Erler &
Kalinowski,
Inc.

Redwood Creek Characterization Report

Redwood City, California

Volume 1 of 2

Prepared by:

Erler & Kalinowski, Inc.
1870 Ogden Drive
Burlingame, California 94010
www.ekiconsult.com

9 November 2016

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Consulting engineers and scientists

Erler & Kalinowski, Inc.

Consulting Engineers and Scientists

1870 Ogden Drive
Burlingame, CA 94010
(650) 292-9100
Fax: (650) 552-9012

9 November 2016

Ramana Chinnakotla
City of Redwood City
Director of Public Works
1400 Broadway Street
Redwood City, CA 94063

Subject: Redwood Creek Characterization Report
Redwood City, California
(EKI B60048.03)

Dear Mr. Chinnakotla:

Erler & Kalinowski, Inc. ("EKI") is pleased to submit the attached Redwood Creek Characterization Report, which has been prepared at the request of the City of Redwood City. The report summarizes and assesses the results of sediment sampling and surface water bacteriological sampling conducted in Redwood Creek and adjacent slough ("Study Area"). The Study Area is part of San Francisco Bay and is linked to the upland urban watershed by Redwood Creek.

Please call us at (650) 292-9100 if you have any questions or comments regarding this report.

Very truly yours,

ERLER & KALINOWSKI, INC.

Vera H. Nelson, P.E. C47418
Vice President

Andrew N. Safford. P.E. C56084
Project Engineer

cc (Electronic Copy):

Donald Sobelman, Downey Brand, LLP
Nicole Granquist, Downey Brand, LLP
Michelle Marchetta Kenyon; Burke, Williams & Sorenson, LLP

Redwood Creek Characterization Report

City of Redwood City, California
9 November 2016

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Prepared for:

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ACRONYMS AND ABBREVIATIONS

APHA	American Public Health Association
AVS	acid volatile sulfide
Basin Plan	2015 San Francisco Bay Basin Plan
BCDC	Bay Conservation and Development Commission
bgs	below ground surface
bml	below mud line
BPTCP	Bay Protection and Toxic Cleanup Program
BSAF	biota-sediment accumulation factor
COPC	chemicals of potential concern identified in San Francisco Estuary Regional Monitoring Program
CWA	Clean Water Act
CWQC	California Water Quality Council
DDT	dichlorodiphenyltrichloroethane
DHS	Department of Health Services
DTSC	Department of Toxic Substances Control
EDR	Environmental Data Resources, Inc.
EKI	Erler & Kalinowski, Inc.
EqP	equilibrium partitioning
ESA	environmental site assessment
ESB	equilibrium partitioning sediment benchmark
ESL	Environmental Screening Level
FIB	fecal indicator bacteria
ft	feet
GI	gastrointestinal

gpm	gallons per minute
HHRA	human health risk assessment
HI	hazard index
ITRC	Interstate Technology & Regulatory Council
LOE	lines of evidence
LUST	leaking underground storage tank
mg/cm^2	milligrams per square centimeter
MLLW	mean lower low water
NOAA	National Oceanic and Atmospheric Administration
OEHHA	Office of Environmental Health Hazard Assessment
Pacific EcoRisk	Pacific EcoRisk Environmental Consulting and Testing
PAH	polycyclic aromatic hydrocarbon
PBDE	polybrominated diphenyl ether
PCB	polychlorinated biphenyl
PG&E	Pacific Gas and Electric Company
Regional Board	Regional Water Quality Control Board, San Francisco Bay Region
RMP	Regional Monitoring Program
RSL	Regional Screening Level
RWQC	regional water quality criterion
RWQCB	Regional Water Quality Control Board, San Francisco Bay Region
SFEI	San Francisco Estuary Institute
SMCDEH	San Mateo County Department of Environmental Health
SQB	sediment quality benchmarks
SQO	sediment quality objective

STV	Statistical Threshold Value
SWRCB	State Water Resource Control Board
TIE	toxicity identification evaluation
TMDL	Total Maximum Daily Load
TPH	total petroleum hydrocarbons
$\mu g/g_t$	micrograms per gram in fish tissue on a wet weight basis
µg/L	micrograms per liter
$\mu mol/g_{DW}$	micromoles per gram dry sediment
USACE	U.S. Army Corps of Engineers
U.S. EPA	United States Environmental Protection Agency
VOC	volatile organic compound
WQO	water quality objective

1 EXECUTIVE SUMMARY

Erler & Kalinowski, Inc. ("EKI") has prepared this Redwood Creek Characterization Report ("Report") on behalf of the City of Redwood City. The Report summarizes and assesses results of sediment sampling and surface water bacteriological sampling conducted in Redwood Creek and adjacent slough ("Study Area"). The Study Area is part of San Francisco Bay ("Bay" or "Estuary"). Redwood Creek links the upland urban watershed to the Bay. Sediments in Redwood Creek and the slough are generally mud composed of clays and silts that are exposed during low tide (ESA, 2015).

The Study Area and vicinity are used for many purposes, including: industrial, waterfront residential, marina, recreational, open space, and institutional uses. Docktown Marina is situated within Redwood Creek in the Study Area. Docktown Marina contains approximately 70 live-aboard boats and 17 recreational boating berths.

1.1 Sediment Chemistry

Pacific EcoRisk Environmental Consulting and Testing ("Pacific EcoRisk") collected sediment samples within Redwood Creek and the adjacent slough in 2011 within the Study Area (Pacific EcoRisk, 2011). Sediment samples were submitted for laboratory analysis of chemicals of potential concern ("COPCs") that are part of the San Francisco Estuary Regional Monitoring Program ("RMP") for Trace Substances. The San Francisco Estuary Institute ("SFEI") administers the RMP on behalf of the Regional Water Quality Control Board, San Francisco Bay Region ("Regional Board" or "RWQCB"). SFEI compiles data on trace substances in water column and sediment samples collected at established "open water" sites along the central axis of the Bay (RWQCB, 1998a).

Analytical results of sediment samples collected by Pacific EcoRisk from the Study Area indicate the presence of COPCs including polychlorinated biphenyls ("PCBs"), organochlorine pesticides [e.g., chlordane, dieldrin, toxaphene, DDT (dichlorodiphenyltrichloroethane) and its metabolites], metals, organotins, and polycyclic aromatic hydrocarbons ("PAHs"). Many of the COPCs, most notably PCBs and organochlorine pesticides, were detected at concentrations greater than San Francisco Bay ambient (i.e., background) values and screening levels for beneficial reuse of dredged materials.

1.2 Potential Sources of Chemicals in Sediments

Based on the information currently available, the specific sources of COPCs in sediments within the Study Area cannot be determined, but numerous regional and local sources are likely contributors. The Regional Board has determined sediments in the Bay are impacted by regional

sources of PCBs, organochlorine pesticides, mercury, copper, lead, nickel, selenium, zinc, and PAHs (RWQCB, 2015 and 1998).

EKI conducted an environmental site assessment of the Study Area and vicinity in 2015 and 2016 that identified potential local sources of COPCs, including a former chemical mixing facility where pesticides were formulated, several boat yards, multiple leaking underground storage tank sites, a landfill and storage yard, and a Pacific Gas & Electric Company electrical substation. Potential impacts from Docktown Marina also were assessed, but the nature and extent of COPCs detected in sediment indicate Docktown Marina is not a likely source of contamination. Copper and PAHs are most commonly associated with marinas and, therefore, concentrations of those COPCs are expected to be elevated if Docktown Marina were a primary source. However, concentrations of copper and PAHs in sediment samples collected from Redwood Creek are not markedly higher than ambient concentrations at the margins of San Francisco Bay. The same is true for other COPCs except pesticides and nickel, neither of which is generally attributable to marina operations.

The highest COPC concentrations were detected in sediment samples from the slough. The slough is located next to Redwood Creek and less subject to flushing and scouring. Softer sediments are present in the slough, which allowed sediment samples to be collected from deeper depths. Deeper sediments are more likely to reflect chemical impacts from historical activities when use of PCBs, organochlorine pesticides, and other chemicals was prevalent and less regulated. In addition, storm drains that collect surface water and groundwater from the Study Area and upland watershed discharge directly into the slough.

1.3 Potential Sediment Toxicity to Benthic Organisms

Total concentrations of organochlorine pesticides and other COPCs in sediment are greater than ambient values and effects-range medians (“ERMs”). ERMs are empirical screening levels above which acute or chronic toxic effects to benthic organisms are reportedly observed. However, a more refined evaluation of the data utilizing a mechanistic approach, which considers the bioavailability of contaminants, not just total concentrations, indicates adverse effects are unlikely to occur to benthic organisms (e.g., worms, snails, shrimp, sponges, starfish) that inhabit sediment within the Study Area.

The conclusion that COPCs in sediment within Redwood Creek are not detrimental to benthic organisms is supported by examining multiple lines of evidence (“LOEs”) that were relied upon in evaluating sediment quality of Mission Creek in San Francisco. Impacts to Mission Creek are similar to those at the Study Area. These LOEs indicate the COPCs do not result in adverse effects to benthic organisms.

1.4 Potential Sediment Human Health Risks

Persons contacting tidal flat sediments and waters in the Study Area may be exposed to COPCs. Moreover, although COPCs do not appear to be affecting survival of benthic organisms in the Study Area, chemicals considered to be bioaccumulative (i.e., methylmercury, organochlorine pesticides, PCBs, and PAHs) may concentrate within the food chain, which could pose threats to humans that consume fish from the Study Area.

EKI performed a screening level human health risk assessment ("HHRA") to evaluate these concerns. The HHRA provides a general indication of whether a potential risk to human health exists and helps identify areas and chemicals of concern. The HHRA evaluates potential human health risks associated with the two identified potential exposure pathways to detected COPCs in sediment within the Study Area:

- **Beach play scenario:** evaluates potential risks to children/adolescents that play on the tidal flats, or adults that wade in water on the tidal flats and are potentially exposed to COPCs by incidental ingestion of contaminated sediment and dermal absorption of COPCs from sediment that sticks to skin. The beach play scenario was assessed based on a conservative exposure frequency of 65 days per year and an exposure time of 1 hour per day for 26 years[1].

- **Angler fish consumption scenario:** evaluates potential risks to individuals that catch and consume fish (i.e., anglers) in which COPCs from the sediment have bioaccumulated. Mercury, organochlorine pesticides, PCBs, and PAHs are considered bioaccumulative chemicals. The angler fish consumption scenario conservatively assumes that anglers eat 16 grams of fish from the Study Area per day for 26 years[2].

Potential increases in both non-carcinogenic risks and carcinogenic risks to potentially exposed populations are estimated for each exposure scenario. Non-carcinogenic risks are quantified based upon a hazard index ("HI") and considered to be insignificant if the HI is less than 1 (U.S. EPA, 1991). Carcinogenic risks are quantified based upon risk levels (U.S. EPA, 1991). Environmental regulatory agencies, including the U.S. EPA, Regional Board, and DTSC generally use a cancer risk range of 1×10^{-6} to 1×10^{-4} as a "target range" within which to manage human health risk as part of site cleanup.[3] U.S. EPA guidance states impacts that result in a cancer risk

[1] These exposure frequencies were derived from Shoaf et al. (2005) and the U.S. EPA Exposure Factors Handbook (U.S. EPA, 2011).

[2] This consumption estimate is based on California Department of Health Services ("DHS") (DHS, 2000) and U.S. EPA 2014 studies (U.S. EPA, 2014a).

[3] This risk range corresponds to one additional person contracting cancer out of 1,000,000 people exposed to one additional person contracting cancer out of 10,000 people exposed.

range between 1×10^{-6} to 1×10^{-4}, and a non-carcinogenic HI less than 1 do not require cleanup unless adverse ecological impacts warrant action (U.S. EPA, 1991).

For the beach play exposure scenario, results of the HHRA indicate that non-carcinogenic risks are insignificant and incremental carcinogenic risks fall within the target cancer risk range of 1×10^{-6} to 1×10^{-4}. These results indicate cleanup is not required to protect individuals that play on or wade in water on the tidal flats. Further, HHRA results show approximately 65 to 75 percent of estimated incremental lifetime carcinogenic risks associated with the beach play scenario are due to exposure to benzo(a)pyrene, which is a high molecular weight PAH. Benzo(a)pyrene concentrations detected in sediments within the Study Area are, nonetheless, consistent with anthropogenic background concentrations in the Bay. Therefore, estimated human health risks associated with the beach play scenario are similar to those that would be calculated from exposure to sediments throughout the Bay. Risks associated with benzo(a)pyrene are not unique to Docktown Marina or the Study Area, and do not warrant further investigation or remediation.

For the angler scenario, the results of the HHRA indicate that COPC concentrations detected in sediment within the Study Area may bioaccumulate in fish consumed by humans to unacceptable levels (i.e., between 1.1×10^{-4} and 1.4×10^{-4} cancer risk, which is above the target cancer risk range of 1×10^{-4} to 1×10^{-6}). However, this estimated risk should not be interpreted as an actual risk, because the HHRA results are based on exposure assumptions and biota sediment accumulation factors ("BSAFs") obtained from studies and not site-specific data. The HHRA results indicate only the potential for risk due to consumption of fish from the Study Area. However, that risk is not attributable to activities at Docktown Marina.

The Office of Environmental Health Hazard Assessment ("OEHHA") has issued fish consumption advisories that pertain to San Francisco Bay for all bioaccumulative COPCs, except PAHs, that were detected in sediments within the Study Area. In the absence of additional information, OEHHA fish consumption advisories should be followed for all fish caught within the Bay, including in the Study Area. EKI's review of available studies indicates PAHs are rarely detected in fish from San Francisco Bay, let alone at concentrations that would pose a threat to human health.

1.5 Surface Water Bacteriological Assessment

Surface water bacteriological sampling was conducted within Redwood Creek and the adjacent slough in July 2016 and August 2016. The objective of this sampling was to evaluate the possible presence of pathogenic microorganisms (e.g., bacteria, viruses, and protozoans) associated with fecal waste in surface water within the Study Area. The presence of such pathogenic microorganisms in surface waters is not uncommon and can be associated with various sources including: wildlife, storm water runoff, sanitary sewer systems, vessels (recreational, live-aboard and anchor-out boats), and wastewater treatment plants.

Fecal contamination in surface water can cause gastrointestinal ("GI") illness and less often identified respiratory illness in humans who are exposed to surface waters during recreational activities such as swimming, wading, boating (U.S. EPA, 2012a). Surface water samples were collected over a 30-day period and analyzed for selected fecal indicator bacteria ("FIB"). FIB are bacterial groups or species that are naturally found in the guts of warm-blooded animals (including humans) and are excreted in high densities in the feces of such animals (U.S. EPA, 2014b). Surface water samples were collected upstream and downstream of Docktown Marina during various tidal cycles to assess potential bacteriological impacts to surface water, if any, of live-aboard boats that are berthed at Docktown Marina.

FIB results from the Study Area were compared to central tendency (e.g., geometric mean) and acute water quality objectives ("WQOs") identified within the San Francisco Bay Basin Plan ("Basin Plan") and U.S. EPA recreational water quality criteria ("RWQC") for water contact recreational uses such as swimming, wading, and surfing (REC 1) and non-contact water recreation uses such as boating, picnicking and beachcombing (REC 2) (RWQCB, 2015). Both REC 1 and REC 2 are identified as beneficial uses of Redwood Creek and the adjacent slough within the Basin Plan.

FIB results from sampling conducted in the Study Area over the 30-day sampling period did not exceed central tendency WQOs (i.e., geometric mean) for either REC 1 or REC 2 uses (RWQCB, 2015). Sporadic exceedances of Basin Plan acute WQOs and U.S. EPA acute RWQC occurred during ebb currents when water was flowing toward San Francisco Bay at sampling locations collected at the mouth of Redwood Creek, which is adjacent to Docktown Marina. Results from subsequent sampling events showed exceedances did not persist into the next tidal cycle, which indicates that tidal action within the Study Area effectively flushes out sporadic bacteriological impacts.

Sporadic exceedances of Basin Plan acute WQOs and U.S. EPA acute RWQC are not uncommon at San Francisco Bay beaches. The Regional Board (2013, 2010) has identified sanitary sewer systems, storm water runoff, vessels, wildlife, and wastewater treatment plants as potential sources of bacteria detected in San Francisco Bay.

U.S. EPA considers central tendency objectives more relevant (than single sample criteria) for ensuring that appropriate actions are taken to protect and improve water quality (U.S. EPA, 2004). When data from all sampling locations are considered as a whole, none of the FIB excursion frequencies exceeded the allowable value of 10 percent over the 30-day period. Therefore, although sporadic exceedance of FIB acute criteria occurred, the FIB results for this 30-day period do not indicate that Basin Plan WQO for REC 1 use or U.S. EPA acute RWQC for the overall Study Area are being exceeded. These results pertain to summer months when surface water runoff from Redwood Creek is limited. Additional sampling would be required to assess long-term compliance with these criteria, particularly during winter months, when urban runoff often

contains greater concentrations of bacteria. However, given that marina operations are not expected to vary seasonally, the data obtained are adequate to conclude Docktown Marina is not a significant source of bacteriological impacts to surface water.

2 INTRODUCTION

Erler & Kalinowski, Inc. ("EKI") has prepared this Redwood Creek Characterization Report ("Report") at the direction of the City of Redwood City. The Report summarizes the findings of sediment and surface water bacteriological sampling in Redwood Creek and the adjacent slough. ("Study Area").

2.1 Study Area and Vicinity

The Study Area is part of San Francisco Bay ("Bay" or "Estuary"). Open waters are primarily located on the north side of the Study Area, connecting to an expansive wetland complex that includes Bair Island and Don Edwards National Wildlife Refuge (Figure 2-1).

Redwood Creek links the upland urban watershed to San Francisco Bay. Redwood Creek flows from the north side of Redwood City under U.S. Highway 101/Bayshore Freeway and is tributary to an adjacent slough. Three storm water drain systems are within the Study Area, all of which discharge into the slough.

Sediments in Redwood Creek and the slough are generally mud composed of clays and silts that are exposed during low tide and provide shorebird foraging habitat. Birds that use this habitat include the western grebe (*Aechmophorus occidentalis*), canvasback (*Aythya valisineria*), and Forster's tern (*Sterna forsteri*). The habitat found in the Study Area also supports a diversity of invertebrates and is considered a suitable foraging area for a number of fishes, including Pacific herring (*Clupea pallasii*), Sacramento splittail (*Pogonichthys macrolepidotus*), and jacksmelt *(Atherinops californiensis*) (ESA, 2015)

The Study Area and vicinity is used for many purposes, including: industrial, waterfront residential, marina, recreational, open space, and institutional uses (i.e., San Mateo County Women's Correctional Facility, Maple Street Shelter, Redwood City Police Station, and Maple Street Correctional Facility). Docktown Marina is situated within Redwood Creek. Docktown Marina contains approximately 70 live-aboard boats and 17 recreational boating berths.

