**Sources, Pathways and Loadings: Multi-Year Synthesis**

**Prepared by**

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**On**

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**For**

**Bay Area Stormwater Management Agencies Association (BASMAA)**

**And**

**Regional Monitoring Program for Water Quality in San Francisco Bay (RMP) Sources Pathways and Loadings Workgroup (SPLWG)  
Small Tributaries Loading Strategy (STLS)**

Table of Contents

# Introduction

* 1. Impetus and objectives of this report
  2. Structure of this report
  3. Overview of the evolution of watershed sources, pathways, and loads information development (pre-2009) and development of the priority management questions, with summary list of other related RMP WG and strategy efforts
  4. Development and implementation of the Small Tributaries Loading Strategy (MRP 1.0)

# Which Bay tributaries (including stormwater conveyances) contribute most to Bay impairment from POCs?

* 1. Where are the sensitive areas (embayments or margins defined by high sediment or biota concentrations or populations) that are disproportionately impacted by pollutant loads?
  2. Which watersheds are disproportionately producing loads?
  3. Which land uses or source areas are disproportionately producing loads?
  4. Which patches or parcels are disproportionately producing loads?
  5. What are the biggest sources of error or uncertainty?

# What are the annual loads or concentrations of POCs from tributaries to the Bay?

* 1. What are the watershed scale concentrations?
  2. What are the watershed scale loads?
  3. What are the regional/sub-regional scale loads?
  4. What are the biggest sources of error or uncertainty?

# What are the decadal-scale loading or concentration trends of POCs from small tributaries to the Bay?

* 1. Where could trend be measured?
  2. What is the appropriate media and metrics upon which to measure trends and what constitutes a suitable baseline against which to measure future changes in relation to management effort and “natural” environmental attenuation?
  3. What data have been collected to-date which may serve as baseline data
  4. What will be reasonable and useful checkpoint for revisiting trends information?

# What are the projected impacts of management actions (including control measures) on tributaries and where should these management actions be implemented to have the greatest beneficial impact?

* 1. What management actions are available and under what scenarios is one action preferable to another?
  2. How effective is each type of management action at reducing POC loads?
  3. Which actions have multiple benefits and what are the multiple benefits?
  4. What are the overall sensitivity/uncertainty issues regarding management actions over the long term?

# Summary and recommendations

# References

# Appendices

**Outline**

Executive summary

[~400 word synthesis of the entire report to provide the reader with an understanding of what we have learned and TMDL implementation drivers (including 2 levels of priority for POCs) why the monitoring and modeling program that supports information development for sources pathways and loads of pollutants in relation to municipal NPDES permits will have a new focus via the next MRP reissuance]

1. Introduction
   1. Impetus and objectives of this report

[~300 word paragraph describing the impetus and objectives of this report in relation to the evolving knowledge and management emphasis in preparation for 2015 MRP 2.0]

* 1. Structure of this report

[~300 word bullet point style overview of the content of the report to guide the reader]

* 1. Overview of the evolution of watershed sources, pathways, and loads information development (pre-2009) and development of the priority management questions, with summary list of other related RMP WG and strategy efforts (see appendix with weblinks for key documents e.g. PCB synthesis & Hg synthesis, RMP Multi-Year Plan, STLS MYP and its appendices)

[~200 word overview paragraph describing the evolution of sources pathways and loads information development to support TMDL development up to 2008 – recognition of the need for the Small Tributaries Loading Strategy]

Figure 1. Map of the Bay and its local (small tributary) watersheds including county boundaries, phase I & II permit boundaries.

* 1. Development and implementation of the Small Tributaries Loading Strategy (MRP 1.0)

[~200 word overview paragraph describing the development and implementation of the Small Tributaries Loading Strategy (MRP 1.0)]

1. Which Bay tributaries (including stormwater conveyances) contribute most to Bay impairment from POCs?
   1. Where are the sensitive areas (embayments or margins defined by high sediment or biota concentrations or populations) that are disproportionately impacted by pollutant loads?

