safety hazard or when the deck is being rehabilitated or replaced. Other than reactive efforts, joint repair and rehabilitation, in most agencies, is associated with deck rehabilitation." Additionally, while guidance documents typically define joint replacement needs in terms of visual degradation of the joint, along with other factors, the NCHRP study stated that agencies often defined failure of a deck joint as leakage, physical damage, or traffic hazard. These conditions could be taken to interpret that agencies are only replacing severely damaged or degraded joints (NCHRP, 2003).

Older joints could be considered more likely to leach into the environment, as the sealant material accumulates damage over time. Typical types of joint seal damage described by the Wyoming Department of Transportation, Aeronautics Division Airport Pavement Management Program (2020) include: (1) stripping of joint sealant, (2) extrusion of joint sealant, (3) weed growth, (4) hardening of the filler (oxidation), (5) loss of bond to the slab edges, and (6) lack or absence of sealant in the joint. These damage types are also consistent with those described in NCHRP (2016). Most of these damage types either directly refer to stripping of the sealant from the joint or create a condition in which the sealant is more likely to be released from the joint when subjected to traffic loads (i.e., conditions such as extrusion, hardening/becoming more brittle, loss of bond). Examples of damaged joint seals from this source are provided in Attachment 2.

F.3.2 Load Reduction Calculation

Lacking a literature-based release rate of sealant over time, two potential annual release rates are provided for the load reduction calculation. Based on the assumption that the joint seal may become degraded over time, it is possible that the sealant releases little during the initial operation period and more as the joint sealant ages. Another possible release pathway is through leaching into surrounding concrete and subsequent degradation of the concrete. Two potential average annual release rates (i.e., average over the life of the seal) were assumed to calculate an estimated load reduction from removing the joint seal – 1% and 0.5%. These average annual release rates were applied to the estimated mass for the 1,477 bridges meeting the identified age criteria (Table F-6). These releases would be eliminated through removal of the joint seal through joint replacement or bridge replacement.

Table F-6: Long-Term Load Reduction (i.e., Replacement of PCBs-Containing Joints in All Older Bridges)

County	Total Sealant PCBs Load Reduced - Joints Only (g/year)		Total Sealant PCBs Load Reduced - Joints and Longitudinal Seal (g/year)	
	1% annual loss rate over life	0.5% annual loss rate over life	1% annual loss rate over life	0.5% annual loss rate over life
Alameda	38	19	112	56
Contra Costa	17	8	73	37
San Mateo	25	12	72	36
Santa Clara	37	19	101	50
Solano	9	5	32	16
Total	126	63	390	195

This is the assumed load reduction by 2080, based on the assumption that all older joints will be removed/replaced within 100 years of installation (this is consistent with recent Caltrans replacement frequency calculated above).

F.4 REFERENCES

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Attachment 1: BASMAA Bridge Sample Photos

Composite A

Composite B

Composite S

Composite C

Composite D

Attachment 2: Images of Joint Seal Damage

Joint sealant damage is any condition that enables soil or rocks to accumulate in the joints or allows significant infiltration of water. Accumulation of incompressible materials prevents the slabs from expanding and may result in buckling, shattering, or spalling. A pliable joint filler bonded to the edges of the slabs protects the joints from accumulation of materials and also prevents water from seeping down and softening the foundation supporting the slab. Typical types of joint seal damage are: (1) stripping of joint sealant, (2) extrusion of joint sealant, (3) weed growth, (4) hardening of the filler (oxidation), (5) loss of bond to the slab edges, and (6) lack of absence of sealant in the joint..

Source: Wyoming Department of Transportation, Aeronautics Division Airport Pavement Management Program (https://www.appliedpavement.com/hosting/wyoming/pavement-inspection/pci-review/distresses-pcc/joint-sealant-damage.html)

Severity	Distress Example	Description
Low		Joint sealer is in generally good condition throughout the sample. Joint seal damage is at low severity if a few of the joints have sealer which has debonded from but is still in contact with the joint edge. This condition exists if a knife blade can be inserted between sealer and joint face without resistance.
Medium		Sealant needs replacement within two years. Joint seal damage is at medium severity if a few of the joints have any of the following conditions: (a) joint sealer is in place, but water access is possible through visible openings no more than 1/8 in (3 mm) wide. If a knife blade cannot be inserted easily between sealer and joint face, this condition does not exist; (b) pumping debris are evident at the joint; (c) joint sealer is oxidized and "lifeless" but pliable (like a rope), and generally fills the joint openings; or (d) vegetation in the joint is obvious, but does not obscure the joint opening.