2.2 Sediment Chemistry

Pacific EcoRisk Environmental Consulting and Testing ("Pacific EcoRisk") performed sediment sampling within the Study Area in 2011 (Pacific EcoRisk, 2011) (Appendix A).[4] Sediment

[4] The sampling was conducted following guidance for dredged material assessments to support potential future applications to the U.S. Army Corps of Engineers ("USACE") and San Francisco Bay Conservation and Development Commission ("BCDC") for 10-year permits and a Regional Water Quality Control Board water quality certification for dredging of the creek channel to facilitate small craft navigation. To accommodate small craft navigation and

samples were submitted for laboratory analysis of chemicals of potential concern ("COPCs") that are part of the San Francisco Estuary Regional Monitoring Program ("RMP") for Trace Substances. The San Francisco Estuary Institute ("SFEI") administers the RMP on behalf of the Regional Water Quality Control Board, San Francisco Bay Region ("Regional Board" or "RWQCB"). SFEI compiles data on trace substances in water column and sediment samples collected at established "open water" sites along the central axis of the Bay (RWQCB, 1998a).

Analytical results of sediment samples collected from the Study Area indicate the presence of COPCs including polychlorinated biphenyls ("PCBs"), organochlorine pesticides [e.g., chlordane, dieldrin, toxaphene, DDT (dichlorodiphenyltrichloroethane) and its metabolites], metals, organotins, and polycyclic aromatic hydrocarbons ("PAHs"). Many of the COPCs, most notably PCBs and organochlorine pesticides, were detected at concentrations greater than San Francisco Bay ambient (i.e., background) values, sediment quality benchmarks ("SQBs"), and screening levels for beneficial reuse of dredged materials.

This Report identifies potential sources of COPCs and examines whether Docktown Marina is a primary source of these COPCs. It also examines whether COPC concentrations conflict with State Water Resource Control Board ("SWRCB") sediment quality objectives ("SQOs") for protection of aquatic life[5] and human health.[6]

2.3 Surface Water Bacteriological Assessment

Surface water bacteriological sampling was conducted within Redwood Creek and the adjacent slough in July and August 2016. The objective of this sampling was to evaluate the possible presence of pathogenic microorganisms (e.g., bacteria, viruses, and protozoans) associated with fecal waste in surface water within the Study Area. The presence of such pathogenic microorganisms in surface waters is not uncommon and can be associated with various sources including: wildlife, storm water runoff, sanitary sewer systems, vessels (recreational, live-aboard and anchor-out boats) and wastewater treatment plants. Fecal contamination in surface water can cause gastrointestinal ("GI") illness and less often identified respiratory illness in humans who are exposed to surface waters during recreational activities such as swimming, wading, boating (U.S. EPA, 2012a).

berthing, dredging of an approximately 50 feet ("ft") channel within Redwood Creek to a depth of –7.0 ft mean lower low water ("MLLW") + 1.0 ft over dredge would be required (Pacific EcoRisk, 2011).

[5] SQO for aquatic life protection states "Pollutants in sediments shall not be present in quantities that, alone or in combination, are toxic to benthic communities in bays and estuaries of California."

[6] SQO for human health states "Pollutants shall not be present in sediments at levels that will bioaccumulate in aquatic life to levels that are harmful to human health."

Surface water samples were collected upstream and downstream of Docktown Marina during various tidal cycles to assess potential contribution, if any, of live-aboard boats that are berthed at Docktown Marina.

2.4 Report Reliance

This report is for the sole benefit, use and reliance of City of Redwood City. Unless specifically authorized in writing in an agreement acceptable to EKI at its sole discretion, use of or reliance on this report by any other entity is not permitted or authorized. Reliance on or use of this report by any third party without written authorization by EKI does not make such entity a third party beneficiary of this report. Any such unauthorized reliance on, modification of, or use of this report, including any of its information or conclusions, will be at such third party's sole risk.

3 SEDIMENT CHEMISTRY

Pacific EcoRisk obtained sediment samples from Redwood Creek and the adjacent slough within the Study Area in 2011. Three sets of composite samples (RWC-A1, RWC-A2, and RWC-A3) were collected and analyzed for COPCs. The locations of these composite samples are shown on Figure 3-1. Although collection of a total of 15 sediment cores [to depths of 7 feet below the mud line ("bml")] was attempted, the sediments were too hard (consisting of hard clays, compact sand, and small gravel) in areas RWC-A1 and RWC-A2, to collect the proposed number of samples and allow penetration to deeper depths in these areas. As such, sediment samples at these locations were collected to the maximum depth that available sampling methods allowed.

3.1 Sampling Depths and Laboratory Analyses Performed

The depths and number of samples per composite were as follows:

- RWC-A1 consisted of 3 samples collected to a depth of 0.5 ft bml.
- RWC-A2 consisted of 2 samples collected to a depth of 2.0 ft bml
- RWC-A3 consisted of five samples to a depth of 6.8 ft bml.

Laboratory analysis of composite sediment samples was conducted for the following COPCs utilizing the identified methods:

- Metals by EPA 6020/7471A
- Organochlorine Pesticides by EPA 8081A
- Organotins by Krone, et al.
- PCBs by EPA 8270C SIM
- PAHs by EPA 8270C SIM

3.2 Types and Concentrations of COPCs Detected

Analytical results of COPCs detected in sediment samples are summarized on Table 3-1. These results are compared to ambient concentrations of COPCs detected in San Francisco Bay and to SQBs, which are used to determine if concentrations of pesticides and other COPCs pose a potential concern to benthic organisms. These values also are employed to determine if dredged sediments can be used as foundation materials at San Francisco Bay and ocean disposal sites.

Further review of COPC concentrations relative to these ambient values and benchmarks is provided in Section 5.

As shown on Table 3-1, the lowest concentrations of COPCs were detected in sample RWC-A1, which was obtained from the area of Docktown Marina. The highest concentrations of COPCs were detected in RWC-A3, within the slough. The presence of higher concentrations of COPCs in sample RWC-A3, could be the result of several factors. The slough is not within Redwood Creek and subject to less flushing and scouring. As such, sediment likely accumulates more readily, which is consistent with the presence of softer sediments found in this area. Softer sediments are present in the slough, which allowed sediment samples to be collected from deeper depths.[7] Therefore, chemical impacts identified in RWC-A3 could reflect impacted sediments from historical periods when use of some COPCs (e.g., PCBs and organochlorine pesticides) was more prevalent and less regulated. In addition, storm drains that collect surface water and groundwater from the vicinity of the Study Area and upland watershed discharge directly into the slough.

[7] Sediment cores for sample RWC-A3 were collected from 6.8 ft bml versus 2 ft bml at RWC-A2 and 0.5 ft bml at RWC-A1.

4 POTENTIAL SOURCES OF COPCs IN SEDIMENT SAMPLES

Both regional and local sources exist for COPCs detected in sediment samples collected from the Study Area.

4.1 Regional COPC Sources

San Francisco Bay is a large, heavily urbanized estuary. Contaminant loads are delivered to the Bay via a range of pathways including the Sacramento–San Joaquin River Delta, local tributaries, municipal wastewater, industrial wastewater, atmospheric deposition, and releases from contaminated sites near the Bay margins (SFEI, 2012b). Numerous regional sources exist for COPCs in sediments within the Study Area.

PCBs are extremely persistent synthetic chemicals that were heavily used from the 1930s to the 1970s in electrical equipment and a wide variety of other applications. PCB production was banned in 1979. Regardless, considerable quantities of PCBs remain in use. As of 2001, transformers and capacitors throughout the San Francisco Bay Area still contained over 400,000 pounds of PCBs (Davis et al., 2007). Urban runoff from local watersheds is a significant pathway for PCB entry into the Bay.

Legacy organochlorine pesticides consisting of chlordane, dieldrin, toxaphene, and DDT and its metabolites are found in both sediment and fish in San Francisco Bay. DDT was banned in 1972. Dieldrin was restricted in 1974, but use for underground termite control continued until 1987. Chlordane production and sales ended in 1988. Toxaphene was banned in 1990. Although legacy pesticides continue to enter San Francisco Bay in runoff from the Central Valley and local watersheds, their persistence is less than that of PCBs. SFEI (2004) cites evidence of long-term declines in pesticide levels in the Bay.

Mercury appears as one of the first anthropogenic metals in the San Francisco Bay sediment record, with mercury and gold mining the most likely early sources of mercury in the Estuary. Determining the contribution of mercury to sediment in San Francisco Bay from an array of sources (e.g., petrochemical and caustic soda manufacturing, household thermometers, dental fillings, contact lens solutions and fluorescent lights, and fungicides) is complicated because of its widespread use and changes in sediment transport as a result of watershed modification during the past 150 years (Donovan et al., 2013; SFEI, 2001).

Other metals identified as COPCs include cadmium, chromium, copper, lead, nickel, selenium, silver, and zinc. Cadmium, copper, lead, and zinc are associated with vehicular tailpipe emissions, and brake and tire wear (RWQCB, 2015; Lough et al., 2005). Storm water runoff and airborne

emissions from roadways are likely significant sources given the proximity of U.S. Highway 101/Bayshore Freeway.

Modern industries first appeared on the shores of San Francisco Bay near the turn of the 20th century, about the same time that metal usage increased in the rest of the United States. Rates of urbanization and industrialization increased after World War II (Hornberger, et al., 1999). Recognized urban and industrial sources of metals throughout the Bay Area include the following:

- Cadmium — Batteries, metal plating, lubricating oil and grease, fertilizer, paint (SFEI, 2012a; U.S. EPA, 2005b)
- Copper — Batteries, circuit boards, wiring, metal plating, plumbing, roofing materials, fertilizer, root killers, cooling tower additives (SFEI, 2012a; Göbel, Dierkes, and Coldewey. 2007; U.S. EPA, 2005b; SFEI 2001)
- Chromium — Metal plating, paint, wood and leather preservatives (SFEI, 2012a)
- Lead — Batteries, circuit boards, wiring, plumbing, preservatives, lighting equipment (SFEI, 2001)
- Nickel — Computer components (SFEI, 2001)
- Organotins — Cooling tower additives (U.S. EPA, 2005b)
- Silver — Batteries, electronics, deodorants, catalytic converters, clothing manufacture, jewelry, film processing (SFEI, 2012a; SFEI, 2001)
- Zinc — Batteries, galvanized steel, roofing materials, paint (SFEI, 2012a; Göbel, Dierkes, and Coldewey. 2007)

According to Oros and Ross (2004), PAHs can originate from a variety of anthropogenic sources in urban areas by thermal combustion processes (e.g., cooking and heating oils and coal burning), vehicular emissions (e.g., automobiles and trucks), and biomass burning (e.g., fireplaces). High molecular weight PAHs (four rings or more) originate from high temperature combustion processes. Low molecular weight PAHs (two to three rings) are minor constituents in crude oil, refined petroleum products, and creosote, but are derived mainly from combustion emissions of vehicles (Oros and Ross, 2004).

From 1989 to 1992, the Regional Board developed and implemented pilot programs for the RMP, through the Bay Protection and Toxic Cleanup Program ("BPTCP") and U.S. EPA grants. In 1993, the RMP was formally established to provide integrated, comprehensive, and systematic information on water quality in the region.

The goal of the RMP is to evaluate the effectiveness of the Regional Board's water quality program in meeting the San Francisco Bay Basin Plan ("Basin Plan") objectives, including protection of

beneficial uses in the Estuary. SFEI, an independent nongovernmental organization, administers and manages the program according to a memorandum of understanding with the Regional Board.

4.2 Local COPC Sources

EKI conducted an environmental site assessment ("ESA") in 2015 and 2016 that focused on Docktown Marina and other potential local sources of COPCs found in sediment in Redwood Creek and the slough. The ESA included:

- Review of available historical land use information provided by Environmental Data Resources, Inc. ("EDR"), which includes historical Sanborn fire insurance maps, historical aerial photographs, topographic maps, and city directories (Appendix B);
- Review of EDR's Radius Map Report for the Study Area vicinity;
- Search of environmental regulatory agency electronic databases, including the Regional Board GeoTracker database and Department of Toxic Substances Control ("DTSC") Envirostor database;
- Review of San Mateo County Department of Environmental Health and Redwood City Fire Department document files for selected sites within the Study Area;
- Review of potentially relevant documents provided by Redwood City; and
- Site reconnaissance of Docktown Marina and vicinity on 8 February 2016.

Multiple local historical chemical use and release sites were identified on the basis of the information reviewed as part of the ESA. These sites include:

- Chemical mixing facility and pesticide producing establishment, where total petroleum hydrocarbons ("TPH"), PAHs, and volatile organic compounds ("VOCs") have been detected in soil and groundwater, but pesticides have not been investigated;
- Leaking underground storage tank ("LUST") sites where petroleum hydrocarbons have been detected in soil and groundwater;
- Properties where asphaltic tar seeps containing elevated PAHs have been identified, in association with former filling of sloughs in the Study Area;
- Railroad spur where elevated chlordane concentrations have been detected in soil;

- Several boat yards and commercial/industrial businesses associated with boat and engine repair, where PAHs, TPH, and copper and other metals were likely used;
- Former landfill and salvage yard that accepted soil for disposal from Pacific Gas and Electric Company ("PG&E"), a common user of PCBs;
- PG&E electrical substation;
- Terminix facility, where storage of pesticides has occurred for decades; and
- Former wastewater treatment plant.

Table 4-1 provides a brief summary of information obtained regarding these sites, and associated references. The location of each site is identified on Figure 4-1. It is difficult to assess the extent to which these sites may have contributed COPCs to sediment. Remedial actions and implementation of risk management plans at known chemical release sites, such as the former Willard Products Site and Harbor View Development area, should aid in limiting migration of chemical-impacted soil from these facilities into Redwood Creek and the slough.

4.3 Docktown Marina

Docktown Marina is one of many local facilities where COPCs were used and, for some sites, known to have been released. Docktown Marina is situated within Redwood Creek, as shown on Figure 4-1. Examination of historical aerial photographs reveals boats have been berthed at the marina since the 1960s. EKI's records review and site reconnaissance found activities at Docktown Marina are typical of marinas. Contractors operated Docktown Marina until March 2013 when Redwood City assumed control.

The marina is accessed through property located at 1548 Maples Street pursuant to an agreement negotiated with the property owner. Although Redwood City leases space for offices, showers, laundry, and general maintenance and storage at 1548 Maples Street, this property is not part of Docktown Marina. Other commercial and industrial activities at 1548 Maples Street are not associated with the marina nor controlled by Redwood City. The property at 1548 Maples Street is sometimes mistakenly identified as Docktown Marina in regulatory agency records and other documents.

According to U.S. EPA (2001), common pollutants at marinas include nutrients and pathogens (pet waste and overboard sewage discharge), sediments (parking lot runoff and shoreline erosion), fish waste (dockside fish cleaning), petroleum hydrocarbons (fuel and oil drippings and spills), metals (antifoulant paint and hull and boat maintenance debris), and liquid and solid wastes (engine and hull maintenance and general marina activities). No boatyard dedicated to maintenance and repair exists at Docktown Marina.

Documented chemical release incidents at the marina include the following:

- 1995: Oily material being discharged from a bilge pump to surface water.
- 1995: Petroleum release from overturned vessel at dock.
- 1997: Release of paint product from sinking vessel.
- 1998: 5 to 10 gallons of diesel fuel spilled from a sinking vessel.
- 1998: Report of several sunken vessels that were leaking.
- 2000: Sinking vessel; possible chemical release.
- 2004: Sinking vessel; cleanup underway.
- 2008: Sinking vessel; reports of water being pumped from vessel.
- 2010: Release of unknown quantity of oil at Slip 36.
- 2010: Sheen observed (approximately 60 feet by 60 feet area).
- 2012: Recreational vehicle leaking oil onto ground.
- 2015: Fuel sheen on water surface.

The majority of these incidents relate to releases of petroleum hydrocarbons, which is not surprising based on studies of marinas. U.S. EPA (2001) comments "[s]tudies have found high concentrations of petroleum hydrocarbons in marinas, particularly polynuclear aromatic hydrocarbons (PAHs), which tend to attach to suspended particles and sediments."

Copper also is found in marina sediments. U.S. EPA (2001) states "[c]opper is the major COPC in sediments [at marinas] because many common antifouling paint preparations contain cuprous oxide as the active biocide component." Other metals associated with marinas include (U.S. EPA, 2003a):

- Arsenic: Used in paint pigments
- Zinc: Used to prevent corrosion of engine parts and metal hulls
- Chromium: Used in wood preservatives
- Lead: Found in batteries
- Mercury: Found in float switches

Although Docktown Marina is subject to these concerns, tidal action and stream flow in Redwood Creek creates significant flushing and scouring of sediments within the marina. Water in the marina is exchanged approximately every 12 hours as the water level drops below the mud line during low tide events. Studies have found that concentrations of COPCs in sediments are much lower in well-flushed marinas (U.S. EPA, 2011).

Further, the nature of COPC concentrations detected in sediment is not consistent with releases at Docktown Marina:

- Concentration of copper, one of the primary COPCs associated with sediment impacts from marinas, was below ambient values in sediment sample RWC-1 collected from Redwood Creek, as explained in Section 5.

- Concentrations of PAHs, another group of COPCs associated with sediment impacts from marinas, were less than effects-range median ("ERMs") in RWC-1 collected from Docktown Marina, as discussed in Section 5.

- Chlordane, the chemical detected at the highest concentration in RWC-1 relative to sediment ambient values and ERMs, is not typically associated with marina operations.

These data indicate Docktown Marina is not a primary source of COPCs detected in sediment within the Study Area.

5 TOXICITY OF COPCs IN SEDIMENTS TO BENTHIC ORGANISMS

Numerous processes influence the fate and distribution of COPCs within San Francisco Bay. As illustrated by Exhibit 5-1, dissolved COPCs may bind to suspended particulates in water or COPCs bound to particulates may dissolve into water. Suspended particulates form larger agglomerates that settle on the bottom of the Estuary. Tidal currents may transport COPCs from San Francisco Bay to the Pacific Ocean.

