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Analysis of Management Strategies for Stormwater Conveyance Systems to Control Input of PCB-Contaminated Sediments to San Francisco Bay

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Problem Statement

PCBs have been found in both the water column and sediments throughout the San Francisco Bay, as shown in Figure 1 *(1)*. In 1998, PCBs were included in the Clean Water Act 303(d) list for all San Francisco Bay segments. This Act requires each state to establish the total pollutant load that a water body can receive each day while still meeting the intended beneficial uses, known as the Total Maximum Daily Loading (TMDL), and to ensure that this limit is not exceeded. The San Francisco Bay Regional Water Quality Control Board is currently in the process of developing the PCB TMDL and its Implementation Plan for San Francisco Bay.

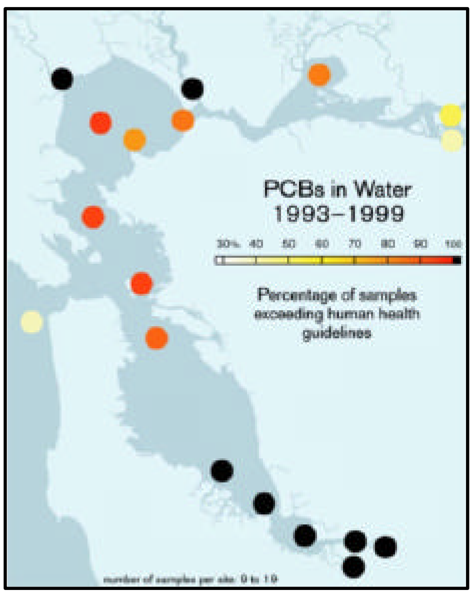

Figure 1. PCB Concentrations in the San Francisco Bay *(1)*

The overall goal of this project was to assist Regional Board staff in preparing the portion of the Implementation Plan regarding stormwater runoff to the Bay. The objective was to develop a methodology to select the optimal management strategy for the elimination of PCB input into the San Francisco Bay from stormwater conveyance systems.

Project Significance

- Information generated from the project will be used in the design of the San Francisco Bay PCB TMDL Implementation Plan.
- The results will help agencies select management strategies to remediate PCB-contaminated sediments in stormwater conveyance systems in a wide range of locations.

Background

PCBs have a biphenyl structure, with ten sites where chlorine can be substituted for hydrogen atoms, resulting in a possible 209 congeners (Figure 2). They were sold under the trade name Aroclor. Due to their chemical stability and high boiling point, PCBs were used widely in industrial and commercial applications, including electrical transformers and capacitors. While the manufacture of PCBs was banned in 1976, products made prior to this date may still contain PCBs. These PCBs may enter the environment through spills, leaks, or other accidental discharges. Once released into the environment, PCBs sorb to soil particles and sediments and can enter the stormwater conveyance systems, subsequently flushing into the San Francisco Bay.

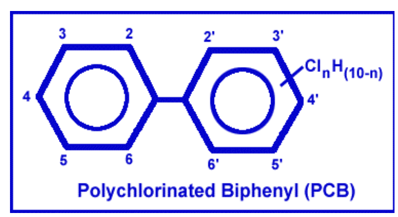

Figure 2. Structure of PCB Molecule *(2)*

PCBs are stable compounds that resist degradation. They are lipophilic and stored in fatty tissue, which

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can result in bioaccumulation in the food web. PCBs can adversely affect the survival rate and reproductive success of fish, birds, and other marine animals through various mechanisms, including thyroid/endocrine tissue malfunction, sex reversal, and reduced fertility. In addition, they have been identified as possible human carcinogens, endocrine disruptors, and immune system disruptors. The main source of human exposure to PCBs is dietary intake, particularly in fish, meat, and dairy products *(3)*.

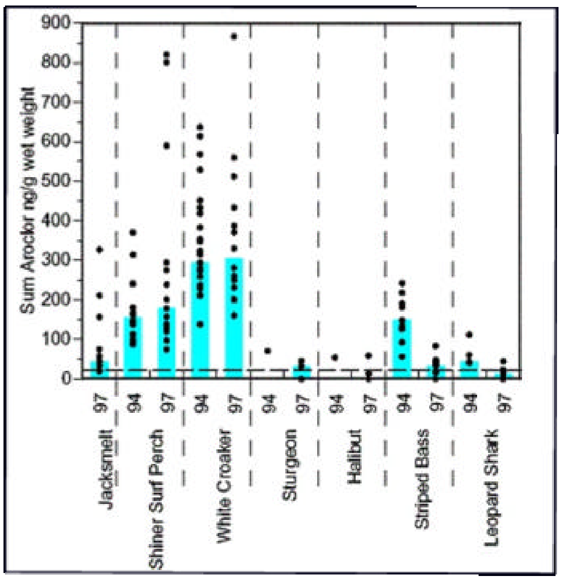


Figure 3. PCB Concentrations in Fish, 1994 and 1997 *(4)*.
Note: The points on the graph are concentrations in each composite sample analyzed. The bars indicate median concentrations. The dashed line indicates the screening value (23 ng/g wet).