Severity	Distress Example	Description
High		Joint sealer is in generally poor condition over the entire surveyed sample. Sealant needs immediate replacement. Joint seal damage is at high severity if 10% or more of the joint sealer exceeds limiting criteria listed above, or if 10% or more of sealer is missing.

APPENDIX G

Enhanced Inlet Cleaning Efficiency Factor Data Analysis for Storm Drain Inlets with and without Inlet-based Full Trash Capture Devices

G.1 PURPOSE AND APPROACH

The purpose of this appendix is to document findings of analysis conducted to determine the enhanced efficiency factors (EE_f) for sediment removal associated with enhanced storm drain inlet maintenance, including increasing the frequency of storm drain inlet cleaning, and the use of small (inlet-based) full trash-capture (FTC) devices, that are expected to capture larger amounts of trash, sediment and vegetation. First, the pollutant removal efficiency was calculated for the baseline control measure, which was assumed to be annual cleanout of storm drain inlets without FTC devices. The efficiency factors were then developed for the following enhancements: (1) increased frequency of cleanouts at inlets without FTC devices; and (2) twice yearly cleanouts at inlets with FTC devices.

Based on a review of available literature, there are limited data available on the reductions of pollutants (including sediment) associated with different storm drain inlet maintenance frequencies. No studies were found that assessed the reduction of either PCBs or mercury due to enhanced inlet cleaning frequencies. Two studies in particular, Woodward Clyde (1994) and Caltrans (2003), however evaluated the increase in the removal of material (i.e., sediment, vegetation, and trash) from inlets under different cleaning frequencies. Results from both studies indicated that the annual volume of material removed from inlets increased with cleaning frequency.

The Caltrans (2003) *Drain Inlet Cleaning Efficacy Study* was designed to measure the potential increases in material volume/mass and water quality benefits due to increased inlet cleaning frequencies on freeways. The study was conducted from 1996 through 2000. The volume and mass of material removed under annual, biannual, and three times per year cleaning frequencies at 55 to 90 inlets, depending on the year, were measured.

The Woodward Clyde (1994) *Storm Inlet Pilot Study* was conducted in Alameda County in 1993. This study was also designed to measure the potential increases in material volume and mass due to increased inlet cleaning frequencies. A total of 15 inlets draining residential, industrial, or commercial land uses were monitored. The volume and mass of material removed under annual, biannual, quarterly, and monthly cleaning frequencies were measured.

None of the inlets in the two studies identified above were equipped with FTC devices. To evaluate pollutant reductions associated with cleanouts of storm drain inlets equipped with small FTC devices, a recent study (SCVURPPP, 2016) documented cleanout volumes of materials removed from inlets equipped with FTC devices. The SCVURPPP (2016) *Storm Drain Trash Monitoring and Characterization* study focused on litter/trash, but also removed and measured other debris (defined as sediment and vegetation) from 119 inlets equipped with small FTC devices. These devices typically require cleaning frequencies of at least twice per year. Each of the 119 inlets was initially cleaned at the start of the project. The volume of trash and debris that accumulated within the inlets was removed and measured during two subsequent monitoring events. The accumulation period between each monitoring event ranged from four to five months. The data were used to estimate the annual average volumes of trash and debris captured in each inlet. The annual volume of debris removed was converted to a mass using the average density of debris removed from inlets during the Woodward Clyde (1994) study, which was 38 pounds per cubic foot.

The percent increase of annual mass of debris removed from storm drain inlets during cleanouts, as measured in each of the three studies described above, is presented in Figure G-1. Caltrans removals for inlet cleaning without FTC devices appear to be much greater than removal efficiencies measured during the Woodward Clyde study, and therefore may not be realistic for the purposes of developing conservative efficiency factors for load reduction accounting. The Woodward Clyde study results were used to represent the enhanced efficiency due to increased cleanout frequency of storm drain inlets without FTC devices. The results of the SCVURPPP (2016) study indicate that the use of inlet-based FTC devices, combined with an increased cleaning frequency of twice annually, appears to substantially increase the annual mass of debris that is captured and removed from these storm drain inlets during cleanouts.