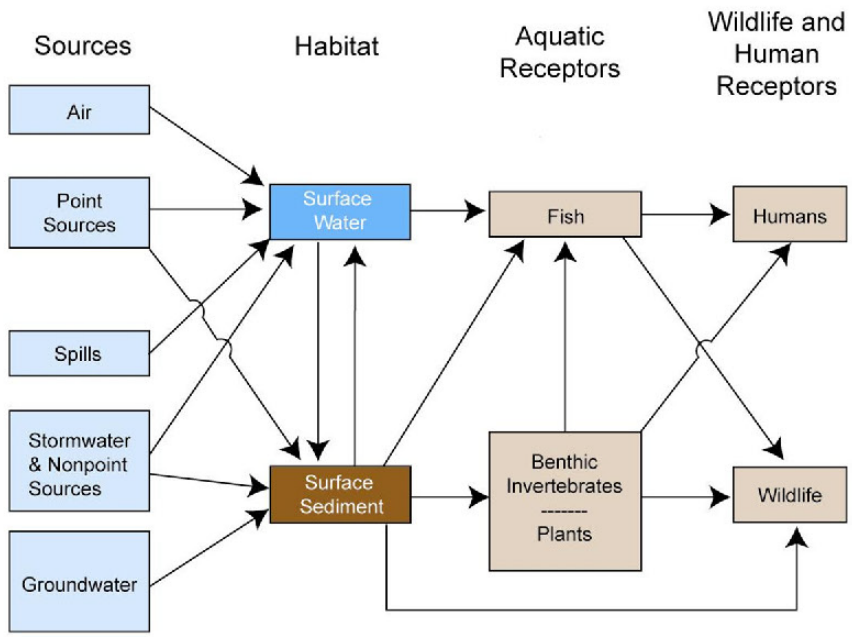

Exhibit 5-1 - Principal Sources, Fates, and Effects of Contaminants in San Francisco Bay (SWRCB, 2011)

Most benthic infauna (e.g., worms, snails, shrimp, sponges, starfish) reside within 2 to 8 inches of the mud line or sediment surface. Consequently, COPCs in deeper sediments generally do not exert much influence on benthic organisms (SWRCB, 2011).

5.1 Comparison to Ambient Values and Empirical SQBs

Unlike water quality programs that routinely rely on individual chemical thresholds to assess water quality, the complex processes affecting contaminant bioavailability in sediments preclude the use of contaminant concentrations to independently assess or identify cause (Beegan and Bay, 2012).

In other words, sediment chemical concentrations cannot be used by themselves to determine if a given site poses a risk to ecological receptors. Sediment chemical concentrations are compared to San Francisco Bay sediment ambient values and SQBs to establish if more site characterization is needed (Anderson, et al. 2007).

EKI compared COPC concentrations measured in Study Area sediments with ambient values for "open water" sediments in San Francisco Bay. Ambient values for open water sediments are concentrations typical of less polluted, or "cleaner," portions of the Bay (SFEI, 2015). SFEI calculates open water sediment ambient values as the 90 percent upper tolerance limit of the 90th percentile concentrations of sediment data compiled as part of the RMP (SFEI, 2015).

EKI also compared COPC concentrations in Study Area sediments with ambient concentrations in sediments at the margins of the Estuary. Chemical concentrations in margin sediments are recognized to be greater than those in open water sediments. SFEI (2012b) states contaminant "[c]ontributions of margins may be high due to patches of higher contaminant concentrations with long residence times due to reduced transport in these low energy environments." COPC concentrations in sediment samples RWC-A1, RWC-A2, and RWC-A3 were compared to concentrations in sediment samples collected from the Port of Redwood City Municipal Marina in 2013 (Weston Solutions, Inc., 2013) and Redwood City Harbor in 2014 (Kinnetic Laboratories, Inc. and Atkins North America, Inc., 2015a and 2015b).

Historical impacts of Bay Area activities were examined by comparing Study Area sediment data to chemical concentration vertical profiles in sediment cores obtained from San Pablo Bay in 1990 (Hornberger, et al., 1999; Venkatesan et al., 1999) and South San Francisco Bay in 2005 (Nilsen et al., 2015). Figure 5-1 depicts the collection locations of these sediment samples and cores. Figure 5-2 depicts the comparison of certain COPC concentrations in Study Area sediments with concentration vertical profiles in cores, and ambient values for open water sediments and nearby margin sites.

Except for pesticides and nickel, COPC concentrations in sediment samples RWC-A1 and RWC-A2 collected from Redwood Creek, where Docktown Marina is located, are not markedly higher than ambient concentrations at the nearby Port of Redwood City Municipal Marina and Redwood City Harbor. In contrast, concentrations of most COPCs in sediment sample RWC-A3 are greater than concentrations in sediments at nearby Redwood City marina and harbor (Table 3-1, Figure 5-2).

Sediment data for the Study Area then were compared to SQBs to determine if the concentrations of pesticides and other COPCs pose a potential concern to benthic organisms. ERMs developed by the National Oceanic and Atmospheric Administration ("NOAA") are widely used SQBs. ERMs are empirical screening levels above which acute or chronic toxic effects to benthic organisms are reportedly observed. Table 3-1 summarizes comparison of COPC concentrations in

Study Area sediments to ERMs. Nickel and chlordane concentrations in all sediment samples are greater than ERMs. Mercury, silver, dieldrin, PCBs, and low molecular weight PAH concentrations in samples RWC-A2 or RWC-A3 also are greater than ERMs. Given these results, EKI examined the Study Area sediment data using a mechanistic approach.

5.2 Comparison to Mechanistic SQBs

The mechanistic approach for the SQBs is predicated on understanding the bioavailability of anthropogenic contaminants in sediments and determining whether those bioavailable contaminants will be present in quantities sufficient to cause adverse effects (Burgess, et al., 2013). Empirical SQBs attempt to predict the likelihood of observing adverse benthic effects based on the total measured concentration of a chemical in sediment without considering the extent to which the chemical is bioavailable. Mechanistic SQBs try to determine if a specific contaminant or mixture of contaminants may be sufficiently bioavailable to cause toxic effects.

The equilibrium partitioning ("EqP") mechanistic approach is based on the concept that the dissolved phase contaminant concentration in sediment interstitial (i.e., pore) water reflects the portion of chemical that is bioavailable to benthic organisms (McGrath, Paquin, and Di Toro, 2002). The total amount of an organic chemical in a sediment sample is the sum of the amounts dissolved in sediment pore water and associated with or sorbed to organic carbon on sediment particulates.

$$\text{Total}_x = \text{Dissolved}_x + \text{Organic Carbon}_x$$

where:

Total_x	=	total amount of organic chemical x in sediment
Dissolved_x	=	amount of organic chemical x dissolved in sediment pore water
Organic Carbon_x	=	amount of organic chemical x sorbed to sediment organic carbon

Acid volatile sulfide ("AVS") is generated in sediments that lack oxygen, which are referred to as anaerobic or anoxic. AVS reacts with metals, including cadmium, copper, lead, nickel, silver, and zinc, to form insoluble and non-bioavailable metal sulfides. Sediment organic carbon also is important to metal bioavailability. The total amount of a metal is a sediment sample is given by the below expression:

$$\text{Total}_y = \text{Dissolved}_y + \text{AVS}_y + \text{Organic Carbon}_y$$

where:

Total_y	=	total amount of metal y in sediment
Dissolved_y	=	amount of metal y dissolved in sediment pore water
AVS_y	=	amount of metal y associated with sediment AVS
Organic Carbon_y	=	amount of metal y associated with sediment organic carbon

EqP-based mechanistic SQBs for organic chemicals are called equilibrium partitioning sediment benchmarks ("ESBs"). The ESB should be interpreted as a chemical concentration below which adverse effects are not expected. Tables 5-1, 5-2, and 5-3 summarize ESBs based on organic chemical and organic carbon concentrations measured in sediment samples RWC-A1, RWC-A2, and RWC-A3, respectively. ESBs are calculated for conventional and narcosis end points.[8] Narcosis refers to alteration of cell membrane function. This alteration can result in mild toxic effects or mortality depending upon the exposure (U.S. EPA, 2009).

Adverse effects to benthic organisms are unlikely to occur if the sediment organic chemical concentration is equal to or less than the ESB (i.e., ≤ 1.0 toxic unit). Adverse effects may occur if sum of the toxic units is greater than 1 (U.S. EPA, 2012b). As shown in Tables 5-1, 5-2, and 5-3, the sums of the toxic units are less than 1 for both conventional and narcosis end points. Thus, the levels of pesticides, PCBs, and PAHs measured in sediment are not expected to result in acute or chronic toxicity to benthic organisms.

ESBs for metal concentrations in Study Area sediments yield a similar conclusion. Metals detected in sediment are not anticipated to be toxic to benthic organisms. Metal $ESB_{AVS\ OC}$ values in Tables 5-1, 5-2, and 5-3 assume an AVS concentration of 3 micromoles per gram dry sediment ("$\mu mol/g_{DW}$") because no AVS analyses have been performed on sediment samples obtained within the Study Area. The assumed AVS concentration is conservative considering AVS levels up to 40 $\mu mol/g_{DW}$ were measured at mud flats near Palo Alto, California (Lee et al., 2001).

U.S. EPA (2005a) interprets $ESB_{AVS\ OC}$ values as follows: (a) adverse effects unlikely if less than 130 $\mu mol/g_{DW}$, (b) adverse effects uncertain if between 130 to 3,000 $\mu mol/g_{DW}$, and (c) adverse effects may occur if greater than 3,000 $\mu mol/g_{DW}$. $ESB_{AVS\ OC}$ values for RWC-A1, RWC-A2, and RWC-A3 are 85, 111, and 129 $\mu mol/g_{DW}$, respectively, which are less than the 130 $\mu mol/g_{DW}$ threshold above which adverse effects may occur.

5.3 Comparison to Lines of Evidence

The conclusion that COPC concentrations in sediment within the Study Area are not detrimental to benthic organisms is supported by examining multiple lines of evidence ("LOEs") that were relied upon to evaluate sediment quality of Mission Creek in San Francisco (Figure 5-1). COPCs in Study Area sediment are similar to those in Mission Creek. LOEs for Mission Creek indicate these COPC concentrations do not result in adverse effects to benthic organisms.

Assessments of sediment quality for the effects of chemical contamination frequently use a triad of chemical concentration, sediment toxicity, and benthic community condition data. As explained

[8] A frequently used effect concentration is the final chronic value employed to derive an ambient water quality criterion in the United States (Burgess et al., 2013).

by Bay and Weisberg (2012), these LOEs are used in combination because "sediments are a complex matrix and chemical concentration data alone fails to differentiate between the fraction that is tightly bound to sediment and that which is biologically available."

SWRCB requires measurement and integration of these LOEs in assessing sediment quality. Descriptions of the LOEs and how they are used pursuant to the Water Quality Control Plan for Enclosed Bays and Estuaries (SWRCB, 2009) are as follows:

1. **Sediment Chemistry** is the measurement of COPC concentrations in surficial sediments.[9] The chemistry LOE is used to assess the potential risk to benthic organisms from toxic pollutants in surficial sediments. As discussed in Sections 5-1 and 5-2, EKI's comparison of sediment chemistry to ambient values, and empirical and mechanistic SQBs indicate COPC concentrations in Study Area sediment are not toxic to benthic organisms.

2. **Sediment Toxicity** is a measure of the response of invertebrates exposed to surficial sediments under controlled laboratory conditions. The sediment toxicity LOE is used to assess both pollutant related biological effects and exposure. Sediment toxicity tests are of short durations and may not duplicate exposure conditions in natural systems. This LOE provides a measure of exposure to all pollutants present, including non-traditional or unmeasured chemicals.

3. **Benthic Community Condition** is a measure of the species composition, abundance and diversity of the sediment-dwelling invertebrates inhabiting surficial sediments. Benthic community composition reflects the biological effects of both natural and anthropogenic stressors.

SFEI (2013) used the above LOEs to determine whether Mission Creek would still be labeled as impaired 15 years after the BPTCP identified the site as a toxic hotspot. The BPTCP labeled Mission Creek as significantly polluted, with elevated sediment chemistry, high sediment toxicity, and a degraded benthic community (RWQCB, 1998b). The condition of the benthic community was resurveyed in 2011 and found still to be disturbed, which suggests sediment quality continues to adversely impact benthic infauna in Mission Creek (SFEI, 2013). Mission Creek is an urban, mostly concrete and rip-rap lined channel that discharges to San Francisco Bay. The creek has been a dead-end slough for more than 100 years. Industries, including lumber mills, municipal dumps, incinerators, and ship building yards, formerly operated along its banks (SFEI, 2013). Seven combined sewer outfalls currently discharge into Mission Creek during wet weather events. Many of the COPCs detected in Mission Creek sediments, including PCBs, organochlorine (i.e., legacy) pesticides, metals, and PAHs, also were found in Redwood Creek sediments.

[9] Surficial sediments are defined to be those sediments representing recent depositional materials and containing the majority of the benthic invertebrate community.

In 2007, SFEI performed a toxicity identification evaluation ("TIE") on Mission Creek sediments to establish the key chemicals responsible for biological impacts (SFEI, 2008b). The TIE involves a series of procedures designed to decrease, increase, or transform the bioavailable fractions of sediment contaminants to assess their contributions to sample toxicity. Toxicity was not attributed to metals, legacy pesticides, PCBs, or most PAHs measured in sediment samples obtained from Mission Creek. These contaminants also comprise COPCs detected in Study Area sediments.

The TIE results did not identify the specific chemicals responsible for toxicity to benthic organisms (Phillips, Anderson, and Lowe. 2011; SFEI, 2008b). The cause of toxicity was characterized as a combination of ammonia and organic chemicals. Ammonia is formed by bacterial decomposition of organic matter containing nitrogen. Accumulation of anthropogenic derived organic wastes and matter containing nitrogenous compounds often leads to elevated ammonia concentrations in marine sediments (Burgess et al., 2003).

University of California, Davis Marine Pollution Studies Laboratory conducted additional studies in 2009 and 2010 to identify chemicals responsible for toxicity to benthic organisms in San Francisco Bay. These studies found pyrethroids are an important class of organic chemicals that may result in adverse effects to benthic organisms (Phillips, Anderson, and Lowe, 2011). Pyrethroids, such as cyfluthrin, are pesticides that became popular among consumers in the 1990s as replacements for older organophosphate pesticides, like diazinon and dursban.

Benthic disturbance at margin areas along the Bay is often greater than at open water sites (SFEI, 2008a).[10] The cause of this disturbance has not been established. SFEI recommends expanding the list of contaminants included in the chemistry indicators for areas at the margins of San Francisco Bay. According to SFEI (2008a), "future efforts should certainly attempt to identify those that have the highest potential for biological effects . . . Pyretheroids and other pesticides will be measured and considered for inclusion in the chemistry exposure LOE." SFEI (2012b) indicates significant effort is needed to advance beyond the current simplified understanding of contaminant processes in San Francisco Bay and to design more effective strategies for managing their impacts on the ecosystem.

Although COPCs do not appear to be affecting the survival of benthic organisms in the Study Area, chemicals considered to be bioaccumulative (i.e., methylmercury, organochlorine pesticides, PCBs, and PAHs) may concentrate within the food chain, which could pose threats to wildlife and

[10] As part of its evaluation of benthic disturbance at margin areas along the Bay, SFEI has performed toxicity testing of sediments and pore water near Redwood Creek. Ten sediment samples collected between 1994 to 2000 were found to have benthic disturbance. Pore water in sediment collected from the creek also was observed to be toxic to benthic organisms (SFEI, 2008b). SFEI did not perform a TIE on Redwood Creek sediments; however, the TIE for Mission Creek sediments and the mechanistic evaluation of SQBs included herein, indicates that COPCs detected in sediments in the Study Area are not the source of this toxicity. Further characterization or analysis of benthic disturbance is therefore not included in this report.

humans that consume fish and shellfish from the Estuary. Comparison of COPC concentrations to empirical or mechanistic SQBs do not consider bioaccumulative effects in fish, wildlife, or humans (Long, Ingersoll, and MacDonald, 2006). Section 6 presents a screening level human health risk assessment ("HHRA") that was conducted to evaluate potential threats to individuals playing on the beach or consuming fish obtained from the Study Area.

6 SCREENING LEVEL HUMAN HEALTH RISK ASSESSMENT

EKI performed a screening level HHRA evaluating COPCs detected in sediment in Redwood Creek and the adjacent slough within the Study Area. A screening level HHRA provides a general indication of whether a potential risk to human health exists and helps identify areas of concern.

U.S. EPA, Regional Board, and DTSC consider a 1×10^{-6} risk level to be a point of departure for establishing cleanup goals based upon potential cancer effects. In other words, U.S. EPA, Regional Board, and DTSC consider risks less than 1×10^{-6} to be insignificant and no further action is required. This risk level is equivalent to 1 person in 1,000,000 people that are exposed contracting cancer. The agencies generally use a cancer risk range of 1×10^{-6} to 1×10^{-4} as a "target range" within which to manage human health risk as part of site cleanup. U.S. EPA guidance states impacts that result in a cancer risk range between 1×10^{-6} to 1×10^{-4}, and a non-carcinogenic hazard index ("HI") is less than 1 do not require cleanup unless adverse ecological impacts warrant action (U.S. EPA, 1991).

6.1 Potential Exposure Scenarios

No generally accepted exposure scenarios have been established for screening level human health risk assessments of contaminated sediment in marine environments. For instance, no Regional Screening Levels ("RSLs") have been developed by U.S. EPA and no Environmental Screening Levels ("ESLs") have been developed by the Regional Board for exposure to contaminated sediment in such settings.[11]

Accordingly, EKI reviewed regulatory guidance documents, scientific studies, and risk assessments conducted at other sites with contaminated sediment to develop exposure scenarios that conform to assumptions and findings made by others. EKI reviewed this information to identify: (1) potentially exposed populations, (2) exposure pathways, and (3) exposure parameters, such as exposure frequency, exposure duration, exposed skin surface area, soil adherence factor, and fraction of COPC absorbed dermally from sediment.

Two exposure scenarios were identified based upon information reviewed:

- Beach play scenario
- Fish consumption scenario

Each exposure scenario, and associated exposure populations, pathways, and variables used to assess potential risks are described herein.

[11] The Regional Board explicitly states ESLs do not apply to sediment (RWQCB, 2016).

Screening level human health risks for the exposure scenarios were calculated based on COPC concentrations detected in composite sediment samples RWC-A1 and RWC-A3 (Pacific EcoRisk, 2011). Sample RWC-A1 was collected from the Docktown Marina in Redwood Creek and sample RWC-A3 was collected from the adjacent slough next to the former South Bay Boat Works, which is now Bair Island Aquatic Center (Figure 3-1).