In 1994, an interim sport fish advisory for the San Francisco Bay was issued due to multiple chemical pollutants, including PCBs. The concentrations of PCBs in Bay fish are shown in Figure 3 for the years 1994 and 1997.

In May 2000, EPA promulgated numeric water quality criteria for PCBs and other priority toxic pollutants to be applied to waters in California, known as the California Toxics Rule (CTR). In this rule, EPA derived a human health criterion for PCBs of 0.00017 µg/L. In 1997, the CTR was exceeded in 100% of the water samples analyzed in the Bay *(5)*. For this reason, it is important that new inputs of PCBs into the Bay be minimized. The current estimated PCB load contributions to the Bay are shown in Figure 4. As the figure shows, stormwater runoff may be a significant source of additional PCB input to the Bay.

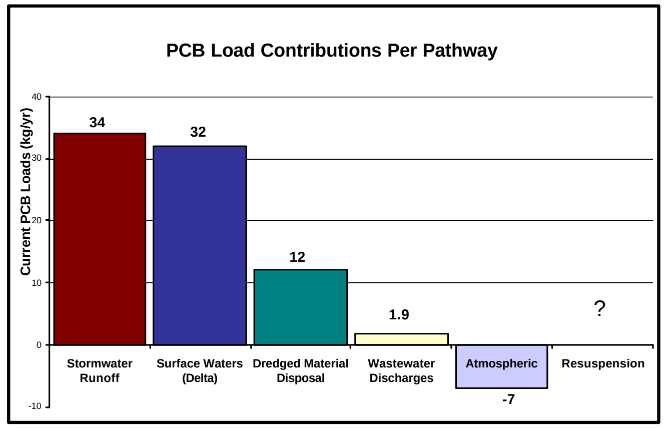


Figure 4. PCB Load Contributions Per Pathway *(6)*.

Approach

To develop a methodology to select the optimal management strategy for the elimination of PCB input into the San Francisco Bay from stormwater conveyance systems, the following tasks were performed:

- Identification of management strategies for PCB-contaminated sediments
- Analysis of these strategies by assessing their effectiveness, cost, social acceptance, environmental impact, and regulatory compliance
- Creation of a ranking matrix based upon the above criteria
- Application of the ranking matrix to a case study
- Performance of a sensitivity analysis to test the robustness of the selected strategy

The Ettie Street watershed in Oakland, California, was selected as a case study for this analysis. Recent sediment surveys have confirmed that, among sources of PCBs from stormwater, the Ettie Street watershed may be a significant contributor of PCB loading to the San Francisco Bay. Within this watershed, the 32nd & Hannah Street catchment has the highest concentration of total PCBs and provides the largest sediment loads to the pump station *(7)*. Figure 5 shows a map of the 32nd & Hannah Street catchment. The analysis of the management strategies was performed using the characteristics of Ettie Street.

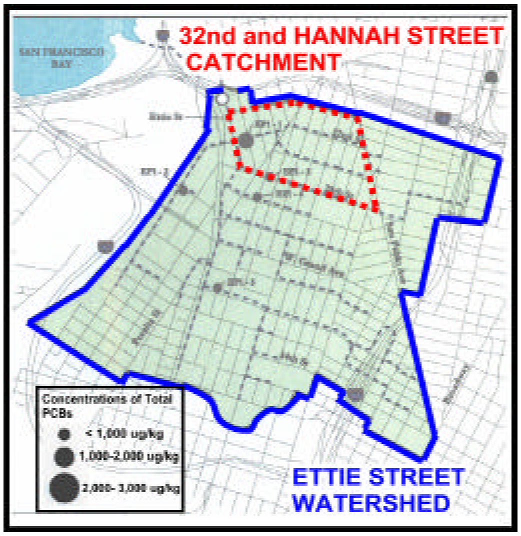


Figure 5. The 32nd & Hannah Street Catchment (catchment borders not to scale) *(7)*.

Identification of Management Strategies

First, all applicable management alternatives, treatment and disposal technologies, and stormwater best management practices (BMPs) were identified.