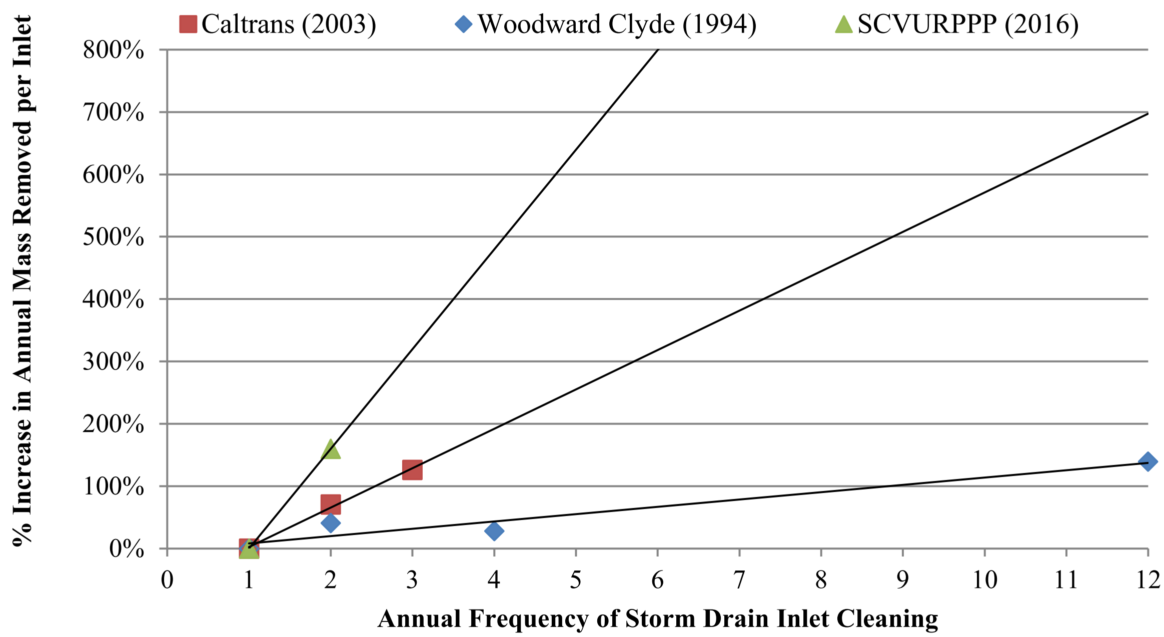

Figure G.1: Reported results of increases in annual mass of debris (e.g., sediment and vegetation) removed as a result of increased cleaning frequency for storm drain inlet with and without small full trash-capture (FTC) devices.

Based on the above findings, Table G-1 presents a conservative estimate of the enhanced efficiency factors for more frequent cleaning of storm drain inlets without FTC devices, and the enhanced efficiency factors for cleaning storm drain inlets equipped with inlet-based FTC devices at least twice per year. For the purposes of load reduction accounting, the method assumes the following:

- Based on an analysis of 36 Alameda County and San Mateo Permittee storm drain inlet cleaning datasets from 1996 through 2009, on average, municipalities clean their inlets once per year (annually);

- Based on the same dataset, an average of 100 kg of material (sediment, vegetation, and litter) is removed from each inlet annually (see descriptive statistics below);

Statistic	Mass (Kg) of Material Removed Annually per Inlet
Maximum	4,049
90^{th} Percentile	476
75^{th} Percentile	284
Mean	268
Geometric Mean	100
Median	91
25^{th} Percentile	41
10^{th} Percentile	21
Minimum	5
# of Municipalities in Dataset	36

- Each inlet (on average) receives drainage from a catchment of 1 acre (BASMAA, 2014), equating to a unit material removal rate of 100 kg per acre per year;
- The mass fraction of material associated with PCBs and mercury yields (i.e., sediment <63um) is approximately 15% on average (McKee et al., 2006);
- The annual suspended sediment load to each inlet is roughly 134 kg per year on average based on the modeled value for Old Urban land use (Paradigm Environmental, 2020, see attachment to Appendix A); and
- Based on the assumptions above, roughly 15 kg of sediment associated with PCBs and mercury is removed from each inlet cleaned on an annual frequency, equating to about a 11% reduction of PCBs and mercury via annual cleaning (i.e., 15 kg / 134 kg). This is the control measure effectiveness of annual cleaning of storm drain inlet without FTC devices.

Assuming the baseline control measure effectiveness for annual cleaning of 11%, data from the studies cited above were used to calculate the enhanced efficiency factors for storm drain inlet cleaning at increasing frequencies for inlets without FTC devices, and twice-yearly cleaning of inlets that have been equipped with small FTC devices, as shown in Table G-1.