[~300 word paragraph describing what is known about sediment and tissue concentrations around the Bay margin]

Figure 2. a) Concentrations of PCBs sediment and b) concentration of PCBs in small fish tissue.

Figure 3. a) Concentrations of Hg/MeHg sediment and b) concentration of Hg in small fish tissue.

* 1. Which watersheds are disproportionately producing loads?

[~300 word paragraph describing what is known about watershed loads per unit watershed area in 11 tributary watersheds including strengths and weaknesses of the information]

Figure 4. XY scatter plot of watershed area versus yield (mass per unit area) based on field sampling from Water Years 2001 - 2014. A) Runoff, B) Suspended sediment, C) PCBs, D) Total mercury, E. Total methyl Hg.

* 1. Which land uses or source areas are disproportionately producing loads?

[~300 word paragraph describing the current knowledge base about the source area coefficients and the results of the application of the RWSM using uncalibrated coefficients for all land uses and source areas (note this would need to be done with RWSM budget pending SPL/STLS decisions on the workplan for this year) and any similar BASMAA information highlighting strengths and weaknesses of the information]

Figure 5. Map of the Bay Area color coded with estimates of PCB yield. A) Bay Area scale, B) Richmond foot print, C) West Oakland footprint, D) San Jose footprint; E San Carlos footprint.

Figure 6. Map of the Bay Area color coded with estimates of Hg yield. A) Bay Area scale, B) Richmond foot print, C) West Oakland footprint, D) San Jose footprint; E San Carlos footprint.

* 1. Which patches or parcels are disproportionately producing loads?

[~300 word paragraph describing the Yee and McKee 2010 and the more recent RWSM patch analysis based on the then available soil and sediment concentration information and any more recent BASMAA information available highlighting strengths and weaknesses of the information]

Figure 7. Maps of averaged Hg and PCB concentrations (mg/kg) in patches (1.5 km radius circular areas over which site results are averaged) in the Bay Area.

Table 1. Patches (1.5 km radius circular areas over which site results are averaged) with highest average PCB concentrations in Bay Area watershed soils and stormwater conveyance sediments for 15 locations exhibiting the highest average concentrations.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **# Sites** | **Avg\_Hg mg/kg** | **Min\_Hg mg/kg** | **Max\_Hg mg/kg** | **Centroid Y** | **Centroid X** | **Patch description** (centroid nearest cross-streets) |
|  |  |  |  |  |  |  |

Table 2. Patches (1.5 km radius circular areas over which site results are averaged) with highest average Hg concentrations in Bay Area watershed soils and stormwater conveyance sediments for 15 locations exhibiting the highest average concentrations.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **# Sites** | **Avg\_PCB mg/kg** | **Min\_PCB mg/kg** | **Max\_PCB mg/kg** | **Centroid Y** | **Centroid X** | **Patch description** (centroid nearest cross-streets) |
|  |  |  |  |  |  |  |

* 1. What are the biggest sources of error or uncertainty?

[~300 word summary]

1. What are the annual loads or concentrations of POCs from tributaries to the Bay?
   1. What are the watershed scale concentrations?

[~300 word paragraph describing what is currently known about Min Max mean and flow weighted mean concentrations in watersheds around the Bay Area based on funded studies from Water Years 2001 - 2014]

Figure 8. Map of concentrations by sampling site. A) PCBs, B) Total Hg, C) Total methyl Hg. Color code the level of information/confidence (no/low/med/high) or no/some/high

* 1. What are the watershed scale loads?

[~300 word paragraph describing what is currently known about loads in watersheds around the Bay Area based on funded studies from Water Years 2001 - 2014 emphasizing strengths and weaknesses of the information]

Refer to Appendix Table 2.

Figure 9. Figure 8. Map of loads by sampling site. A) PCBs, B) Total Hg, C) Total methyl Hg. Color code the level of information/confidence (no/low/med/high) or no/some/high

* 1. What are the regional/sub-regional scale loads?