6.2 Beach Play Scenario

The first scenario estimates risks to children/adolescents that play on the tidal flats, or adults that wade in water on the tidal flats and are potentially exposed to COPCs by incidental ingestion of contaminated sediment and dermal absorption of COPCs from sediment that sticks to skin. The following generally conservative exposure parameters were assumed:

- Exposed skin-weighted average soil adherence factors of 3.9 milligrams per square centimeter ("mg/cm^2") for children (2 to 12 years old)[12] and 0.3 mg/cm^2 for adults, based on U.S. EPA Exposure Factors Handbook (U.S. EPA, 2011).

- Exposure frequency of 65 days per year and an exposure time of 1 hour per day for 26 years based on Shoaf et al. (2005) and the U.S. EPA Exposure Factors Handbook (U.S. EPA, 2011).

6.3 Angler Fish Consumption Scenario

The second scenario estimates risks to individuals that catch and consume fish (i.e., anglers) in which COPCs from the sediment have bioaccumulated. Bioaccumulative COPCs consist of mercury, organochlorine pesticides, PCBs, and PAHs.

The Dredged Material Management Office ("DMMO") requires bioaccumulation testing prior to dredging if COPC concentrations in sediment are greater than ambient concentrations in San Francisco Estuary or similar values applied elsewhere in the United States (SFEI, 2016).[13] Most COPC concentrations in sediment samples RWC-A1 and RWC-A3 are greater than DMMO bioaccumulation triggers.

[12] No exposure to children under 2 years of age was assumed.

[13] DMMO is a joint program of the BCDC, Regional Water Board, State Lands Commission, USACE, and U.S. EPA that review sediment quality sampling plans, analyze the results of sediment quality sampling and make suitability determinations for material proposed for disposal in San Francisco Bay. Also participating in this interagency process are California Department of Fish and Game, National Marine Fisheries Service, and Fish and Wildlife Service.

Consistent with methodologies for performing a screening level risk assessment, EKI estimated COPC concentrations in fish through use of biota-sediment accumulation factors ("BSAFs"), which are defined by the following equation (U.S. EPA, 2000):

$$BSAF = \frac{C_l}{C_{soc}}$$

where:

C_l = Lipid-normalized chemical concentration in biota tissue ($\mu g/g_{lipid}$)

C_{SOC} = Organic-carbon normalized chemical concentration in sediment ($\mu g/g_{oc}$)

BASFs are site-specific and testing would need to be conducted at Redwood Creek and the adjacent slough to establish representative values that could be used to estimate risk to anglers with confidence. In the absence of site-specific BASFs, EKI obtained values from national studies (Wong, Capel, and Nowell, 2001) and evaluation of national studies by SFEI (SFEI, 2005). According to the Interstate Technology & Regulatory Council ("ITRC"), site-specific field measurements have clear scientific precedence over generic or literature-derived values (ITRC, 2011).

Moreover, application of BSAFs implicitly assumes all exposures occur within the area under investigation. Fish may actually forage over a larger area, which results in lower exposure and reduced bioaccumulation of COPCs in fish.

EKI assumed anglers eat 16 grams per day for 26 years based on California Department of Health Services ("DHS") (DHS, 2000) and U.S. EPA 2014 studies (U.S. EPA, 2014a). The lipid fraction of the fish is assumed to be 0.03 based on U.S. EPA default values (U.S. EPA, 2003b).[14] The lipid-normalized chemical concentration in fish is multiplied by the lipid fraction to obtain the chemical concentration in micrograms per gram in fish tissue on a wet weight basis ("$\mu g/g_t$").

6.4 Estimated Screening Level Human Health Risks

The U.S. EPA RSL calculator was utilized to perform human health risk calculations for COPCs detected in each sample. Cumulative carcinogenic risks and non-cancer hazards based on measured concentrations of COPCs in samples RWC-1A and RWC-A3 are presented in Tables 6-1 and 6-2,

[14] U.S. EPA's national default consumption-weighted mean values of the lipid fractions of fish commonly eaten throughout the United States are 0.026 and 0.03. (U.S. EPA, 2003b).

respectively, for the beach play exposure scenario, and Tables 6-3 and 6-4, respectively, for the fish consumption exposure scenario. Results of these risk calculations are summarized below.

6.4.1 Beach Play Scenario

Incremental carcinogenic human health risks associated with the beach play scenario were estimated to be 1.5×10^{-5} for COPC concentrations detected in the sediment sample from the Docktown Marina area and 1.7×10^{-5} for COPC concentrations detected the sediment sample collected in the slough. These estimated incremental human health risks are based upon conservative exposure assumptions[15] and are within the target cancer risk range of 1×10^{-6} to 1×10^{-4}. The non-carcinogenic HI associated with the beach play scenario are all well below 1, and therefore not a concern to human health. Such impacts generally do not require cleanup unless adverse ecological impacts warrant action.

Review of Tables 6-3 and 6-4 shows benzo(a)pyrene, a high molecular weight PAH, contributes approximately 65 to 75 percent of the estimated incremental lifetime carcinogenic risks associated with the beach play scenario. However, benzo(a)pyrene concentrations detected in sediments within the Study Area are consistent with anthropogenic background concentrations detected in the Bay. Benzo(a)pyrene was measured at 200 and 280 $\mu g/kg_{dw}$ in sediment samples RWC-A1 and RWC-A3, respectively. These concentrations are less than the ambient value of 430 µg/kg reported for benzo(a)pyrene in sediment throughout the San Francisco Estuary (SFEI, 2015). Therefore, estimated human health risks associated with the beach play scenario in the Study Area are similar to those that would be calculated from exposure to sediments throughout the Bay. Risks associated with benzo(a)pyrene are not unique to Docktown Marina or the Study Area, and do not warrant further investigation or remediation.

6.4.2 Angler Fish Consumption Scenario

Incremental carcinogenic human health risks associated with the angler fish consumption scenario were estimated to be 1.1×10^{-4} for COPC concentrations detected in sediment sample RWC-A1 collected from the Docktown Marina and 1.4×10^{-4} for COPC concentrations detected in sediment sample collected from the slough. The non-cancer hazards associated with the fish consumption scenario for both sediment samples are less than a HI of 1 (U.S. EPA, 2010).[16] The screening level calculations indicate the fish consumption scenario leads to unacceptable risks. However, these estimated risks should not be interpreted as actual risks, because they are based on exposure

[15] An individual is exposed 1 hour/day on 65 days/year for 26 years.

[16] Screening level risks in Tables 6-3 and 6-4 exclude contribution, if any, by mercury. Nearly all of the mercury that bioaccumulates in fish tissue derives from methylmercury (U.S. EPA, 2010). Mercury risks could not be calculated because no sediment methylmercury data are available.

assumptions and BSAFs obtained from studies and not site-specific data. Moreover, these screening level risks are not attributable to activities at Docktown Marina.

6.4.2.1 COPC Origins

As shown in Tables 6-3 and 6-4, potential human health risks associated with the fish consumption scenario are driven by the presence of PAHs, chlordane, dieldrin, toxaphene, p,p'-DDE, and PCBs. None of these COPCs, except for PAHs, are likely associated with activities at Docktown Marina.

Chlordane, dieldrin, and toxaphene are legacy organochlorine pesticides. p,p'-DDE is a metabolite of DDT, which also is a legacy organochlorine pesticide. None of these pesticides are used in the United States. Federal bans were instituted in 1972 for DDT, 1988 for chlordane, 1987 for dieldrin, and 1990 for toxaphene. San Francisco Bay is listed as an impaired water body due to the presence of DDT, chlordane, and dieldrin (SWRCB, 2016). Studies show that fish and shellfish throughout the Bay contain legacy pesticides (SFEI, 2004). Current inputs to the water body include runoff from local watersheds, discharge of municipal and industrial wastewater, atmospheric deposition, erosion of historically contaminated sediment, and dredging and disposal of dredged material (SFEI, 2007).

Concentrations of legacy pesticides in aquatic food webs across the state have generally shown declines over the past 30 years in response to the federal bans (SFEI, 2007). Modeling performed by SFEI indicates the mass of legacy pesticides in the Bay will continue to decrease mostly through degradation in sediment (SFEI, 2004).

San Francisco Bay also is listed as an impaired water body for PCBs. PCBs are persistent despite being federally banned in 1979. Leakage from PCB-containing equipment over many decades has led to ongoing contamination of San Francisco Bay. SFEI expects it will take 50 to 100 years for PCB concentrations in certain fish (i.e., white croaker and shiner surfperch) in the Bay to fall below the applicable threshold for human health concern (SFEI, 2007). In response, the Regional Board has adopted a PCB Total Maximum Daily Load ("TMDL") and implementation plan to accelerate recovery of the Bay (RWQCB, 2015).

The Office of Environmental Health Hazard Assessment ("OEHHA") has issued fish consumption advisories for the following chemicals detected in fish within San Francisco Bay:[17]

- PCBs
- DDT and its metabolites,

[17] OEHHA is the agency responsible for evaluating potential public health risks from chemical contamination of sport fish. This includes issuing state advisories, when appropriate, based on mandates in the California Health and Safety Code, Section 59009, to protect public health and Section 59011, to advise local health authorities, and the California Water Code, Section 13177.5 to issue health advisories. There are key differences between fish consumption

- Dieldrin
- Chlordane
- Mercury
- Selenium
- PBDEs (polybrominated diphenyl ethers)

Fish consumption advisories for San Francisco Bay can be found on OEHHA's website http://oehha.ca.gov/advisories/san-francisco-bay.

OEHHA has not issued fish consumption advisories for PAHs. Our review of available studies indicate PAHs are rarely detected in fish, let alone at concentrations that would pose a threat to human health. In 1994, the Regional Board directed a pilot study to screen for COPCs in the tissue of fish caught near public fishing piers and accesses surrounding San Francisco Bay. The study found PAH concentrations in fish tissue were "near or below method detection limits in all samples measured." (RWQCB, 1995) Analytical method reporting limits were 0.002 to 0.003 $\mu g/g_t$ (RWQCB, 1995), which were sufficient to measure PAHs at concentrations of concern.

Review of Tables 6-3 and 6-4 shows benzo(a)pyrene contributes significantly to estimated incremental lifetime carcinogenic risks associated with the fish consumption scenario in the Study Area. The concentration of this PAH in fish tissue was estimated to be 0.06 and 0.03 $\mu g/g_t$ based on benzo(a)pyrene concentrations measured in sediment samples RWC-A1 and RWC-A3, respectively. Fish caught from San Francisco Bay in 1994 did not contain benzo(a)pyrene near these estimated concentrations. Benzo(a)pyrene concentrations in fish caught within the Study Area are not expected to be significantly different than levels in fish obtained elsewhere in the Bay because, as discussed in Section 6.4.1, benzo(a)pyrene in sediment in the Study Area is consistent with anthropogenic background concentrations in San Francisco Bay.

PAHs are the only bioaccumulative COPCs potentially associated with operations at Docktown Marina. PAHs are components of petroleum hydrocarbons and exhausts from fuel combustion (Eklund, 2014). Common petroleum hydrocarbon products used in marinas include fuel, oil, grease, lubricants, finishes, and cleansers (U.S. EPA, 2001). PAHs also originate from regional activities as evidenced by ambient levels of PAHs in sediment throughout San Francisco Bay. Primary PAH sources to the San Francisco Estuary are combustion processes, associated with urbanization and industrialization (Nilsen et al., 2015). PAHs are transported to the Bay by atmospheric deposition, and from rivers, streams, and storm drains (Greenfield and Davis, 2005).

advisories and other environmental risk criteria; advisories consider the significant benefits of fish consumption, while criteria may be strictly risk-based and may not take into account other factors.

6.4.2.2 Conclusions Regarding Angler Fish Consumption Screening Level Risks

The screening level risk assessment indicates COPC concentrations in sediment may bioaccumulate to unacceptable levels in fish for human consumption. We stress that estimated risks in Tables 6-3 and 6-4 should not be interpreted as actual risks because they are based on exposure assumptions and BSAFs obtained from studies and not site-specific data. The HHRA results indicate only the potential for risk due to consumption of fish from the Study Area. However, that risk is not attributable to activities at Docktown Marina.

OEHHA has issued fish consumption advisories that pertain to San Francisco Bay for all bioaccumulative COPCs, except PAHs, that were detected in sediment within the Study Area. In the absence of additional information, OEHHA fish consumption advisories should be followed for all fish caught in the Bay, including in the Study Area.

7 SURFACE WATER BACTERIOLOGICAL ASSESSMENT

Surface water bacteriological sampling was conducted within Redwood Creek and the adjacent slough in July and August 2016. The objective of this sampling was to evaluate the possible presence of pathogenic microorganisms (e.g., bacteria, viruses, and protozoans) associated with fecal waste in the Study Area. The presence of such pathogenic microorganisms in surface waters is not uncommon and can be associated with various sources including: wildlife, storm water runoff, sanitary sewer systems, vessels (recreational, live-aboard and anchor-out boats) and wastewater treatment plants. Fecal contamination in surface water can cause gastrointestinal ("GI") illness and less often identified respiratory illness in humans who are exposed to surface waters during recreational activities such as swimming, wading, boating (U.S. EPA, 2012a).

Surface water samples were collected from the Study Area during both low and high tide events over a 30-day period to assess concentrations of fecal indicator bacteria ("FIB") in surface water. FIB are bacterial groups or species that are naturally found in the guts of warm-blooded animals (including humans) and are excreted in high densities in the feces of such animals (U.S. EPA, 2014b). Surface water samples were collected adjacent to, upstream, and downstream of Docktown Marina during each event to assess potential contribution, if any, of live-aboard boats that are berthed at Docktown Marina.

7.1 Bacteriological Limits

The Regional Board has identified existing beneficial uses of Redwood Creek and the adjacent slough to include both water contact recreation (REC 1) and non-contact water recreation (REC 2). The Regional Board (2015) defines these recreational uses as follows:

REC 1: "Uses of water for recreational activities involving body contact with water where ingestion of water is reasonably possible. These uses include, but are not limited to, swimming, wading, water -skiing, skin activities, fishing, and uses of natural hot springs."

REC 2: "Uses of water for recreational activities involving proximity to water, but not normally involving contact with water where water ingestion is reasonably possible. These uses include, but are not limited to, picnicking, sunbathing, hiking, beachcombing, camping, boating, tide pool and marine life study, hunting, sightseeing, or aesthetic enjoyment in conjunction with the above activities."

The Regional Board has adopted numerical bacteriological water quality objectives ("WQOs") for San Francisco Bay for both REC 1 and REC 2 uses within the 2015 Basin Plan (RWQCB, 2015). These WQOs are based upon FIB. FIB are bacterial groups or species that are naturally found in the guts of warm-blooded animals (including humans) and are excreted in high densities in the

feces of such animals (U.S. EPA, 2014b). A variety of pathogens can be present in waters impacted by fecal pollution. The types and numbers of pathogens present will be determined by the source and magnitude of the fecal pollution reaching a water body. Because of the great diversity of pathogens that can affect human health, and the fact that pathogens are often seasonally and geographically distributed, widespread monitoring of recreational waters directly for all disease-causing microorganisms from fecal pollution is infeasible. Therefore, protection of public health for those using recreational waters is accomplished through the use of FIB. Basin Plan WQOs are based upon the following FIB: total coliform, fecal coliform and *Enterococcus* sp.

Other relevant bacteriological limits include U.S. EPA's recommended recreational water quality criteria ("RWQC") for protection of primary contact recreation in coastal and non-coastal waters, which were developed in 2012 (EPA, 2012a). U.S. EPA's RWQCs supersede their 1986 criteria upon which many of the Basin Plan WQOs are based. Although the geometric mean values remain similar to 1986 criteria, STVs (or single sample maximums) no longer distinguish between different levels of beach usage. The STVs, published in 2012, approximate the 90th percentiles of the water quality distribution observed during U.S. EPA's epidemiological studies (U.S. EPA, 2012a).

U.S. EPA's RWQC also focus solely on two FIB, *E. coli* and enterococci, and are based on the latest studies, which conclude that fecal coliform and total coliform are not good indicators of fecal contamination.[18] SWRCB is currently scoping a proposed statewide water contact recreation bacteria objective amendment to water quality control plans for inland surface waters, enclosed bays and estuaries and the ocean waters of California (SWRCB, 2015). Preliminary recommendations include:

- Use of *E. coli* as the sole indicator organism for fresh water, and
- Use of enterococci as a sole indicator for marine waters.

The SWRCB website indicates that the amendment is under development and scheduled for adoption in December 2016. Therefore, bacteriological data collected as part of this sampling effort, have been compared to both Basin Plan WQOs and U.S. EPA RWQCs, which are summarized on Table 7-1. Both acute and central tendency WQOs and RWQCs are identified within the Basin Plan and by U.S. EPA. The central tendency WQOs and RWQCs are based on sampling protocols where five equally-spaced samples are collected over a 30-day period and the geometric mean, median, or mean is calculated.

[18] Studies have also found that while enterococci acts as a good indicator in some fresh waters, it can exist and multiply in other fresh waters and create false positives in samples. *E. coli* has been found to be the most reliable indicator organism in all fresh waters. Additionally, studies have shown that enterococci is a good indicator organism in marine waters.

Acute WQO and RWQC are based on either:

- Single sample maximum (where no samples are allowed to exceed this acute objective)
- 90th percentile value of the sample population. (where there is not greater than a 10 percent excursion frequency of the acute objective in the same 30-day interval).
- Statistical Threshold Value ("STV"), which approximates the upper 90th percentile of the water quality distribution using EPA epidemiological beach water quality datasets from the 1970s and 1980s, and assuming lognormality. (where there is not greater than a 10 percent excursion frequency of the STV magnitude in the same 30-day interval)

A summary of these central tendency and acute WQOs and RWQCs are presented on Table 7-1.

7.2 Study Area Sample Locations and Sample Collection Schedule

Water levels and currents in Redwood Creek and the slough, are controlled by tidal action in San Francisco Bay. Review of data compiled by NOAA indicates water depths in Redwood Creek upland of Docktown Marina range from zero to approximately eight feet above the bottom of the creek during low and high tides, respectively (NOAA, 2013). Collection of surface water samples was scheduled to occur when:

- Depths of surface water are sufficient for recreational activities (e.g., boating, wading, or swimming), and
- Direction of surface water flow (i.e., ebb and flood currents) is evident, so sample locations can be readily classified as "upstream" or "downstream" of Docktown Marina.

The above conditions are met midway between high and low tides as illustrated on Figure 7-1. The depth of surface water during such periods is 3 to 5 feet in Redwood Creek and direction of surface water flow is clearly identifiable. EKI scheduled sampling events to coincide with the approximate midpoints between high and low tides.