Table G-1: Enhanced efficiency factors (EE_f) for increased storm drain inlet cleaning frequencies for storm drain inlets both with and without small full trash-capture (FTC) devices.

<table>
<tr><td colspan="2" rowspan="2"></td><th colspan="4">Enhanced Cleaning Frequency for Inlets without FTC devices</th><th>Enhanced Cleaning Frequency for Inlets with FTC Devices</th></tr>
<tr><td>Annually</td><td>Biannually</td><td>Quarterly</td><td>Monthly</td><td>Biannually</td></tr>
<tr><th rowspan="2">Original Cleaning Frequency</th><td>No Cleaning or New Inlet</td><td>0.11</td><td>0.16</td><td>0.16</td><td>0.27</td><td>0.29</td></tr>
<tr><td>Annually</td><td></td><td>0.05</td><td>0.05</td><td>0.16</td><td>0.18</td></tr>
</table>

E.2 References

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APPENDIX H
Enhanced Street Sweeping Efficiency Factors

H.1 DESCRIPTION OF THE ANALYSIS

The Clean Watersheds for Clean Bay (CW4CB)[12] Task 4 pilot projects evaluated enhancements of municipal operation and maintenance activities that remove sediments and associated pollutants, including PCBs and mercury. This objective coincided with Municipal Regional Stormwater NPDES Permit (MRP, Order R2-2009-0074) Provision C.12.d, which required MRP Permittees to evaluate at the pilot scale in five drainages, ways to enhance existing sediment removal and management practices such as municipal street sweeping, curb clearing parking restrictions, inlet cleaning, catch basin cleaning, stream and stormwater conveyance system maintenance, and pump station cleaning via increased effort and/or retrofits. MRP Provision C.12.d also required Permittees to evaluate existing information on high-efficiency street sweepers, with the goal of evaluating the cost-effectiveness of high-efficiency street sweeping relative to reducing pollutant loads.

Appendix B-1 of the CW4CB Final Report summarizes the results of the Task 4 enhanced street sweeping pilot project that occurred in four pilot study areas (two sites in Richmond and one each in San Jose and Sunnyvale). This study entailed collecting monitoring data in each pilot study area representative of the baseline sweeping condition. The monitoring data were then used to calibrate the Windows Source Loading and Management Model (WinSLAMM) to evaluate sediment, PCBs, and mercury in the pilot study areas. Once WinSLAMM calibrated using the pilot study data, it was used to model street sweeping performance in the pilot study areas during the baseline condition for sediment, PCBs, and mercury. WINSLAMM was also used to model the effectiveness of various street sweeping scenarios for the pilot study areas for removing sediment, PCBs, and mercury. The modeled scenarios included (1) different sweeper types, (2) sweeping frequencies, and (3) street roughness values. The modeled scenarios assumed parking controls were in effect.

The results of the scenario analysis are presented in Tables H-1 and H-2 below for PCBs and mercury, respectively.

[12] For more information, see: http://basmaa.org/Clean-Watersheds-for-a-Clean-Bay-Project.

Table H-1: Change in PCBs Mass Removal Efficiency (%) from Initial Street Sweeping Scenario to Final Scenario

				Final Scenario							
			Sweeper Type	Vacuum							
			Street Roughness	Rough	Intermediate	Rough	Intermediate	Rough	Intermediate	Intermediate	Rough
Initial Scenario	**Sweeper Type**	**Street Roughness**	**Frequency**	Once per 4 weeks	Once per 4 weeks	Once per 2 weeks	Once per 2 weeks	Once per week	Once per week	Twice per week	Twice per week
	None	None	None	9.9%	14%	15%	18%	19%	21%	21%	22%
	Vacuum	Intermediate	Once per week	-11%	-7%	-6%	-3%	-2%	0%	0%	1%
		Intermediate	Once per 2 weeks	-8%	-4%	-3%	0%	1%	3%	3%	3%
		Intermediate	Once per 4 weeks	-4%	0%	1%	4%	5%	7%	7%	8%
		Intermediate	Twice per week	-11%	-7%	-6%	-3%	-2%	0%	0%	1%
		Rough	Once per week	-9%	-5%	-4%	-1%	0%	2%	2%	2%
		Rough	Once per 2 weeks	-5%	-1%	0%	3%	4%	6%	6%	6%
		Rough	Once per 4 weeks	0%	4%	5%	8%	9%	11%	11%	12%
		Rough	Twice per week	-12%	-8%	-6%	-3%	-2%	-1%	-1%	0%

Notes:
1. Change in efficiency resulting from change in sweeping scenario shown in red (reduction in efficiency) and blue (increase in efficiency).