Management Strategies Evaluated

- **No Action**
- **Natural Attenuation**
- **Confined Aquatic Disposal**
- **Landfill Disposal**
- **In-Bay Disposal**
- **Reuse of Sediments**
- **Best Management Practices**
- **Treatment Technologies**
  - **Destructive Technologies**
    - **Incineration**
    - **Chemical Destruction**
    - **Bioremediation**
  - **Extractive Technologies**
    - **Thermal Desorption**
    - **Soil Washing**
    - **Solvent Extraction**

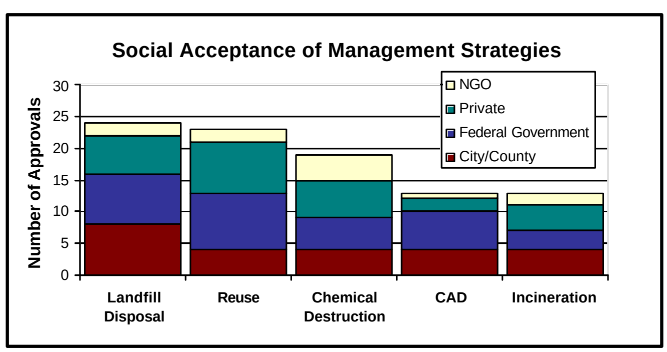
Contaminated sediments can be reused for various activities, including construction activities, such as backfill or raw material for bricks. When reuse is implemented properly, PCBs are no longer bioavailable. Treatment technologies can be utilized after sediments are removed from the stormwater system. These include processes that destroy the PCBs and those that physically separate PCBs from the sediments. Due to the continuous entrance of PCBs to the stormwater system, both structural and non-structural stormwater BMPs were also analyzed for long-term management. However, as the exact amount that BMPs will reduce PCBs within the stormwater system in uncertain, BMPs were not included in the final comparison among management options.

Analysis of Management Strategies

Once the management strategies were identified, an initial assessment was performed based on two criteria: compliance with legal constraints and effectiveness in reaching the cleanup goal. The final target concentration of 2.5 µg/kg for PCBs in sediments, which is proposed for the PCB TMDL, was used for the cleanup goal. Five alternatives satisfied these criteria, including confined aquatic disposal, landfill disposal, reuse of sediments, incineration, and chemical destruction.

Next, each of these five alternatives was analyzed based upon its cost, social acceptance, and environmental impact. For the cost analysis, all individual costs and elements that comprise the total proposed price of any given project were examined. All costs were adjusted to 2002 values using an annual three percent inflation rate from the date of the studies. To compare the proposed alternatives, the expected cash flows were discounted over a five- and ten- year period. Confined aquatic disposal and reuse of sediments had the lowest net present value (NPV) for both the five- and ten-year period.

To assess social acceptance for the various remediation strategies, a questionnaire was distributed to various Bay Area government agencies, private firms, and non-governmental organizations (NGOs). Based on the questionnaire, reuse of sediments and landfill disposal received the highest approval ratings.



The environmental impact of each strategy was assessed through the probability of PCBs or hazardous by-products being released into the environment. Based on this analysis, the reuse of sediments, landfill disposal, and chemical destruction were found to have a low potential environmental impact.

Ranking Matrix for Strategy Evaluation

The results from the analyses of cost, social acceptance, and environmental risk were placed into a ranking matrix that was created to methodically select the most appropriate strategy for the cleanup of PCBs in a conveyance system. Relative weights were assigned to each criterion and the strategies were ranked based on an overall score.

Ranking of Cost, Social Acceptability and Environmental Impact for Management Strategies

Description	Cost	Social Acceptance	Environmental Impact
CAD	3	4	3
Landfill Disposal	2	2	1
Reuse	1	1	2
Incineration	5	5	2
Chemical Destruction	4	3	1

Upon completion of the ranking of the strategies, a sensitivity analysis was performed by varying the weights of each criterion. Three scenarios were used in the sensitivity analysis, allowing examination of the optimal alternative when cost, social acceptance, and environmental impact were in turn designated as the most important aspect.

Results and Recommendations

For the San Francisco Bay Area, this analysis determined that the reuse of sediments for construction purposes and landfill disposal were the optimal management strategies for stormwater conveyance systems. In all three scenarios, reuse of sediments was ranked highest, followed by landfill disposal. The consistency of these results demonstrates the robustness of the analysis.

The reuse of contaminated sediments within legal regulations is recommended for limited applications. The placement of sediment into situations where PCBs are likely to re-enter the environment is not recommended, as this may outweigh the potential benefits of removal. Instead, it would be appropriate to reuse this material only in construction activities that are not prone to erosion or environmental exposure.

Results of Sensitivity Analysis

Highest Weighted Criterion	1st	2nd
Cost	Reuse of Sediments	Landfill Disposal
Social Acceptance	Reuse of Sediments	Landfill Disposal
Environmental Impact	Reuse of Sediments	Landfill Disposal

In addition, BMPs can significantly reduce the sediment loads entering the stormwater systems. This analysis showed that filtration and street sweeping are cost effective and viable options for the Bay Area. The incorporation of BMPs in long-term planning strategies will minimize the need for future management actions and aid in reducing further input of PCBs to the Bay.

It should be taken into account that such a ranking system was based on data gathered for the Ettie Street watershed in Oakland, California, and therefore may change with site-specific characteristics and social acceptance. However, the management strategies evaluated here are applicable for other situations, such as those with higher sediment contamination.

While the selected alternatives may change based upon regional differences, the selection process utilized in this analysis can serve as a guide for numerous other systems in the United States.

References

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