The American Public Health Association ("APHA") states sampling locations for recreational areas should reflect water quality within the entire recreational zone (APHA, 2012). Sites should include upstream peripheral areas and locations adjacent to drains or natural contours that would discharge storm water. Accordingly, surface water samples were collected at the following four locations during each event:

- WS-1: Upland of Docktown Marina
- WS-2: Within Docktown Marina

- WS-3: Bayside of Docktown Marina
- WS-4: Near boat dock at Bair Island Aquatic Center (1450 Maple Street, Redwood City)

These sample locations are shown on Figure 2. Consistent with regulatory guidance, samples were collected on 5 different days equally spaced over a 30-day interval. Two sampling events were conducted on each day that samples were collected. Sampling events were scheduled to occur approximately 6 hours apart and timed to coincide approximately midway between high and low tides (i.e., approximately 3 hours after high or low tide) on each of the 5 sampling days. Samples collected 3 hours after low tide coincide with flood currents at the mouth of Redwood Creek and the slough when surface water is flowing inland. Samples collected 3 hours after high tide coincide with ebb currents at the mouth of Redwood Creek and the slough, when surface water is flowing toward San Francisco Bay. The City provided EKI with a boat and personnel to operate the boat to accomplish sampling.

The table below lists the approximate times and dates samples were scheduled to be collected.

Day	Approximate Sampling Event Time	
	After Low Tide (Flood)	After High Tide (Ebb)
Monday, 18 July 2016	10:17 AM	4:17 PM
Monday, 25 July 2016	2:48 PM	7:59 AM
Monday 1 August 2016	9:58 AM	3:58 PM
Monday, 8 August 2016	2:21 PM	7:48 AM
Monday, 15 August 2016	9:00 AM	3:00 PM

Surface water samples consisted of grab samples of water for laboratory analyses of FIB. Actual dates and sample times at each location are identified on Table 7-2. A total of 3 duplicate samples were collected. Sampling collection procedures were conducted pursuant procedures described in Appendix C.

7.3 Fecal Indicator Bacteria Laboratory Analyses

BioVir, Inc., located in Benicia, California, performed the following FIB laboratory analyses on each sample that was collected:

- Total coliform by Standard Method 9221B
- Fecal coliform by Standard Method 9221C
- *E. coli* by Standard Method 9222B
- *Enterococcus* sp. by U.S. EPA Method 1600

Laboratory analytical reports and sample chain-of-custody forms are included in Appendix D.

7.4 Fecal Indicator Bacteria Analytical Results

Analytical results of FIB sampling are summarized in Table 7-2. Single sample values obtained at each sampling location are compared to "acute objectives" and "central tendency objectives" identified in the Basin Plan for REC-1 and REC-2 uses (Regional Board, 2015) and to U.S. EPA RWQC (EPA, 2012a) for each FIB.[19] Sample analytical results on Table 7-2 show:

- FIB single sample results and central tendency values did not exceed Basin Plan acute or central tendency WQOs for REC 2 uses, and
- FIB central tendency values did not exceed Basin Plan central tendency WQOs (e.g., geometric mean, median) for REC 1 use or U.S. EPA central tendency RWQC at any sample location for any FIB over the 30-day period.

However, FIB results did exceed:

- Basin Plan acute WQO for REC 1 uses in 4 of 41 samples collected, and
- U.S. EPA acute RWQC for marine and estuarine waters, which are solely based on enterococci results, in 1 of the 41 samples collected.

Samples that exceeded these acute objectives and criteria were collected during ebb sampling events conducted on 18 July 2016 and on 8 August 2016 at sampling locations W-1 and W-2 (Figure 2). These sampling locations were at the mouth of Redwood Creek, which is adjacent to Docktown Marina. Samples were collected approximately 3 hours following high tide, when water was flowing toward San Francisco Bay (ebb current).

The excursion frequency of acute water quality objectives was calculated at each sampling locations over the 30-day sampling period. As shown in Table 7-2, the Basin Plan acute WQO for fecal coliform was the only acute objective or criterion that surpassed the allowable excursion frequency of 10 percent over a 30-day period at locations W-1 and W-2. Results of enterococci analyses, which recent U.S. EPA studies consider the most reliable FIB for marine and estuarine waters, did not exceed the allowable excursion frequency of 10 percent over the 30-day period at either W-1 or W-2.

[19] Table 7-2 identifies the percent exceedance frequency of each FIB at each sampling to the most stringent applicable acute objective for that FIB. It also identifies the overall percent exceedance frequency for each FIB acute objective for all of the samples collected and analyzed for that FIB over the 30-day period, which is considered more representative of the overall water body.

When data from all locations are considered as a whole, the excursion frequencies for all FIB were below the allowable excursion frequency 10 percent over the 30-day period. Therefore, although sporadic exceedance of FIB acute criteria occurred, the FIB results for this 30-day period do not exceed Basin Plan Acute WQO for REC 1 use or U.S. EPA acute RWQC for the overall Study Area. These results pertain to summer months when surface water runoff from Redwood Creek is limited. Additional sampling would be required to assess long-term compliance with these criteria, particularly during winter months, when urban runoff often contains greater concentrations of bacteria, as found at other nearshore beach locations sampled along San Francisco Bay, and described below. However, given that marina operations are not expected to vary seasonally, the bacteriological data obtained are adequate to conclude that Docktown Marina is not a significant source of bacteriological impacts to surface water.

7.5 Fecal Indicator Bacteria Results at San Francisco Bay Beaches

EKI compiled recent bacteriological results from San Francisco Bay beaches in San Mateo County that are regularly sampled by the San Mateo County Department of Environmental Health ("SMCDEH"). This information was electronically downloaded from the California Water Quality Council ("CWQC") for the following locations:[20]

- Aquatic Park, San Mateo
- Coyote Point, San Mateo
- Kite Board Beach, Foster City
- Lakeshore Park, San Mateo
- Oyster Point Marina, South San Francisco

Figure 7-3 shows the locations of these San Francisco Bay beaches and their relative location to bacteriological sampling locations at Redwood Creek and the slough.

Graphs of single sample FIB results and relevant central tendency values (e.g., geometric mean and/or median) for these beaches are included in Appendix E. These graphs are based on data collected between May 2015 and May 2016.[21] The graphs show exceedances of:

- Both acute and central tendency objectives are common for all FIB at most beaches in winter months (i.e., October through April).
- Acute FIB objectives is not common during summer months but does occur.

[20] Graphs were created from data files downloaded from CWQC (2016).

[21] More recent data (i.e., post May 2016) were not available on CWQC website.

- Central tendency FIB objectives occurs regularly in summer months at Aquatic Park and Lake Shore Park, which are on the Clean Water Act ("CWA") Section 303(d) list of impaired water bodies due to exceedances of bacteria objectives (RWQCB, 2013).[22]

- Total coliform Basin Plan central tendency objective (which is based on median total coliform concentrations) occurs consistently at Aquatic Park, Lake Shore Park, Oyster Point and Kite Board Beach.

The Regional Board (2013, 2010) has identified sanitary sewer systems, storm water runoff, vessels, wildlife, and wastewater treatment plants as potential sources of bacteria detected in San Francisco Bay.

Fecal coliform results from sampling locations at the mouth of Redwood Creek and at Docktown Marina appear to have a slightly higher excursion frequency of acute WQO than fecal coliform results from other San Mateo beaches during summer months. However, enterococci results from the Study Area, which recent U.S. EPA studies consider the most reliable FIB for marine and estuarine waters are not inconsistent with data from other beaches and none of the central tendency FIB objectives were exceeded in the Study Area. The duration of the Study Area sampling effort is, however, inadequate to make a valid statistical comparison.

[22] A Project Definition report has been prepared by the RWQCB that represents the first step in the process of developing a TMDL for the 303(d)-listed beaches (RWQCB, 2013).

8 CONCLUSIONS

Review of available information indicates COPCs in sediments may be attributable to numerous regional and local sources. The Regional Board has determined sediments in San Francisco Bay are impacted by regional sources of PCBs, organochlorine pesticides, mercury, copper, lead, nickel, selenium, zinc, and PAHs (RWQCB, 2015 and 1998).

An ESA of the Study Area and vicinity identified potential local sources of COPCs including a former chemical mixing facility where pesticides were formulated, several boat yards, multiple leaking underground storage tank sites, a landfill and storage yard, and a PG&E electrical substation. Potential impacts from Docktown Marina also were assessed. The nature and extent of COPCs detected in sediment indicate Docktown Marina is not a primary source of contamination. Copper and PAHs are most commonly associated with marinas. However, except for pesticides and nickel, which are not generally attributable to marina operations, COPC concentrations in sediment samples collected from Redwood Creek are not markedly higher than ambient concentrations at the margins of San Francisco Bay.

The highest COPC concentrations were detected in sediment samples from the slough. The slough is located next to Redwood Creek and less subject to flushing and scouring. Softer sediments are present in the slough, which allowed sediment samples to be collected from deeper depths. Deeper sediments are more likely to reflect chemical impacts from historical activities when use of PCBs, organochlorine pesticides and other chemicals was prevalent and less regulated. In addition, storm drains that collect surface water and groundwater from the Study Area and upland watershed discharge directly into the slough.

8.1 Potential Sediment Toxicity to Benthic Organisms

Sediment concentrations of organochlorine pesticides and other COPCs are greater than ambient values and ERMs. However, evaluation of the data utilizing a mechanistic approach, which considers the bioavailability of contaminants, indicates adverse effects to benthic organisms are unlikely to occur.

The conclusion that COPCs in sediment within Redwood Creek are not detrimental to benthic organisms is supported by examining multiple LOEs that were relied upon in evaluating sediment quality of Mission Creek in San Francisco. Impacts at Mission Creek are similar to those at the Study Area. These LOEs indicate the COPCs do not result in adverse effects to benthic organisms.

Although COPCs do not appear to be affecting survival of benthic organisms in the Study Area, chemicals considered to be bioaccumulative (i.e., methylmercury, organochlorine pesticides, PCBs, and PAHs) may concentrate within the food chain, which could pose threats to humans that consume fish from the Study Area. EKI performed an HHRA to evaluate this and other concerns.

8.2 Potential Sediment Human Health Risks

The HHRA, performed to assess potential human health risks associated with exposure to COPCs in sediment within the Study Area, considers the

- **Beach play scenario**, which evaluates potential risks to individuals that play on the tidal flats or wade in water on tidal flats within the Study Area, and
- **Angler fish consumption scenario**, which evaluates potential risks to individuals that catch and consume fish (i.e., anglers) from the Study Area.

For the beach play exposure scenario, results of the HHRA indicate that non-carcinogenic risks are insignificant and incremental carcinogenic risks fall within the target cancer risk range of 1×10^{-6} to 1×10^{-4}. Moreover, these estimated human health risks are not unique to Docktown Marina or the Study Area, and are similar to those that would be calculated from exposure to sediments throughout the Bay. Further action to address these risks is not warranted.

For the angler scenario, the results of the HHRA indicate that COPC concentrations detected in sediment within the Study Area may bioaccumulate to unacceptable levels in fish for human consumption. However, this estimated risk should not be interpreted as an actual risk because the HHRA results are based on exposure assumptions and BSAFs obtained from studies and not site-specific data. The HHRA results indicate only that there is the potential for risk due to consumption of fish from the Study Area. However, that risk is not attributable to activities at Docktown Marina.

OEHHA has issued fish consumption advisories that pertain to San Francisco Bay for all bioaccumulative COPCs, except PAHs, that were detected in sediment within the Study Area. In the absence of additional information, OEHHA fish consumption advisories should be followed for fish caught within all portions of the Bay, including within the Study Area. PAHs are rarely detected in fish from San Francisco Bay and are not expected to bioaccumulate at concentrations that would pose a threat to human health.

8.3 Surface Water Bacteriological Assessment

FIB results of surface water bacteriological sampling conducted within Redwood Creek and the adjacent slough over a 30-day period (i.e., 15 July to 16 August 2016) did not exceed central tendency WQOs (i.e., geometric mean) for either REC 1 or REC 2 uses (RWQCB, 2015). Sporadic exceedances of Basin Plan acute WQOs and U.S. EPA acute RWQC occurred during ebb currents when water was flowing toward San Francisco Bay at sampling locations collected at the mouth of Redwood Creek, which is adjacent to Docktown Marina. Results from subsequent sampling

events showed exceedances did not persist into the next tidal cycle, which indicates that tidal action within the Study Area effectively flushes out sporadic bacteriological impacts.

Sporadic exceedances of Basin Plan acute WQOs and U.S. EPA acute RWQC are not uncommon at San Francisco Bay beaches. The Regional Board (2013, 2010) has identified sanitary sewer systems, storm water runoff, vessels, wildlife, and wastewater treatment plants as potential sources of bacteria detected in San Francisco Bay.

U.S. EPA considers central tendency objectives more relevant (than single sample criteria) for ensuring that appropriate actions are taken to protect and improve water quality (U.S. EPA, 2004). When data from all sampling locations are considered as a whole, none of the FIB excursion frequencies exceeded the allowable value of 10 percent over the 30-day period. Therefore, although sporadic exceedance of FIB acute criteria occurred, the FIB results for this 30-day period do not indicate that Basin Plan WQO for REC 1 use or U.S. EPA acute RWQC for the overall Study Area are being exceeded. These results pertain to summer months when surface water runoff from Redwood Creek is limited. Additional sampling would be required to assess long-term compliance with these criteria, particularly during winter months, when urban runoff often contains greater concentrations of bacteria. However, given that marina operations are not expected to vary seasonally, the data obtained are adequate to conclude that Docktown Marina is not a significant source of bacteriological impacts to surface water.

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Table 3-1
Comparison of Study Area Sediment Data with
San Francisco Bay Ambient Values and Effects-Range Median ("ERM") Sediment Quality Benchmarks ("SQBs")

Redwood Creek, Redwood City, California
EKI B60048.03

Chemical of Potential Concern	Redwood Creek Composite Sediment Sample			San Francisco Bay 2015 Ambient Sediment Value	ERM SQB
	RWC-A1	RWC-A2	RWC-A3		
Metals (mg/kg dry wt)					
Arsenic	5.28	6.46	7.44	13.9	70
Cadmium	**0.584**	**0.746**	**8.18**	0.33	9.6
Chromium	**141**	**154**	**202**		370
Copper	41.8	**59.1**	**197**	53.9	270
Lead	**40**	**59.7**	**130**	25.1	218
Mercury	**0.529**	**0.957**	**1.72**	0.33	0.71
Nickel	**200**	**219**	**160**	98.3	51.6
Selenium	**0.489**	**0.549**	**0.925**	0.36	
Silver	0.298	**0.53**	**12.9**	0.32	3.7
Zinc	122	**163**	**405**	136	410
Organochlorine Pesticides (µg/kg dry wt)					
Aldrin	<0.50	<0.56	<0.71	0.03	
alpha-BHC	<0.48	<0.53	<0.68		
beta-BHC	<0.41	<0.46	<0.59		
delta-BHC	<0.51	<0.57	<0.73		
gamma-BHC (Lindane)	<0.37	<0.41	<0.53	0.05	
alpha-Chlordane	19	11	15		
gamma-Chlordane	10	6.7	11		
Chlordane	**120**	**83**	**130**	0.34	6
Dieldrin	**4.5**	**2.6**	**15**	0.16	8
Endosulfan I	<0.58	<0.64	<0.82		
Endosulfan II	<0.28	<0.32	<0.40		
Endosulfan sulfate	<0.42	<0.47	<0.61		
Endrin	<0.33	<0.36	<0.47	0.01	
Endrin aldehyde	<0.32	<0.35	<0.45		
Heptachlor	<0.36	<0.40	<0.51		
Heptachlor epoxide	<0.30	<0.33	<0.42		
Toxaphene	110	160	210		
2,4'-DDD	<0.32	<0.36	<0.46	0.51	
2,4'-DDE	<0.29	<0.32	<0.41	0.11	
2,4'-DDT	<0.23	<0.25	<0.32	0.04	27
4,4'-DDD	<0.42	<0.46	<0.60	1.98	
4,4'-DDE	12	10	34	1.98	
4,4'-DDT	<0.53	<0.59	<0.76	0.27	
Total Detected DDT	**12**	**10**	**34**	4.68	46.1

Table 3-1
Comparison of Study Area Sediment Data with
San Francisco Bay Ambient Values and Effects-Range Median ("ERM") Sediment Quality Benchmarks ("SQBs")

Redwood Creek, Redwood City, California
EKI B60048.03

Chemical of Potential Concern	Redwood Creek Composite Sediment Sample			San Francisco Bay 2015 Ambient Sediment Value	ERM SQB
	RWC-A1	RWC-A2	RWC-A3		
Organotins (µg/kg dry wt)					
Monobutyltin	<1.6	<1.8	<2.2		
Dibutyltin	10	19	60		
Tributyltin	12	9	33		
Tetrabutyltin	<0.58	<0.64	<0.83		
Total Detected Organotins	22	28	93		
PCBs (µg/kg dry wt)					
PCB 008	<0.90	<1.0	8	0.14	
PCB 018	<0.99	<1.1	17	0.07	
PCB 028	<1.0	<1.2	12	0.28	
PCB 031	<1.2	<1.3	13	0.13	
PCB 033	<0.98	<1.1	11	0.08	
PCB 044	<1.1	<1.2	12	0.33	
PCB 049	<1.2	<1.4	6	0.25	
PCB 052	<1.5	<1.7	19	0.39	
PCB 056	<1.3	<1.5	6	0.14	
PCB 060	<1.1	<1.3	3	0.07	
PCB 066	<0.83	<0.93	9	0.48	
PCB 070	<1.2	<1.3	14	0.59	
PCB 074	<1.2	<1.3	6		
PCB 087	<1.2	<1.3	10	0.46	
PCB 095	2	2	17	0.60	
PCB 097	2	<1.1	9		
PCB 099	<1.2	<1.4	8	0.65	
PCB 101	3	3	27	1.15	
PCB 105	2	<1.2	11	0.36	
PCB 110	3	2	23	1.04	
PCB 118	2	2	21	0.98	
PCB 128	<1.0	<1.1	6	0.28	
PCB 132	<1.1	<1.2	<1.5	0.37	
PCB 138/158	6	5	30	1.83/0.15	
PCB 141	1	<1.2	5	0.20	
PCB 149	4	4	20	1.25	
PCB 151	2	2	6	0.56	
PCB 153	6	5	30	1.74	
PCB 156	<1.2	<1.3	4	0.16	
PCB 170	2	<1.1	11	0.47	
PCB 174	2	2	7	0.49	

Table 3-1
Comparison of Study Area Sediment Data with
San Francisco Bay Ambient Values and Effects-Range Median ("ERM") Sediment Quality Benchmarks ("SQBs")

Redwood Creek, Redwood City, California
EKI B60048.03

Chemical of Potential Concern	Redwood Creek Composite Sediment Sample			San Francisco Bay 2015 Ambient Sediment Value	ERM SQB
	RWC-A1	RWC-A2	RWC-A3		
PCB 177	<1.1	<1.2	4	0.36	
PCB 180	5	3	18	1.02	
PCB 183	1	<1.0	4	0.37	
PCB 187	3	2	9	0.87	
PCB 194	<0.99	<1.1	<1.4	0.33	
PCB 195	<0.89	<0.99	<1.3	0.11	
PCB 201	2	<0.95	6	0.05	
PCB 203	<1.1	<1.2	<1.5	0.17	
PCB 206	1	<1.0	<1.3		
PCB 209	<1.5	<1.6	<2.1		
Total Detected PCBs	**47.4**	**31**	**421**	18.3	180
PAHs (µg/kg dry wt)					
Acenaphthene	**22**	10	**35**	13.5	500
Acenaphthylene	7	11	18	32.6	640
Anthracene	45	29	50	80.1	1,100
Benzo(a)anthracene	200	180	190	212	1,600
Benzo(a)pyrene	270	290	280	428	1,600
Benzo(b)fluoranthene	220	270	250	227	
Benzo(g,h,i)perylene	210	220	200	416	
Benzo(k)fluoranthene	220	230	210	231	
Chrysene	260	280	240	252	2,800
Dibenzo(a,h)anthracene	46	**51**	37	49.9	260
Fluoranthene	470	380	460	620	5,100
Fluorene	23	15	**47**	27.1	540
Indeno(1,2,3-cd)pyrene	170	180	150	337	
Naphthalene	34	45	**3,800**	56.4	2,100
Phenanthrene	**290**	**190**	**240**	176	1,500
Pyrene	510	470	490	791	2,600
Total PAHs	2,996	2,851	**6,697**	4,540	44,792
Sum of Low Molecular Weight PAHs	421	300	**4,190**	3,870	3,160
Sum of High Molecular Weight PAHs	**2,576**	**2,551**	**2,507**	574	9,600

Notes:

(a) Bold black value is greater than relavant ambient value. Bold red value is greater than relevant ERM SQB.