Table H-2: Change in Mercury Mass Removal Efficiency (%) from Initial Street Sweeping Scenario to Final Scenario

				Final Scenario							
			Sweeper Type	Vacuum							
			Street Roughness	Rough	Intermediate	Rough	Intermediate	Rough	Intermediate	Intermediate	Rough
Initial Scenario	**Sweeper Type**	**Street Roughness**	**Frequency**	Once per 4 weeks	Once per 4 weeks	Once per 2 weeks	Once per 2 weeks	Once per week	Once per week	Twice per week	Twice per week
	None	None	None	9.1%	10%	10%	10%	10%	11%	11%	11%
	Vacuum	Intermediate	Once per week	-1%	0%	0%	0%	1%	2%	2%	2%
		Intermediate	Once per 2 weeks	0%	0%	0%	0%	1%	2%	2%	2%
		Intermediate	Once per 4 weeks	0%	0%	1%	1%	1%	2%	2%	2%
		Intermediate	Twice per week	-1%	0%	0%	0%	1%	2%	2%	2%
		Rough	Once per week	-2%	-2%	-2%	-2%	-1%	0%	0%	0%
		Rough	Once per 2 weeks	-2%	-2%	-2%	-2%	-1%	0%	0%	0%
		Rough	Once per 4 weeks	-1%	-1%	-1%	-1%	0%	1%	1%	1%
		Rough	Twice per week	-2%	-2%	-2%	-2%	-1%	0%	0%	0%

Notes:
Change in efficiency resulting from change in sweeping scenario shown in red (reduction in efficiency) and blue (increase in efficiency).

APPENDIX I
Large Trash Capture Device Unit Efficiency Factor Data Analysis

I.1 Purpose and Approach

The purpose of this appendix is to document findings of studies and analyses conducted to determine the effectiveness for removing total suspended solids (TSS), PCBs, and mercury by large (non-inlet-based) trash capture devices, including hydrodynamic separator (HDS) units, gross solids removal devices (GSRDs), and baffle boxes. Other types of non-inlet-based trash capture devices, such as trash netting devices and trash booms, are assumed to remove negligible amounts of sediment, PCBs, and mercury, so are not included in this appendix. Inlet-based devices, including inlet baskets and connector pipe screens, are discussed in Appendix G. For the purposes of load reduction accounting, the method assumes that HDS units, GSRDs, and baffle boxes reduce PCBs and mercury concentrations in direct proportion to TSS reduction.

I.2 HDS Units

Percent Removal of TSS. Percent removal of TSS in HDS units was calculated from the BASMAA Clean Watersheds for a Clean Bay (CW4CB) Task 5 Leo Avenue pilot project data (BASMAA 2017a). For this project, a prefabricated Contech HDS unit called the Continuous Deflective Separator (CDS) was retrofitted into the existing storm drain system in the Leo Avenue Watershed in San Jose.

Influent and effluent water quality was sampled at four events as summarized in Table I-1 below. The CDS unit removed an average of 30% of TSS coming into the unit.

Table I-1: Percent Removal of TSS at Leo Ave CDS Unit

Event	Date	Sample Location	TSS (mg/L)	% Removal
1	28-Feb-14	Inflow	110	17%
		Outflow	91	
2	29-Mar-14	Inflow	230	17%
		Outflow	190	
3	31-Oct-14	Inflow	62	88%
		Outflow	7.5	
4	02-Dec-14	Inflow	82	-3%
		Outflow	84.5	
Average				**30%**

The International Stormwater BMP Database (http://bmpdatabase.org/) was evaluated for potentially useful studies. Twenty studies of manufactured devices were identified as useful for analysis. These studies had a total of 334 paired inflow/outflow data points for TSS. Percent removal was calculated for each paired data point and then averaged for the BMP. The results for these studies along with descriptions of land use type and watershed size and imperviousness are presented in Table I-2 below. Average percent removal ranged from -85% (i.e., an increase in TSS concentration in outflow compared to inflow) to 73% and averaged 19% across all studies (including the City of San Jose’s Leo Avenue unit).

The dataset was also analyzed by removing BMPs that were treating just roads or highways, parking lots, or college campuses. In this scenario, ten studies remained that had mixed, other, or unknown land use type. The average percent removal of TSS from the BMPs evaluated in this group of studies was slightly higher at 22%.