[~300 word paragraph describing the history of knowledge evolution and what is currently known about regional and sub-regional scale loads in watersheds around the Bay Area emphasizing strengths and weaknesses of the information]

Table 3. Estimates of long-term average total PCB loads to San Francisco Bay from the main pathways. Note estimates are independent of each other.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Method summary** | **Estimated load (kg)** | | | **Author** |
| **Best** | **Minimum** | **Maximum** |
| ***Large river loads*** | | | | |
|  |  |  |  | Davis et al. (2000) |
|  |  |  |  | Hetzel (2007) |
| ***Urban runoff loads*** | | | | |
|  |  |  |  | KLI (2002) |
|  |  |  |  | Hetzel (2004) |
|  |  |  |  | (Mangarella et al. (2006) |
|  |  |  |  | McKee et al. (2006) |
| ***Non-urban runoff loads*** | | | | |
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|  |  |  |  |  |
| ***Atmospheric deposition loads*** | | | | |
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|  |  |  |  |  |
| ***Municipal and industrial wastewater loads*** | | | | |
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| ***Net erosion of contaminated Bay sediment*** | | | | |
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| --- | --- | --- |
| 2000 knowledge | 2007 knowledge | 2014 knowledge |
|  |  |  |

Figure 8. Summary of the evolution of knowledge of annual average PCB loads entering San Francisco Bay. Note we could annotate main studies that caused each major change in knowledge.

Table 4. Estimates of long-term average total Hg loads to San Francisco Bay from the main pathways. Note estimates are independent of each other.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Method summary** | **Estimated load (kg)** | | | **Author** |
| **Best** | **Minimum** | **Maximum** |
| ***Large river loads*** | | | | |
|  |  |  |  | Davis et al. (2000) |
|  |  |  |  | Johnson & Looker |
| ***Urban runoff loads*** | | | | |
|  |  |  |  | KLI (2002) |
|  |  |  |  | Johnson & Looker |
|  |  |  |  | (Mangarella et al. (2006) |
|  |  |  |  | McKee et al. (2006) |
| ***Non-urban runoff loads*** | | | | |
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| ***Atmospheric deposition loads*** | | | | |
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| ***Municipal and industrial wastewater loads*** | | | | |
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| ***Net erosion of contaminated Bay sediment*** | | | | |
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| --- | --- | --- |
| 2000 knowledge | 2007 knowledge | 2014 knowledge |
|  |  |  |

Figure 9. Summary of the evolution of knowledge of annual average total Hg loads entering San Francisco Bay. Note we could annotate main studies that caused each major change in knowledge.

* 1. What are the biggest sources of error or uncertainty?

[~300 word summary]

1. What are the decadal-scale loading or concentration trends of POCs from small tributaries to the Bay?
   1. Where could trend be measured?

[~300 word paragraph conceptually discussing the options for categories of locations with an emphasis on the rationale for site selection pros and cons associated with each category taking into account spatial proximity to sources and management effort and information gaps]

* 1. What is the appropriate media and metrics upon which to measure trends and what constitutes a suitable baseline against which to measure future changes in relation to management effort and “natural” environmental attenuation?

[~300 word paragraph conceptually discussing the options available taking into account spatial proximity to sources or management effort and temporal variability and the general lack of analysis to determine the appropriate metrics and statistical measures with the exception of Melwani et al 2010 with an emphasis on information gaps]

Table 8. Illustration of possible indicator parameters for measuring in relation to potential trends associated with management effort in small tributaries.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Media** | **Units** | **Period to observe measurable change** | **Advantages** | **Disadvantages** | **Existence of base line data (Yes or No)** |
| Stormwater concentrations | (ng/L) | Unknown |  |  | Yes |
| Stormwater particle ratio | (mg/kg) | A decade for x% change |  |  |  |
| Stormwater load | (kg/month) | Unknown |  |  |  |
| Bed sediment particle concentration | (mg/kg) | Unknown |  |  |  |
| Mass removed | (kg/ year) | Unknown |  |  |  |
| Bio-indicators | (mg/kg tissue dry-weight) | Unknown |  |  |  |
| Surrogate measures | (mg/kg) | Unknown |  |  |  |

* 1. What data have been collected to-date which may serve as baseline data

[~300 word paragraph discussing the available baseline data and information gaps]

Refer to Appendix Table 3.