TABLE 4-1
Historical/Current Chemical Use Sites
Potential Local Sources of COPCs in Sediment

Redwood Creek, Redwood City, California
EKI B60048.03

Site	Redwood City Address	Historical/Current Use(s)	Potential Chemicals of Concern	Investigations Conducted	Source of historical Use Data
Former Willard Products	70 Chemical Way	• Former chemical mixing facility (1967 to 1993) • Pesticides formulated on-site based on U.S. EPA records. • The Site was registered as a pesticide producing establishment pursuant to the Federal Insecticide, Fungicide, and Rodenticide Act ("FIFRA"). U.S. EPA fined Willard Products in 1976 for FIFRA violations. • Site redeveloped and currently houses SMC Correctional Facility.	Pesticides, PAHs, Metals, VOCs, and TPH	• DTSC/RWQCB Site • PAHs, metals, VOCs, and TPH detected in soil and groundwater • No pesticide soil sampling identified. • Elevated levels of chlordane were detected on the adjacent railroad spur (i.e., 2,300 ug/kg). • Site redeveloped and capped under oversight of RWQCB	EDR, DTSC & RWQCB Files, and U.S. EPA Records (EDR,2015) (Iris, 2014) (US, EPA, 1997a) (US EPA, 1997b) (Canonie, 1989) (DHS,1990) (DTSC,2002) (Landels, 1991) (RRM,2002)
Former Franks Tannery (includes 1548 Maple Street)	1548 Maple St. occupies a portion of the former tannery. 1548 Maple Street is a commercial industrial property used for vehicle and boat storage and other commercial uses. This Property provides access to Docktown Marina. The property is sometimes identified as Docktown Marina; however, this property is not part of Docktown Marina.	• Tannery (late 1800s – 1960) • Former tannery included use of large quantities of wood bark were stored on-site. • Could have used pesticides to control termites. • Since the 1970s,1548 Maple Street has housed multiple commercial/Industrial tenants • EDR identifies the following potential commercial industrial use operations at 1548 Maple Street Summit Marine, VIP Marine, Jims Diesel Repair, Mallard Industries, North Bay Boat Center, Glasco Marine, Summit Marine, Marine Engine and RV Collision Repair, Peninsula Painting • Redwood City currently leases office and laundry space in several buildings to support operation at Docktown Marina, but performs no boat maintenance activities on this property.	Metals, TPH, pesticides	• Phase I and Phase II environmental investigations performed. • Closed UST site • 10 to 20 soil samples, and groundwater and soil gas samples collected. • Most soil samples collected from depths greater than 2 feet bgs • PAHs detected in soil samples. Levels of PAHs consistent with background levels found in urban areas. • Elevated metal concentrations detected in near surface soil sample collected (i.e., lead, mercury, copper). • No pesticide data obtained near former wood bark sheds • No further action letter issued by RWQCB	• EDR, SMCDEH and RWQCB Files • (EDR,2015) • (West, 2011) • (EKI, 2012) • (RWQCB, 2012)
Former South Bay Boat Works	1450 Maple Street	• Former Boatyard (1960s to 1999) • Former boatyard, operations likely included vessel maintenance and repair • Site Redeveloped into Bair Island Aquatic Center in 1999.	Primary COPCs: Copper and PAHs Other metals: Arsenic, Zinc, Chromium, Lead, Mercury	• EDR Records identify fuel release incidents at this site and generation of less than 1 ton of hazardous waste per year. • Between 1993 and 1994, hydrocarbon solvents, inorganic solid wastes, and oxygenated solvents used on-site • Soil samples collected at two locations on the property. • Samples were collected from 4 feet bgs, no elevated concentrations of metals, PCBs, TPH, or pesticides detected. • No surface soil samples collected • TPH detected in groundwater. • Data provided to SMCDEH	• SMCDEH Files • (AEI, 2008) • (Iris,2009)

TABLE 4-1
Historical/Current Chemical Use Sites
Potential Local Sources of COPCs in Sediment

Redwood Creek, Redwood City, California
EKI B60048.03

Site	Redwood City Address	Historical/Current Use(s)	Potential Chemicals of Concern	Investigations Conducted	Source of Historical Use Data
Former Landfill and Salvage Yard	195 Seaport Boulevard	▪ 1944-1955 landfill/ refuse/disposal area ▪ 1961, salvage yard (possible auto salvage yard). ▪ 1980 to 1996 SMCDEH records indicate facility was operated as a concrete and soil recycling facility by SRDC and that much of the material they accepted was from PG&E. ▪ Operations on the Property were taken over by Granite Rock in 1996, the Property Owner.	▪ Import fill soil/ debris may have contained COPCs including metals, pesticides, and PCBs.	▪ No information found regarding environmental investigations performed	EDR, SMCDEH Records. (EDR,2015) (SMCDEH, 1989), (SMCDEH,1996) (SRDC, 1991a) (SRDC,1991b)
PG&E Substation	Seaport Boulevard	▪ Constructed around 1963. ▪ Surface water runoff from the PG&E substation site discharges directly to the slough.	▪ PCBs in transformer dielectric fluids.	▪ There are no reports of chemical spills or releases at this site. No known environmental investigations	EDR (EDR,2015)
Former SBSA Wastewater Treatment Plant	1581 Maple Street	▪ Former wastewater treatment plant (1950s to 1980s)	▪ Pesticides, metals, PCBs were historically commonly present in discharges from wastewater treatment plants	▪ Wastewater treatment plant may have discharged to slough and Redwood Creek	EDR, SMCDEH (EDR,2015) (historical Topographical maps)
Former Terminix	1189 and 1193 Oddstad Drive	▪ Pesticide operators at this location for decades ▪ Over 200 gallons of Hazardous waste storage ▪ Located adjacent to storm drain that ultimately discharges to Redwood Creek	▪ Pesticides	▪ No environmental soil or groundwater investigations identified	EDR (EDR,2015)
Harbor View Development (Multiple LUST Sites and Area of Tar Seeps)	320, 330, 340 and 350, 410 Blomquist St; 19 Seaport Blvd.; 15,19, 30 Stein AM Rhein Ct,	▪ 320 Blomquist St. Former entertainment complex and Rail Road easement on Eastern Portion of the Parcel 6,000 gallon UST removed in 1989 ▪ 330 Blomquist St. Granite rock building materials office space, retail facility and storage yard. Sump and 9 USTs ▪ 340 Blomquist St., former miniature go-kart racing area. 6,000 gallon gasoline UST ▪ Commercial and Residential Redevelopment Planned	▪ TPH, VOCs ▪ PAHs associated asphaltic tar seeps in fill placed at 320 and 340 Blomquist St. Former Marshland, Sites likely filled after 1943	▪ Investigations conducted under oversight of SMCDEH. ▪ Soil and groundwater impacted by VOCs and TPH. ▪ Soil impacted by PAHs benzo(a)pyrene detected in asphaltic tar seeps ▪ Remedial Actions and Risk Management Plan being implemented under oversight of SMCDEH.	SMCDEH files (Iris,2014)
Docktown Marina	Redwood Creek	▪ Operating Marina in Redwood Creek. Has (see further description in Text)	Primary COPCs associated with Sediment Impacts: Copper and PAHs Other COPCs: TPH, Arsenic, Zinc, Chromium, Lead, Mercury	▪ Reported potential historical chemical release incidents (e.g., TPH) generally associated sinking vessels (see Section 4.3)	SMCDEH files

Table 5-1
Comparison of Study Area Sediment Sample RWC-A1 Data with Mechanistic Sediment Quality Benchmarks

Redwood Creek, Redwood City, California
EKI B60048.03

Chemical of Concern (COC_i)	Measured Concentration ($\mu g/g_{DW}$); (a)	Organic Carbon Normalized Concentration ($\mu g/g_{oc}$); (b), (c)	Published Toxicity LC50 Values (d) ($\mu g/g_{DW}$)	Published Toxicity LC50 Values (d) ($\mu g/g_{oc}$)	ESB_i SEM_i (e) ($\mu mol/g_{DW}$)	Equilibrium Partitioning Sediment Benchmark (ESB_i) Conventional ($\mu g/g_{oc}$)	Equilibrium Partitioning Sediment Benchmark (ESB_i) Narcosis ($\mu g/g_{oc}$)	ESB_i Toxic Units Conventional ($\mu g/g_{oc}$)	ESB_i Toxic Units Narcosis ($\mu g/g_{oc}$)
Metals									
Arsenic	5.28								
Cadmium	0.584		9,810		0.005				
Chromium	141								
Copper	41.8		534		0.66				
Lead	40				0.19				
Mercury	0.529		13.1						
Nickel	200				3.4				
Selenium	0.489								
Silver	0.298				0.001				
Zinc	122		276		0.9				
ΣSEM_i					5.2				
$ESB_{AVS} = \Sigma SEM_i$ - AVS (f)					2.2				
$ESB_{AVS\ oc} = ESB_{AVS}/f_{oc}$ (g)					**85**				
Nonionic Organic Chemicals									
Organochlorine Pesticides									
Total Chlordane (h)	0.12	4.62	>31.4						
Dieldrin	0.0045	0.17				28		0.006	
Toxaphene	0.11	4.23				54		0.078	
Total Detected DDT	0.012	0.46	0.554	101					
Total Detected Organotins (i)	0.022	0.85		78 (j)		6 (k)		0.14	
Total Detected PCBs	0.0474	1.82	11						
Polycyclic Aromatic Hydrocarbons									
Acenaphthene	0.022	0.85		2,577			491		0.0017
Acenaphthylene	0.007	0.25					452		0.0006
Anthracene	0.045	1.73					594		0.0029
Benz(a)anthracene	0.20	7.69					841		0.0091
Benzo(a)pyrene	0.27	10.38					965		0.011
Benzo(b)fluoranthene	0.22	8.46					979		0.0086
Benzo(g,h,i)perylene	0.21	8.08					1,095		0.0074
Benzo(k)fluoranthene	0.22	8.46					981		0.0086
Chrysene	0.26	10					844		0.012
Dibenz(a,h)anthracene	0.046	1.77					1,123		0.0016
Fluoranthene	0.47	18.08		3,533			707		0.026
Fluorene	0.023	0.88					538		0.0016
Indeno(1,2,3-cd)pyrene	0.17	6.54					1,115		0.0059
Naphthalene	0.034	1.31					385		0.0034
Phenanthrene	0.29	11.15		4,010			596		0.019
Pyrene	0.51	19.62					697		0.028
$\Sigma TU_i = COC_i / ESB_i$ (l)								**0.23**	**0.15**

Table 5-1
Comparison of Study Area Sediment Sample RWC-A1 Data with Mechanistic Sediment Quality Benchmarks

Redwood Creek, Redwood City, California
EKI B60048.03

Notes:

(a) Measured concentration in composite sediment sample on a dry weight basis.

(b) Composite sample was measured to contain 2.6 percent total organic carbon (TOC), which corresponds to a fraction of organic carbon (f_{oc}) of 0.026 g organic carbon/g dry sediment.

(c) Measured concentration normalized to TOC in composite sediment sample.

(d) Published lethal concentration 50 (LC50) for amphipod *Eohaustorius estuarius* , which is the benchmark species used in the State of California's sediment quality objectives program. LC50 value is chemical concentration in sediment sample on a dry weight basis ($\mu g/g_{DW}$) or normalized to TOC in sediment sample ($\mu g/g_{OC}$) that kills 50 percent of amphipod during the observation (e.g., 96-hour) period.

(e) Simultaneously extracted metal (SEM) concentration in micromoles per gram dry sediment.

(f) A sediment acid volatile sulfide (AVS) concentration of 3 $\mu mol/g_{DW}$ is assumed. This AVS concentration is conservative based on AVS levels up to 40 $\mu mol/g_{DW}$ at mud flats near Palo Alto, California. See Lee, J. et al. 2001. *Influence of Reactive Sulfide (AVS) and Supplementary Food on Ag, Cd and Zn Bioaccumulation in the Marine Polychaete Neanthes arenaceodentata* . Marine Ecology Progress Series. Vol. 216. pp. 129–140. AVS is a measure of reactive sulfides in sediment. When there is an excess of AVS, metals will form insoluble and nonbioavailable metal sulfides (e.g., NiS, ZnS, CdS, PbS, CuS, and Ag_2S) rather than partition into the dissolved phase and become bioavailable to aquatic organisms.

(g) U.S. EPA interprets $ESB_{AVS\ oc}$ as follows: (a) adverse effects unlikely if less than 130 $\mu mol/g_{DW}$, (b) adverse effects uncertain if between 130 to 3,000 $\mu mol/g_{DW}$, and (c) adverse effects may occur if greater than 3,000 $\mu mol/g_{DW}$. U.S. EPA. 2005. *Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms: Metal Mixtures (Cadmium, Copper, Lead, Nickel, Silver and Zinc)* . Office of Research and Development. EPA-600-R-02-011.

(h) Total chlordane refers to the sum of alpha-chlordane, beta-chlordane, cis-nonachlor, trans-nonachlor, heptachlor, heptachlor epoxide, and oxychlordane.

(i) Total organotins refers to the sum of monobutyltin, dibutyltin, tributyltin, and tetrabutyltin.

(j) LC50 value for tributyltin.

(k) ESB_i value for tributyltin from Meador, J.P., T.K. Collier, and J.E. Stein. 2002. *Determination of a Tissue and Sediment threshold for Tributyltin to Protect Prey Species of Juvenile Salmonids Listed Under the U.S. Endangered Species Act* . Aquatic Conservation: Marine and Freshwater Ecosystems. Vol. 12. pp. 539–551.

(l) Adverse effects to benthic organisms are unlikely to occur if the sum of the concentrations are equal to or less than the ESBs [i.e., ≤ 1.0 toxic unit (TU_i)]. Adverse effects may occur if sum of the TU_i is greater than 1.

Table 5-2
Comparison of Study Area Sediment Sample RWC-A2 Data with Mechanistic Sediment Quality Benchmarks

Redwood Creek, Redwood City, California
EKI B60048.03

Chemical of Concern (COC_i)	Measured Concentration ($\mu g/g_{DW}$); (a)	Organic Carbon Normalized Concentration ($\mu g/g_{oc}$); (b), (c)	Published Toxicity LC50 Values (d) ($\mu g/g_{DW}$)	Published Toxicity LC50 Values (d) ($\mu g/g_{oc}$)	ESB_i SEM_i (e) ($\mu mol/g_{DW}$)	Equilibrium Partitioning Sediment Benchmark (ESB_i) Conventional ($\mu g/g_{oc}$)	Equilibrium Partitioning Sediment Benchmark (ESB_i) Narcosis ($\mu g/g_{oc}$)	ESB_i Toxic Units Conventional ($\mu g/g_{oc}$)	ESB_i Toxic Units Narcosis ($\mu g/g_{oc}$)
Metals									
Arsenic	6.46								
Cadmium	0.746		9,810		0.007				
Chromium	154								
Copper	59.1		534		0.93				
Lead	59.7				0.29				
Mercury	0.957		13.1						
Nickel	219				3.7				
Selenium	0.549								
Silver	0.53				0.002				
Zinc	163		276		1.2				
ΣSEM_i					6.2				
$ESB_{AVS} = \Sigma SEM_i$ - AVS (f)					3.2				
$ESB_{AVS\ oc} = ESB_{AVS}/f_{oc}$ (g)					**111**				
Nonionic Organic Chemicals									
Organochlorine Pesticides									
Total Chlordane (h)	0.083	2.86	>31.4						
Dieldrin	0.0026	0.09				28		0.003	
Toxaphene	0.16	5.52				54		0.102	
Total Detected DDT	0.01	0.34	0.554	101					
Total Detected Organotins (i)	0.0284	0.98		78 (j)		6 (k)		0.16	
Total Detected PCBs	0.031	1.07	11						
Polycyclic Aromatic Hydrocarbons									
Acenaphthene	0.010	0.34		2,577			491		0.0007
Acenaphthylene	0.011	0.38					452		0.0008
Anthracene	0.029	1.00					594		0.0017
Benz(a)anthracene	0.18	6.21					841		0.0074
Benzo(a)pyrene	0.29	10.00					965		0.010
Benzo(b)fluoranthene	0.27	9.31					979		0.0095
Benzo(g,h,i)perylene	0.22	7.59					1,095		0.0069
Benzo(k)fluoranthene	0.23	7.93					981		0.0081
Chrysene	0.28	10					844		0.011
Dibenz(a,h)anthracene	0.051	1.76					1,123		0.0016
Fluoranthene	0.38	13.10		3,533			707		0.019
Fluorene	0.015	0.52					538		0.0010
Indeno(1,2,3-cd)pyrene	0.18	6.21					1,115		0.0056
Naphthalene	0.045	1.55					385		0.0040
Phenanthrene	0.19	6.55		4,010			596		0.011
Pyrene	0.47	16.21					697		0.023
$\Sigma TU_i = COC_i / ESB_i$ (l)								**0.27**	**0.12**

Table 5-2
Comparison of Study Area Sediment Sample RWC-A2 Data with Mechanistic Sediment Quality Benchmarks

Redwood Creek, Redwood City, California
EKI B60048.03

Notes:

(a) Measured concentration in composite sediment sample on a dry weight basis.