Table I-2: Percent Removal of TSS for Studies in BMP Database

Site and BMP	Device Model	Land Use Type	Watershed % impervious	Watershed Area (ac)	Average TSS % Removal[1]
OP Soccer Complex: PMSU56_40_40	Contech CDS, Model PMSU56_40_10	Parking lots adjacent to soccer fields.	90	3.98	-85%
NW Birch Place CDS unit: Continuous Deflective Separation unit	CDS Unit	Low Density Residential: 47.4% Office Commercial: 42.2% Multi-Family Residential: 10.3%	--	45.0	-14%
Broadway Outfall: CDS Unit	CDS			132	-6%
University of New Hampshire F3: Continuous Deflective Separation	CDS	College Campus: 100%	100	0.32	-5%
Lake O Sediment Demo: CDS Unit	PSW56_53		--	--	-3%
I-210 / Orcas Ave: Orcas	CDS	Roads/Highway: 100%	100	1.11	-3%
USGS_WI_HSD_DD: Hydrodynamic Settling Device	Downstream Defender®, manufactured by Hydro International.		84	1.90	-1%
I-210 / Filmore Street: Filmore CDS	CDS	Roads/Highway: 100%	100	2.50	2%
University of New Hampshire F2: Environment 21 V2B1	Environment 21 V2B1	College Campus: 100%	100	0.32	5%
University of New Hampshire F1: Vortechnics	Vortechnics	College Campus: 100%	100	0.32	13%
USGS_WI_HSD: HSD	Hydrodynamic Settling Device, Contech	The HSD treats a 0.25-acre deck section of the westbound I–794 freeway	100	0.25	26%
Harrisburg Public Works Yard: PAYardTerreKleene	Terre Kleen	--	90	3.21	28%
SC_StructBMP3: BMP3	Vortechnics	BMP3 is located along the westbound lane of S.C. Highway 802	--	--	29%

Site and BMP	Device Model	Land Use Type	Watershed % impervious	Watershed Area (ac)	Average TSS % Removal[1]
Indian River Lagoon CDS Unit: CDS Unit	CDS	Open Space: 38% Light Industrial: 32% Office Commercial: 19%	11	61.5	30%
Leo Avenue: HDS Unit[2]	Contech CDS	--	--	--	30%
SC_StructBMP1&2: BMP2	CDS Technologies	BMP2 is located along the southbound lane of U.S. Highway 21	100	1.11	39%
University of New Hampshire E1: Aqua Swirl	Aqua Swirl	College Campus: 100%	100	0.99	40%
Timothy Edwards Middle School: Vortechs No 5000	Vortechs	--	80	1.95	45%
VC: VC	Vortcapture	Residential area with lots of organic matter/leaf litter loading	--	--	53%
Marine Village Watershed: VortechsTM Stormwater Treatment System	Vortechs	Office Commercial: 50% Medium Density Residential: 45% Unknown: 5%	95	9.34	72%
NJ Manasquan Bank: NJManasquanCDS	High Efficiency Continuous Deflective Separator (CDS), Model 20_25	--	79	0.89	73%

Notes: -- indicates information was not provided.

1. Based on analysis of paired inflow/outflow results.
2. Leo Ave CW4CB study. Not a BMPDB Study.

The manufacturer's removal efficiency claims and the tested removal efficiencies of six of the BMPs evaluated in the studies were summarized as reported in the Massachusetts Stormwater Technology Evaluation Project (MASTEP) clearinghouse database (Table I-3).

Table I-3: Percent Removal of TSS for Six Manufactured Devices from MASTEP

Product (BMP)	Manufacturer	Manufacturer's Removal Efficiency claim	Tested Removal Efficiency
Aqua-Swirl	Aqua Shield	85%	84-87%
CDS	Contech	70%	65-95%
Vortechs	Contech	35-85%	35-64%
Downstream Defender	Hydro International	90%	70%
V2B1	Environment 21	80%	65%

Product (BMP)	Manufacturer	Manufacturer's Removal Efficiency claim	Tested Removal Efficiency
Terre Kleen	Terre Hill	78%	17-50%
Average[1]			56%

Notes: 1. Average based on low end of reported efficiency range.

Based on the above findings, 20% is a conservative estimate of the average percent removal of TSS by HDS units.