* 1. What will be reasonable and useful checkpoint for revisiting trends information?

[~300 word discussion of times lines for trends analysis]

1. What are the projected impacts of management actions (including control measures) on tributaries and where should these management actions be implemented to have the greatest beneficial impact?
   1. What management actions are available and under what scenarios is one action preferable to another?

[~300 word paragraph discussing the available management options and what has been learned to date through BASMAA related permit efforts emphasizing information gaps and current directions]

* 1. How effective is each type of management action at reducing POC loads?

[~300 word paragraph discussing the available management options and what has been learned to-date through BASMAA related permit efforts (e.g what conditions or constraints influence effectiveness) and emphasizing a) information gaps such as relative costs and b) current directions]

* 1. Which actions have multiple benefits and what are the multiple benefits?

[~300 word paragraph discussing the available management options and what has been learned to date through BASMAA related permit efforts emphasizing information gaps and current directions]

* 1. What are the overall sensitivity/uncertainty issues regarding management actions over the long term?

[~300 word paragraph discussing the these issues]

1. Summary and recommendations

[~500 word section synthesizing (table or bulleted form) the available knowledge to-date, current strengths and weaknesses of that knowledge and main data gaps and recommendations setting up the basis for the proposed changes to the monitoring program that supports information development for sources pathways and loads of pollutants in relation to the municipal NPDES permit]

1. References
2. Appendices

Appendix Table 1. Summary of concentrations (mg/L, µg/L, ng/L) of PCBs, total Hg, total methyl Hg based the field sampling program to-date at Bay Area sampling locations from Water Years 2001 - 2014.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Watershed location** | **Suspended sediment**  **(mg/L)** | | | | | **PCBs**  **(ng/L** | | | | | **Total Hg**  **(ng/L)** | | | | | **Total methyl-Hg**  **(ng/L)** | | | | | **Reference** |
| Count | min | max | mean | FWMC | Count | min | max | mean | FWMC | Count | min | max | mean | FWMC | Count | min | max | mean | FWMC |
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| ~25 locations |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

Appendix Table 2. Discharge of water and loads of suspended sediment, PCBs, total Hg, total methyl Hg in Bay Area watersheds based on field observations from Water Years 2001 - 2014.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Watershed location** | **Water**  **Year** | **Discharge**  **(Mm3)** | **SS**  **(t)** | **PCBs**  **(g)** | **HgT**  **(g)** | **MeHgT**  **(g)** | **Mean annual loads**  **confidence** | **Likely bias  (High or Low)** | **Main issues** | **Reference** |
| Richmond | 2011 |  |  |  |  |  |  |  |  | Hunt et al |
|  | 2012 |  |  |  |  |  |  |  |  | Gilbreath et al (in prep) |
|  | 2013 |  |  |  |  |  |  |  |  |  |
|  | 2014 |  |  |  |  |  |  |  |  |  |
|  | Est. climate-weighted mean |  |  |  |  |  |  |  |  |  |
| ~11 locations |  |  |  |  |  |  |  |  |  |  |

Appendix Table 3. Amount of baseline data that may possibly be suitable for future trends analysis associated with Bay Area watershed loads and management Large (16+ data points); Medium 8-16 data points); Small (4-7 data points); Very small (3 or less data points); None.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Watershed** | **Stormwater concentrations**  (ng/L) | **Stormwater particle ratio**  (mg/kg) | **Stormwater load** | **Bed sediment particle concentration**  (mg/kg) | **Mass removed**  (kg/ year) | **Bio-indicators**  (mg/kg tissue dry-weight) | **Surrogate measures**  (mg/kg) |
| Guadalupe | Large | Large | Medium | Very small | Documented for riparian removal | None | None |
|  |  |  |  |  |  |  |  |
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| ~25 (perhaps more if we include recent BASMAA efforts) |  |  |  |  |  |  |  |

Perhaps add other information such as watershed size/proportion in relation to total. Could group “watersheds” with similar data profiles in the Medium to Very Small range (e,g, those with one season of recon). Watersheds not included would implicitly have not data available.