(b) Composite sample was measured to contain 2.9 percent total organic carbon (TOC), which corresponds to a fraction of organic carbon (f_{oc}) of 0.029 g organic carbon/g dry sediment.

(c) Measured concentration normalized to TOC in composite sediment sample.

(d) Published lethal concentration 50 (LC50) for amphipod *Eohaustorius estuarius* , which is the benchmark species used in the State of California's sediment quality objectives program. LC50 value is chemical concentration in sediment sample on a dry weight basis ($\mu g/g_{DW}$) or normalized to TOC in sediment sample ($\mu g/g_{OC}$) that kills 50 percent of amphipod during the observation (e.g., 96-hour) period.

(e) Simultaneously extracted metal (SEM) concentration in micromoles per gram dry sediment.

(f) A sediment acid volatile sulfide (AVS) concentration of 3 $\mu mol/g_{DW}$ is assumed. This AVS concentration is conservative based on AVS levels up to 40 $\mu mol/g_{DW}$ at mud flats near Palo Alto, California. See Lee, J. et al. 2001. *Influence of Reactive Sulfide (AVS) and Supplementary Food on Ag, Cd and Zn Bioaccumulation in the Marine Polychaete Neanthes arenaceodentata* . Marine Ecology Progress Series. Vol. 216. pp. 129–140. AVS is a measure of reactive sulfides in sediment. When there is an excess of AVS, metals will form insoluble and nonbioavailable metal sulfides (e.g., NiS, ZnS, CdS, PbS, CuS, and Ag_2S) rather than partition into the dissolved phase and become bioavailable to aquatic organisms.

(g) U.S. EPA interprets $ESB_{AVS\ oc}$ as follows: (a) adverse effects unlikely if less than 130 $\mu mol/g_{DW}$, (b) adverse effects uncertain if between 130 to 3,000 $\mu mol/g_{DW}$, and (c) adverse effects may occur if greater than 3,000 $\mu mol/g_{DW}$. U.S. EPA. 2005. *Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms: Metal Mixtures (Cadmium, Copper, Lead, Nickel, Silver and Zinc)* . Office of Research and Development. EPA-600-R-02-011.

(h) Total chlordane refers to the sum of alpha-chlordane, beta-chlordane, cis-nonachlor, trans-nonachlor, heptachlor, heptachlor epoxide, and oxychlordane.

(i) Total organotins refers to the sum of monobutyltin, dibutyltin, tributyltin, and tetrabutyltin.

(j) LC50 value for tributyltin.

(k) ESB_i value for tributyltin from Meador, J.P., T.K. Collier, and J.E. Stein. 2002. *Determination of a Tissue and Sediment threshold for Tributyltin to Protect Prey Species of Juvenile Salmonids Listed Under the U.S. Endangered Species Act* . Aquatic Conservation: Marine and Freshwater Ecosystems. Vol. 12. pp. 539–551.

(l) Adverse effects to benthic organisms are unlikely to occur if the sum of the concentrations are equal to or less than the ESBs [i.e., ≤ 1.0 toxic unit (TU_i)]. Adverse effects may occur if sum of the TU_i is greater than 1.

Table 5-3
Comparison of Study Area Sediment Sample RWC-A3 Data with Mechanistic Sediment Quality Benchmarks

Redwood Creek, Redwood City, California
EKI B60048.03

Chemical of Concern (COC_i)	Measured Concentration ($\mu g/g_{DW}$); (a)	Organic Carbon Normalized Concentration ($\mu g/g_{oc}$); (b), (c)	Published Toxicity LC50 Values (d) ($\mu g/g_{DW}$)	Published Toxicity LC50 Values (d) ($\mu g/g_{oc}$)	ESB_i SEM_i (e) ($\mu mol/g_{DW}$)	Equilibrium Partitioning Sediment Benchmark (ESB_i) Conventional ($\mu g/g_{oc}$)	Equilibrium Partitioning Sediment Benchmark (ESB_i) Narcosis ($\mu g/g_{oc}$)	ESB_i Toxic Units Conventional ($\mu g/g_{oc}$)	ESB_i Toxic Units Narcosis ($\mu g/g_{oc}$)
Metals									
Arsenic	7.44								
Cadmium	8.18		9,810		0.073				
Chromium	202								
Copper	197		534		3.10				
Lead	130				0.63				
Mercury	1.72		13.1						
Nickel	160				2.7				
Selenium	0.925								
Silver	12.9				0.060				
Zinc	405		276		3.1				
ΣSEM_i					9.7				
$ESB_{AVS} = \Sigma SEM_i$ - AVS (f)					6.7				
$ESB_{AVS\ oc} = ESB_{AVS}/f_{oc}$ (g)					**129**				
Nonionic Organic Chemicals									
Organochlorine Pesticides									
Total Chlordane (h)	0.13	2.50	>31.4						
Dieldrin	0.015	0.29				28		0.010	
Toxaphene	0.21	4.04				54		0.075	
Total Detected DDT	0.034	0.65	0.554	101					
Total Detected Organotins (i)	0.093	1.79		78 (j)		6 (k)		0.30	
Total Detected PCBs	0.421	8.10	11						
Polycyclic Aromatic Hydrocarbons									
Acenaphthene	0.035	0.67		2,577			491		0.0014
Acenaphthylene	0.018	0.35					452		0.0008
Anthracene	0.050	0.96					594		0.0016
Benz(a)anthracene	0.19	3.65					841		0.0043
Benzo(a)pyrene	0.28	5.38					965		0.006
Benzo(b)fluoranthene	0.25	4.81					979		0.0049
Benzo(g,h,i)perylene	0.20	3.85					1,095		0.0035
Benzo(k)fluoranthene	0.21	4.04					981		0.0041
Chrysene	0.24	5					844		0.005
Dibenz(a,h)anthracene	0.037	0.71					1,123		0.0006
Fluoranthene	0.46	8.85		3,533			707		0.013
Fluorene	0.047	0.90					538		0.0017
Indeno(1,2,3-cd)pyrene	0.15	2.88					1,115		0.0026
Naphthalene	3.8	73.08					385		0.1898
Phenanthrene	0.24	4.62		4,010			596		0.008
Pyrene	0.49	9.42					697		0.014
$\Sigma TU_i = COC_i / ESB_i$ (l)								**0.38**	**0.26**

Table 5-3
Comparison of Study Area Sediment Sample RWC-A3 Data with Mechanistic Sediment Quality Benchmarks

Redwood Creek, Redwood City, California
EKI B60048.03

Notes:

(a) Measured concentration in composite sediment sample on a dry weight basis.

(b) Composite sample was measured to contain 5.2 percent total organic carbon (TOC), which corresponds to a fraction of organic carbon (f_{oc}) of 0.052 g organic carbon/g dry sediment.

(c) Measured concentration normalized to TOC in composite sediment sample.

(d) Published lethal concentration 50 (LC50) for amphipod *Eohaustorius estuarius* , which is the benchmark species used in the State of California's sediment quality objectives program. LC50 value is chemical concentration in sediment sample on a dry weight basis ($\mu g/g_{DW}$) or normalized to TOC in sediment sample ($\mu g/g_{OC}$) that kills 50 percent of amphipod during the observation (e.g., 96-hour) period.

(e) Simultaneously extracted metal (SEM) concentration in micromoles per gram dry sediment.

(f) A sediment acid volatile sulfide (AVS) concentration of 3 $\mu mol/g_{DW}$ is assumed. This AVS concentration is conservative based on AVS levels up to 40 $\mu mol/g_{DW}$ at mud flats near Palo Alto, California. See Lee, J. et al. 2001. *Influence of Reactive Sulfide (AVS) and Supplementary Food on Ag, Cd and Zn Bioaccumulation in the Marine Polychaete Neanthes arenaceodentata* . Marine Ecology Progress Series. Vol. 216. pp. 129–140. AVS is a measure of reactive sulfides in sediment. When there is an excess of AVS, metals will form insoluble and nonbioavailable metal sulfides (e.g., NiS, ZnS, CdS, PbS, CuS, and Ag_2S) rather than partition into the dissolved phase and become bioavailable to aquatic organisms.

(g) U.S. EPA interprets $ESB_{AVS\ oc}$ as follows: (a) adverse effects unlikely if less than 130 $\mu mol/g_{DW}$, (b) adverse effects uncertain if between 130 to 3,000 $\mu mol/g_{DW}$, and (c) adverse effects may occur if greater than 3,000 $\mu mol/g_{DW}$. U.S. EPA. 2005. *Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms: Metal Mixtures (Cadmium, Copper, Lead, Nickel, Silver and Zinc)* . Office of Research and Development. EPA-600-R-02-011.

(h) Total chlordane refers to the sum of alpha-chlordane, beta-chlordane, cis-nonachlor, trans-nonachlor, heptachlor, heptachlor epoxide, and oxychlordane.

(i) Total organotins refers to the sum of monobutyltin, dibutyltin, tributyltin, and tetrabutyltin.

(j) LC50 value for tributyltin.

(k) ESB_i value for tributyltin from Meador, J.P., T.K. Collier, and J.E. Stein. 2002. *Determination of a Tissue and Sediment threshold for Tributyltin to Protect Prey Species of Juvenile Salmonids Listed Under the U.S. Endangered Species Act* . Aquatic Conservation: Marine and Freshwater Ecosystems. Vol. 12. pp. 539–551.

(l) Adverse effects to benthic organisms are unlikely to occur if the sum of the concentrations are equal to or less than the ESBs [i.e., ≤ 1.0 toxic unit (TU_i)]. Adverse effects may occur if sum of the TU_i is greater than 1.

Table 6-1
Screening Level Risk Assessment Of Child And Adult Recreators At Tidal Flats Near Docktown Marina (RWC-A1)

Redwood Creek, Redwood City, California
EKI B60048.03

Chemical of Potential Concern	Sediment Measured Concentration ($\mu g/g_{dw}$)	Incremental Lifetime Cancinogenic Risk				Child Non-Carcinogenic Hazard Index				Adult Non-Carcinogenic Hazard Index			
		Exposure Pathway			Total	Exposure Pathway			Total	Exposure Pathway			Total
		Incidental Ingestion	Dermal Absorption	Inhalation		Incidental Ingestion	Dermal Absorption	Inhalation		Incidental Ingestion	Dermal Absorption	Inhalation	
Metals													
Chromium	141					1.5E-04			1.5E-04	2.1E-05			2.1E-05
Copper	41.8					1.7E-03			1.7E-03	2.3E-04			2.3E-04
Lead	40												
Mercury	0.529							3.8E-04	3.8E-04			3.8E-04	3.8E-04
Selenium	0.489					1.6E-04		1.3E-10	1.6E-04	2.2E-05		1.3E-10	2.2E-05
Silver	0.298					9.4E-05			9.4E-05	1.3E-05			1.3E-05
Zinc	122					6.4E-04			6.4E-04	9.1E-05			9.1E-05
Non-Ionic Organic Chemicals													
Organochlorine Pesticides													
Chlordane	0.12	8.4E-09	1.3E-08	2.2E-11	2.1E-08	3.8E-04	7.0E-04	8.3E-07	1.1E-03	5.3E-05	3.9E-05	8.3E-07	9.3E-05
Dieldrin	0.0045	1.4E-08	5.4E-08	4.2E-14	6.8E-08	1.4E-04	6.6E-04		8.0E-04	2.0E-05	3.6E-05		5.6E-05
Toxaphene	0.11	2.4E-08	9.0E-08	7.1E-14	1.1E-07								
p,p'-DDE	0.012	8.1E-10		1.5E-12	8.1E-10								
Organotins	0.022					1.2E-04	5.4E-04		6.5E-04	1.6E-05	3.0E-05		4.6E-05
Polychlorinated Biphenyls	0.0474	1.9E-08	9.9E-08	1.4E-10	1.2E-07								
Polycyclic Aromatic Hydrocarbons													
Acenaphthene	0.022					5.8E-07	3.5E-06		4.1E-06	8.2E-08	1.9E-07		2.7E-07
Acenaphthylene	0.007												
Anthracene	0.045					2.4E-07	1.4E-06		1.7E-06	3.3E-08	7.9E-08		1.1E-07
Benz[a]anthracene	0.2	1.2E-07	6.8E-07	3.8E-11	8.0E-07								
Benzo[a]pyrene	0.27	1.7E-06	9.2E-06	1.7E-12	1.1E-05								
Benzo[b]fluoranthene	0.22	1.4E-07	7.5E-07	1.4E-13	8.8E-07								
Benzo[g,h,i]perylene	0.21												
Benzo[k]fluoranthene	0.22	1.4E-08	7.5E-08	1.4E-13	8.8E-08								
Chrysene	0.26	1.6E-09	8.8E-09	1.6E-14	1.0E-08								
Dibenz[a,h]anthracene	0.046	2.9E-07	1.6E-06	3.1E-13	1.8E-06								
Fluoranthene	0.47					1.9E-05	1.1E-04		1.3E-04	2.6E-06	6.2E-06		8.8E-06
Fluorene	0.023					9.1E-07	5.5E-06		6.4E-06	1.3E-07	3.0E-07		4.3E-07
Indeno[1,2,3-cd]pyrene	0.17	1.1E-07	5.8E-07	1.0E-13	6.8E-07								
Naphthalene	0.034			6.9E-11	6.9E-11	2.7E-06	1.6E-05	1.8E-06	2.1E-05	3.8E-07	8.9E-07	1.8E-06	3.1E-06
Phenanthrene	0.29												
Pyrene	0.51					2.7E-05	1.6E-04		1.9E-04	3.8E-06	8.9E-06		1.3E-05
Total Incremental Cancer Risk or HI		**2.4E-06**	**1.3E-05**	**2.7E-10**	**1.5E-05**	**3.4E-03**	**2.2E-03**	**3.8E-04**	**6.0E-03**	**4.8E-04**	**1.2E-04**	**3.8E-04**	**9.8E-04**

Table 6-1
Screening Level Risk Assessment Of Child And Adult Recreators At Tidal Flats Near Docktown Marina (RWC-A1)

Notes:

(a) Measured concentration in composite sediment sample on a dry weight basis.

(b) Incremental lifetime carcinogenic risk and non-carcinogenic hazard index were derived utilizing U.S. EPA RSL calculator assuming exposed skin-weighted average soil adherence factors of 3.9 milligrams per square centimeter ("mg/cm2") for children (2 to 12 years old) and 0.3 mg/cm2for adults, based on U.S. EPA, September 2011.Exposure Factors Handbook: 2011 Edition. Office of Research and Development. EPA/600/R-090/052F, and an exposure frequency of 65 days per year and an exposure time of 1 hour per day for 26 years based on U.S. EPA Exposure Factors Handbook (2011) and Shoaf et al. 2005.Child Dermal Sediment Loads Following Play in a Tide Flat. Journal of Exposure Analysis and Environmental Epidemiology. Vol. 15. pp. 407-412.

(c) Chlordane refers to total chlordane, which is the sum of alpha-chlordane, beta-chlordane, cis-nonachlor, trans-nonachlor, heptachlor, heptachlor epoxide, and oxychlordane.

(d) Organotins refer to the sum of monobutyltin, dibutyltin, tributyltin, and tetrabutyltin.

Table 6-2
Screening Level Risk Assessment Of Child And Adult Recreators At Tidal Flats In Slough Area (RWC-A3)

Redwood Creek, Redwood City, California
EKI B60048.03

Chemical of Potential Concern	Sediment Measured Concentration ($\mu g/g_{dw}$)	Incremental Lifetime Cancinogenic Risk				Child Non-Carcinogenic Hazard Index				Adult Non-Carcinogenic Hazard Index			
		Exposure Pathway			Total	Exposure Pathway			Total	Exposure Pathway			Total
		Incidental Ingestion	Dermal Absorption	Inhalation		Incidental Ingestion	Dermal Absorption	Inhalation		Incidental Ingestion	Dermal Absorption	Inhalation	
Metals													
Chromium	202					2.1E-04			2.1E-04	3.0E-05			3.0E-05
Copper	197					7.8E-03			7.8E-03	1.1E-03			1.1E-03
Lead	130												
Mercury	1.72							1.2E-03	1.2E-03			1.2E-03	1.2E-03
Selenium	0.925					2.9E-04			2.9E-04	4.1E-05		2.5E-10	4.1E-05
Silver	12.9					4.1E-03			4.1E-03	5.7E-04			5.7E-04
Zinc	405					2.1E-03			2.1E-03	3.0E-04			3.0E-04
Non-Ionic Organic Chemicals													
Organochlorine Pesticides													
Chlordane	0.13	9.1E-09	1.4E-08	2.3E-11	2.3E-08	4.1E-04	7.6E-04	9.0E-07	1.2E-03	5.8E-05	4.2E-05	9.0E-07	1.0E-04
Dieldrin	0.015	4.8E-08	1.8E-07	1.4E-13	2.3E-07	4.8E-04	2.2E-03		2.7E-03	6.7E-05	1.2E-04		1.9E-04
Toxaphene	0.21	4.6E-08	1.7E-07	1.4E-13	2.2E-07								
p,p'-DDE	0.034	2.3E-09		4.3E-12	2.3E-09								
Organotins	0.093					4.9E-04	2.3E-03		2.8E-03	6.9E-05	1.2E-04		1.9E-04
Polychlorinated Biphenyls	0.421	1.7E-07	8.8E-07	1.2E-09	1.0E-06								
Polycyclic Aromatic Hydrocarbons													
Acenaphthene	0.035					9.2E-07	5.6E-06		6.5E-06	1.3E-07	3.1E-07		4.4E-07
Acenaphthylene	0.018												
Anthracene	0.05					2.6E-07	1.6E-06		1.9E-06	3.7E-08	8.7E-08		1.2E-07
Benz[a]anthracene	0.19	1.2E-07	6.5E-07	3.6E-11	7.6E-07								
Benzo[a]pyrene	0.28	1.7E-06	9.5E-06	1.7E-12	1.1E-05								
Benzo[b]fluoranthene	0.25	1.6E-07	8.5E-07	1.5E-13	1.0E-06								
Benzo[g,h,i]perylene	0.2												
Benzo[k]fluoranthene	0.21	1.3E-08	7.1E-08	1.3E-13	8.4E-08								
Chrysene	0.24	1.5E-09	8.2E-09	1.5E-14	9.6E-09								
Dibenz[a,h]anthracene	0.037	2.3E-07	1.3E-06	2.5E-13	1.5E-06								
Fluoranthene	0.46					1.8E-05	1.1E-04		1.3E-04	2.6E-06	6.0E-06		8.6E-06
Fluorene	0.047					1.9E-06	1.1E-05		1.3E-05		6.2E-07		6.2E-07
Indeno[1,2,3-cd]pyrene	0.15	9.3E-08	5.1E-07	9.3E-14	6.0E-07								
Naphthalene	3.8			7.7E-09	7.7E-09	3.0E-04	1.8E-03	2.0E-04	2.3E-03	4.2E-05	9.9E-05	2.0E-04	3.4E-04
Phenanthrene	0.24												
Pyrene	0.49					2.6E-05	1.6E-04		1.8E-04	3.6E-06	8.5E-06		1.2E-05
Total Incremental Cancer Risk or HI		**2.6E-06**	**1.4E-05**	**9.0E-09**	**1.7E-05**	**1.6E-02**	**7.3E-03**	**1.4E-03**	**2.5E-02**	**2.3E-03**	**4.0E-04**	**1.4E-03**	**4.1E-03**

Table 6-2
Screening Level Risk Assessment Of Child And Adult Recreators At Tidal Flats In Slough Area (RWC-A3)

Notes:

(a) Measured concentration in composite sediment sample on a dry weight basis.