Percent Removal of PCBs and Mercury. To further evaluate the pollutant removal performance of HDS units, BASMAA (2019) conducted a combined monitoring and modeling study in 2017 and 2018 based on the removal of solids captured within HDS unit sumps. The Project collected samples of the solids captured and removed from eight different HDS unit sumps during cleanouts. The solid samples were analyzed for PCBs and mercury concentrations. Maintenance records and construction plans for these HDS units were reviewed to develop estimates of the average volume of solids removed per cleanout and the typical number of cleanouts per year. This information was combined with the measured pollutant concentrations to calculate the annual mass of PCBs and mercury captured in the sumps and removed during cleanouts. Next, the annual pollutant loads discharged from each HDS unit catchment were estimated using two different load calculation methods. Method #1 used the land use-based pollutant yields described in the BASMAA Interim Accounting Methodology (BASMAA 2017b) to estimate catchment loads. Method #2 used the Regional Watershed Spreadsheet Model (RWSM, Wu et al. 2017) to estimate runoff volumes and stormwater concentrations and calculate catchment-specific loads. Finally, HDS unit performance was evaluated for both catchment load estimates by calculating the average annual percent removal of PCBs and mercury due to the annual mass removal of solids from the HDS unit sumps. Results are presented in Table I-4.

For catchment loads calculated using Method #1 (land use-based yields), the median percent PCBs removal across all eight units ranged from 5% to 10%, while the mean ranged from 17% to 28%. For catchment loads calculated using Method #2 (RWSM runoff volume x concentration), the median percent PCBs removal ranged from 15% to 32%, while the mean ranged from 23% to 36%. Variability in removal rates was high between individual units, ranging from almost no removal to 100% removal of the estimated loads. For mercury, across all eight units, the median percent removal for catchment loads calculated using Method #1 (land use-based yields) ranged from 3% to 4%, while the mean ranged from 5% to 8%. For all units under Method #1, the removal rates were lower for mercury than for PCBs. For catchment loads calculated using Method #2 (RWSM runoff volume x concentration) the median removal ranged from 13% to 19%, while the mean ranged from 28% to 35%. Similar to PCBs, removal rates for mercury in individual HDS units were highly variable (Table I-4).

Table I-4. HDS Unit Performance - Annual Percent Removal Calculated for Two Catchment Load Estimates.

HDS Unit ID	PCBs Removal				Mercury Removal			
	Method #1		Method #2		Method #1		Method #2	
	Low	High	Low	High	Low	High	Low	High
1	80%	100%	100%	100%	26%	40%	100%	100%
2	8%	18%	10%	22%	4%	6%	65%	98%
3	4%	9%	21%	45%	2%	3%	8%	12%
4	38%	83%	27%	59%	5%	7%	17%	26%
5	0.06%	0.13%	0.21%	0.46%	0.1%	0.2%	1.1%	1.6%
6	5%	11%	20%	43%	0.01%	0.02%	0.1%	0.2%
7	0.6%	1.4%	0.5%	1.1%	0.06%	0.09%	2%	3%
8	1.4%	3.1%	7%	16%	3%	4%	27%	41%
Median	5%	10%	15%	32%	3%	4%	13%	19%
Mean	17%	28%	23%	36%	5%	8%	28%	35%

The BASMAA study results were highly variable and limited by the small sample size. However, pollutant load reductions achieved by HDS units, on average, approach or even exceed 20%, the value identified as a conservative estimate of TSS removal by HDS units in the analysis presented previously. These results support the continued use of a 20% efficiency factor for calculating the annual average PCBs and mercury loads reduced by HDS units.

I.3 Gross Solids Removal Devices

Caltrans conducted the Gross Solids Removal Devices (GSRDs) Pilot Program to develop and evaluate the performance of non-proprietary, full trash capture devices that could be retrofitted into existing highway drainage systems or incorporated into new highway projects (Sobelman et al.). The GSRD Pilot Program consisted of multiple phases with each phase representing one pilot study. The pilot studies consisted of one or more devices that were developed from concept through design and installation, with two years of pilot testing of overall performance. Five phases were constructed and monitored covering eleven designs. Four general types of GSRDs were developed and studied: linear, inclined screen, baffle box, and v-screen. Of the many configurations tested, the most promising devices, based on considerations of particle capture, clogging, passing design flow, drainage, stage capacity and maintenance requirements, were the Linear Radial (louvered modular well casing), the Inclined Screen (parabolic wedgewire screen) and the Inclined Screen (sloped flat wedge-wire screen). The linear radial and inclined screen devices have been certified by the Los Angeles Regional Water Quality Control Board as being full capture devices. Standard designs were developed for these screen systems that provided the best solids removal performance in the pilot tests.

The results of the first phase of the pilot program, which tested the linear radial and inclined screen devices, are summarized in Table I-5 below.

Table I-5. GSRD Unit Performance Observed by Caltrans (2003)

Device Type	Gross Solids Capture Efficiency by Wet Weight (%)	
	2000 – 2001	2001 – 2002
Linear Radial 1 (I-10)	100[1]	100
Linear Radial 2 (I-210)	97	87
Linear Radial 2 (I-5)	94	100
Inclined Screen 1 (SR-170)	100	100
Inclined Screen 2 (I-210)	83[2]	100
Inclined Screen 2 (US-101)	86[2]	73[2]
Average	**93%**	**93%**

Notes:

1 Material collected in the bypass bag was presumed to be windblown.

2 GSRD overflowed. Gross solids escaped the overflow structure and were unaccounted for. As a result, the calculated capture efficiencies are overstated.

Source: Caltrans, 2003.

Based on the above findings and assuming that the mass fraction of material associated with PCBs and mercury yields (i.e., sediment <63 µm) is approximately 15% on average of the captured debris (McKee et al., 2006), then the percent removal of PCBs and mercury by GSRDs is approximately 14% (93% gross solids removal x 15% of captured debris that is associated with PCBs and mercury).

I.4 Baffle Boxes

Baffle boxes are subsurface rectangular vaults that are placed inline in the stormwater system to reduce pollutant loadings by capturing sediments, gross solids, and associated pollutants. Treatment mechanisms typically include filtration, hydrodynamic separation, and adsorption. Several different types of baffle boxes are available commercially and have footprints that vary in size from approximately 10 square feet to over 200 square feet. These subsurface vaults are commonly subdivided into a series of chambers by vertical baffles that interrupt the stormwater flow and promote capture of suspended particles by sedimentation.

The treatment effectiveness of the Nutrient Separating Baffle Box ® (NSBB) by Suntree Technologies has been recently evaluated by the manufacturer to assess the suspended sediment removal efficiency under controlled conditions (Suntree Technologies, 2018). The NSBB contains an additional basket screen that is located above the top of the chamber baffles. The screen captures floating and suspended solids and holds them out of the water column during nonflow periods (Suntree Technologies, 2018). The performance evaluation was conducted on the NSBB model 3-6-72, which has an effective sedimentation area (i.e., footprint) of 18 square feet (6 feet by 3 feet). Additional details of this and other models can be found on the Suntree Technologies, Inc. website. Influent suspended sediment concentrations were measured at 200 mg/L with a median particle size of 100 µm; influent flow rates ranged from 0.35 to 1.75 cfs. Resulting annualized TSS removal efficiency ranged from approximately 51 to 68 percent, with a weighted annualized TSS removal efficiency of 62.9%. The annualized TSS removal efficiency for different flow rates is shown in Table I-6 below.

Table I-6: Nutrient Separating Baffle Box (Model 3-6-72) TSS Removal Efficiency

Mean Flow Rate Tested (cfs)	Measured Removal Efficiency	Annual Weighting Factor	Weighted Removal Efficiency
0.35	67.9%	0.25	16.98%
0.70	65.8%	0.3	19.74%
1.05	63.1%	0.2	12.62%
1.40	56.4%	0.15	8.46%
1.75	50.6%	0.1	5.06%
Weighted Annualized TSS Removal Efficiency			**62.9%**

Source: Suntree Technologies, Inc., 2018

A similar baffle box, the Debris Separating Baffle Box, is sold by Bio Clean. It is assumed that the unit processes in the two proprietary baffle box devices are similar, thus the expected removal efficiencies would be the same.

Based on the above study and assuming that the mass fraction of material associated with PCBs and mercury yields (i.e., sediment <63 µm) is approximately 63% of the captured sediment, then the percent removal of PCBs and mercury by baffle boxes is approximately 40% (63% TSS removal with a median particle size of 100 µm x 63% of material that is associated with PCBs and mercury). Given the limited data available on the effectiveness of baffle boxes in reducing PCBs and mercury, however, and the similarity of the baffle box to the mechanistic removal processes used in HDS systems, a conservative estimate is being used for PCB and mercury reduction for baffle boxes. The pollutant removal efficiency that will be used for baffle boxes is 20%, the same as HDS systems.

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