(b) Incremental lifetime carcinogenic risk and non-carcinogenic hazard index were derived utilizing U.S. EPA RSL calculator assuming exposed skin-weighted average soil adherence factors of 3.9 milligrams per square centimeter ("mg/cm2") for children (2 to 12 years old) and 0.3 mg/cm2for adults, based on U.S. EPA, September 2011.Exposure Factors Handbook: 2011 Edition. Office of Research and Development. EPA/600/R-090/052F, and an exposure frequency of 65 days per year and an exposure time of 1 hour per day for 26 years based on U.S. EPA Exposure Factors Handbook (2011) and Shoaf et al. 2005.Child Dermal Sediment Loads Following Play in a Tide Flat. Journal of Exposure Analysis and Environmental Epidemiology. Vol. 15. pp. 407-412.

(c) Chlordane refers to total chlordane, which is the sum of alpha-chlordane, beta-chlordane, cis-nonachlor, trans-nonachlor, heptachlor, heptachlor epoxide, and oxychlordane.

(d) Organotins refer to the sum of monobutyltin, dibutyltin, tributyltin, and tetrabutyltin.

Table 6-3
Screening Level Risk Assessment Of Adult Angler At Tidal Flats Near Docktown Marina (RWC-A1)

Redwood Creek, Redwood City, California
EKI B60048.03

Bioaccumulative Chemical of Potential Concern	Sediment Measured Concentration ($\mu g/g_{dw}$)	DMMO Sediment Bioaccumulation Trigger ($\mu g/g_{DW}$)	BSAF	Sediment Organic Carbon Normalized Concentration ($\mu g/g_{oc}$)	Fish Tissue Lipid Normalized Concentration ($\mu g/g_{lipid}$)	Fish Tissue Wet Weight Concentration ($\mu g/g_{lipid}$)	Incremental Lifetime Carcinogenic Risk	Non-Carcinogenic Hazard Index
Non-Ionic Organic Chemicals								
Organochlorine Pesticides								
Chlordane	0.12	0.037	2	4.62	9.23	0.28	6.9E-06	0.1
Dieldrin	0.0045	0.0019	3.4	0.17	0.59	0.02	2.0E-05	0.1
Toxaphene	0.11		1.96	4.23	8.29	0.25	1.9E-05	
p,p'-DDE	0.012	0.05	8.6	0.46	3.97	0.12	2.9E-06	
Polychlorinated Biphenyls (PCBs)	0.0474	0.018	1.64	1.82	2.99	0.09	1.3E-05	
Polycyclic Aromatic Hydrocarbons (PAHs)								
Acenaphthene	0.022		0.19	0.85	0.16	0.005		1.5E-05
Acenaphthylene	0.0065		0.19	0.25	0.05	0.001		
Anthracene	0.045		0.19	1.73	0.33	0.01		6.3E-06
Benz[a]anthracene	0.2		0.19	7.69	1.46	0.04	2.3E-06	
Benzo[a]pyrene	0.27		0.19	10.38	1.97	0.06	3.1E-05	
Benzo[b]fluoranthene	0.22		0.19	8.46	1.61	0.05	2.5E-06	
Benzo[g,h,i]perylene	0.21		0.19	8.08	1.53	0.05		
Benzo[k]fluoranthene	0.22		0.19	8.46	1.61	0.05	2.5E-07	
Chrysene	0.26		0.19	10.00	1.90	0.06	3.0E-08	
Dibenz[a,h]anthracene	0.046		0.19	1.77	0.34	0.01	5.3E-06	
Fluoranthene	0.47		0.19	18.08	3.43	0.10		4.9E-04
Fluorene	0.023		0.19	0.88	0.17	0.01		2.4E-05
Indeno[1,2,3-cd]pyrene	0.17		0.19	6.54	1.24	0.04	1.9E-06	
Naphthalene	0.034		0.19	1.31	0.25	0.01		7.2E-05
Phenanthrene	0.29		0.19	11.15	2.12	0.06		
Pyrene	0.51		0.19	19.62	3.73	0.11		7.2E-04
Total PAHs	3	4.5						
Total Incremental Cancer Risk or HI							**1.1E-04**	**0.18**

Table 6-3
Screening Level Risk Assessment Of Adult Angler At Tidal Flats Near Docktown Marina (RWC-A1)

Notes:

(a) Measured concentration in composite sediment sample on a dry weight basis.

(b) Dredged Material Management Office ("DMMO") requires bioaccumulation testing if chemical of potential concern ("COPC") concentrations in sediments are greater than ambient concentrations in San Francisco Estuary or similar values applied elsewhere in the United States.

(c) Biota sediment accumulation factors ("BSAFs") for toxaphene, PCBs, and PAHs compiled from SFEI. March 2005.Fate of Contaminants in Sediment of *San Francisco Estuary: A Review of Literature and Data. Final Report. Remaining BSAFs obtained from Wong., C.S., P.D. Capel, and L.H. Nowell. 2001. National-Scale, Field-Based Evaluation of the Biota-Sediment Accumulation Factor Model. Environmental Science & Technology. Vol. 35, No. 9. pp. 1709-1715.*

(d) Composite sample was measured to contain 2.6 percent total organic carbon ("TOC"), which corresponds to a fraction of organic carbon (foc) of 0.026 g organic carbon/g dry sediment. Measured concentration normalized to TOC in composite sediment sample by dividing measured concentration in sample by measured TOC content in sample.

(e) Organic carbon-normalized concentration was multiplied by BSAF to obtain lipid-normalized concentration in fish tissue.

(f) Lipid-normalized concentration is multiplied by a lipid fraction of 0.03 to obtain fish tissue wet weight concentration. Lipid fraction is based on U.S. EPA national default consumption-weighted mean values of the lipid fractions of fish commonly eaten throughout the United States are 0.026 and 0.03. U.S. *EPA. December 2003. Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (2000) Technical Support Document, Volume 2: Development of National Bioaccumulation Factors. Office of Water and Office of Science and Technology. EPA-822-R-03-030. p. 6-28.*

(g) Incremental lifetime carcinogenic risk and non-carcinogenic hazard index were derived utilizing U.S. EPA RSL calculator assuming a fish consumption rate of 16 g/day for 26 years based on California Department of Health Services. Technical Report: San Francisco Bay Seafood Consumption Report. Environmental Health Investigations Branch. Prepared for San Francisco Estuary Institute. and U.S. EPA, April 2014.Estimated Fish Consumption Rates *for the U.S. Population and Selected Subpopulations (NHANES) 2003-2010. EPA-820-R-12-002.*

(h) Chlordane refers to total chlordane, which is the sum of alpha-chlordane, beta-chlordane, cis-nonachlor, trans-nonachlor, heptachlor, heptachlor epoxide, and oxychlordane.

(i) Measured concentration of p,p'-DDE is compared to DMMO bioaccumulation trigger for total DDT.

Table 6-4
Screening Level Risk Assessment Of Adult Angler At Tidal Flats In Slough Area (RWC-A3)

Redwood Creek, Redwood City, California
EKI B60048.03

Bioaccumulative Chemical of Potential Concern	Sediment Measured Concentration ($\mu g/g_{dw}$)	DMMO Sediment Bioaccumulation Trigger ($\mu g/g_{DW}$)	BSAF	Sediment Organic Carbon Normalized Concentration ($\mu g/g_{oc}$)	Fish Tissue Lipid Normalized Concentration ($\mu g/g_{lipid}$)	Fish Tissue Wet Weight Concentration ($\mu g/g_{lipid}$)	Incremental Lifetime Carcinogenic Risk	Non-Carcinogenic Hazard Index
Non-Ionic Organic Chemicals								
Organochlorine Pesticides								
Chlordane	0.13	0.037	2	2.50	5.00	0.15	3.7E-06	0.1
Dieldrin	0.015	0.0019	3.4	0.29	0.98	0.03	3.4E-05	0.1
Toxaphene	0.21		1.96	4.04	7.92	0.24	1.9E-05	
p,p'-DDE	0.034	0.05	8.6	0.65	5.62	0.17	4.1E-06	
Polychlorinated Biphenyls (PCBs)	0.421	0.018	1.64	8.10	13.28	0.40	5.7E-05	
Polycyclic Aromatic Hydrocarbons (PAHs)								
Acenaphthene	0.035		0.19	0.67	0.13	0.004		1.2E-05
Acenaphthylene	0.018		0.19	0.35	0.07	0.002		
Anthracene	0.05		0.19	0.96	0.18	0.01		3.5E-06
Benz[a]anthracene	0.19		0.19	3.65	0.69	0.02	1.1E-06	
Benzo[a]pyrene	0.28		0.19	5.38	1.02	0.03	1.6E-05	
Benzo[b]fluoranthene	0.25		0.19	4.81	0.91	0.03	1.4E-06	
Benzo[g,h,i]perylene	0.2		0.19	3.85	0.73	0.02		
Benzo[k]fluoranthene	0.21		0.19	4.04	0.77	0.02	1.2E-07	
Chrysene	0.24		0.19	4.62	0.88	0.03	1.4E-08	
Dibenz[a,h]anthracene	0.037		0.19	0.71	0.14	0.00	2.1E-06	
Fluoranthene	0.46		0.19	8.85	1.68	0.05		2.4E-04
Fluorene	0.047		0.19	0.90	0.17	0.01		2.5E-05
Indeno[1,2,3-cd]pyrene	0.15		0.19	2.88	0.55	0.02	8.6E-07	
Naphthalene	3.8		0.19	73.08	13.88	0.42		4.0E-03
Phenanthrene	0.24		0.19	4.62	0.88	0.03		
Pyrene	0.49		0.19	9.42	1.79	0.05		3.4E-04
Total PAHs	7	4.5						
Total Incremental Cancer Risk or HI							**1.4E-04**	**0.17**

Table 6-4
Screening Level Risk Assessment Of Adult Angler At Tidal Flats In Slough Area (RWC-A3)

Notes:

(a) Measured concentration in composite sediment sample on a dry weight basis.

(b) Dredged Material Management Office ("DMMO") requires bioaccumulation testing if chemical of potential concern ("COPC") concentrations in sediments are greater than ambient concentrations in San Francisco Estuary or similar values applied elsewhere in the United States.

(c) Biota sediment accumulation factors ("BSAFs") for toxaphene, PCBs, and PAHs compiled from SFEI. March 2005.*Fate of Contaminants in Sediment of San Francisco Estuary: A Review of Literature and Data*. Final Report. Remaining BSAFs obtained from Wong., C.S., P.D. Capel, and L.H. Nowell. 2001. *National-Scale, Field-Based Evaluation of the Biota-Sediment Accumulation Factor Model*. Environmental Science & Technology. Vol. 35, No. 9. pp. 1709-1715.

(d) Composite sample was measured to contain 5.2 percent total organic carbon ("TOC"), which corresponds to a fraction of organic carbon (foc) of 0.052 g organic carbon/g dry sediment. Measured concentration normalized to TOC in composite sediment sample by dividing measured concentration in sample by measured TOC content in sample.

(e) Organic carbon-normalized concentration was multiplied by BSAF to obtain lipid-normalized concentration in fish tissue.

(f) Lipid-normalized concentration is multiplied by a lipid fraction of 0.03 to obtain fish tissue wet weight concentration. Lipid fraction is based on U.S. EPA national default consumption-weighted mean values of the lipid fractions of fish commonly eaten throughout the United States are 0.026 and 0.03. U.S. EPA. *December 2003. Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (2000) Technical Support Document, Volume 2: Development of National Bioaccumulation Factors. Office of Water and Office of Science and Technology. EPA-822-R-03-030. p. 6-28.*

(g) Incremental lifetime carcinogenic risk and non-carcinogenic hazard index were derived utilizing U.S. EPA RSL calculator assuming a fish consumption rate of 16 g/day for 26 years based on California Department of Health Services. Technical Report: San Francisco Bay Seafood Consumption Report. Environmental Health Investigations Branch. Prepared for San Francisco Estuary Institute. and U.S. EPA, April 2014.Estimated Fish Consumption Rates for the U.S. *Population and Selected Subpopulations (NHANES) 2003-2010. EPA-820-R-12-002.*

(h) Chlordane refers to total chlordane, which is the sum of alpha-chlordane, beta-chlordane, cis-nonachlor, trans-nonachlor, heptachlor, heptachlor epoxide, and oxychlordane.

(i) Measured concentration of p,p'-DDE is compared to DMMO bioaccumulation trigger for total DDT.

Table 7-1
Bacteriological Limits for Recreation in Estuarine Water

Redwood Creek, Redwood City, California
EKI B60048.03

Water Quality Objectives and Criteria (a)	E. coli	Enterococci	Fecal coliform	Total coliform
RWQCB Basin Plan 2015 Water Quality Objectives (b)				
Basin Plan REC 1 (Acute Objective)	-	104 MPN/100 mL (maximum) (d)	400 MPN/100 mL (90th percentile)	10,000 MPN/mL (Maximum)
Basin Plan REC 1 (Central Tendency Objective) (c)		35 MPN/100 mL (GM) (d)	200 MPN/100mL (GM)	240 MPN/mL (median)
Basin Plan REC 2 (Acute Objective)	-	-	4000 MPN/100 mL (90th percentile)	-
Basin plan Rec 2 (Central Tendency Objective) (c)	-	-	2000 MPN/100 mL (mean)	-
US EPA 2012 Recreational Water Quality Criteria				
U.S. EPA 2012 (Acute Criteria)	410 CFU/100 mL STV (f)	130 CFU/100 mL STV (f)	-	-
U.S. EPA 2012 (Central Tendency Critiera) (c)	126 CFU/100 mL GM (f)	35 CFU/100 mL GM (f)	-	-

Notes:

(a) WQOs for FIB in the Basin Plan are identified in units of most probable number ("MPN") of bacteria per 100 milliliters ("MPN/100 mL"). These WQOs are based on analytical results from serial dilution tests which measure the concentration of a target microbe in a sample with an estimate called the most probable number (MPN). Recent RWQC identified by U.S. EPA are quantified in "colony forming units" per 100 mL ("CFU/100 mL") (U.S. EPA, 2012). These U.S. EPA RWQC are based on membrane filtration techniques that generate results in CFU/100 mL.

(b) RWQCB, 2015, Water Quality Control Plan for the San Francisco Bay Basin ("Basin Plan"). California Regional Water Quality Control Board, San Francisco Bay Region, March 2015.

(c) Based on a minimum of five consecutive samples equally spaced over a 30-day period.

(d) Applicable to marine and estuarine waters only.

(e) U.S. EPA, 2012, Recreational Water Quality Criteria. Office of Water, EPA 820-F-12-058.

(f) Applicable to both fresh and marine waters. E. coli criteria can be used in fresh water.

Table 7-2
Redwood Creek Surface Water Bacteriological Results

Redwood Creek, Redwood City, California
EKI B60048.03

Sampling Location	Sample Date	Sample Time	Tidal Current	E. coli by EPA 9222B (CFU/100mL)	Enterococci by EPA 1600 (CFU/100mL)	Fecal coliform by EPA 9221C (MPN/100mL)	Total coliform by EPA 9221B (MPN/100mL)
WS-1	18 Jul 2016	10:50	flood	50	20	4	22
WS-1 (a)	18 Jul 2016	"10:52" (a)	flood	50	<10	12	41.6
WS-1	18 Jul 2016	16:07	ebb	<10	<10	7	14
WS-1	25 Jul 2016	8:08	ebb	300	60	**500**	1600
WS-1	25 Jul 2016	15:07	flood	<10	10	4	60
WS-1	1 Aug 2016	10:19	flood	60	<10	240	500
WS-1	1 Aug 2016	15:41	ebb	<10	10	7	130
WS-1	8 Aug 2016	7:49	ebb	**660**	130	**1600**	≥1600
WS-1	8 Aug 2016	14:25	flood	20	<10	4	70
WS-1 (a)	8 Aug 2016	"14:25" (a)	flood	<10	<10	50	130
WS-1	15 Aug 2016	9:10	flood	<10	<10	7	80
WS-1	15 Aug 2016	15:12	ebb	10	<10	13	70
Percent Exceedance of Acute Objective (WS-1) (b)				**8%**	**0%**	**17%**	**0%**
RWQCB Basin Plan REC 1 Acute Objective				*410 CFU/100 mL STV (c)*	*130 CFU/100 mL STV (c)*	*400 MPN/100 mL STV (c)*	*10,000 MPN/100 mL Maximum*
Central Tendancy Value (WS-1) (b)				**29 CFU/100 mL**	**15 CFU/100 mL**	**24 MPN/100 mL**	**75 MPN/100 mL**
RWQCB Basin Plan REC 1 Central Tendancy Objective				*126 CFU/100 mL GM*	*35 CFU/100 mL GM*	*200 MPN/100 mL GM*	*240 MPN/100 mL Median*
WS-2	18 Jul 2016	10:41	flood	20	10	9	240
WS-2	18 Jul 2016	16:13	ebb	30	<10	4	80
WS-2	25 Jul 2016	8:20	ebb	130	50	170	900
WS-2 (a)	25 Jul 2016	"09:40" (a)	ebb	180	30	**900**	900
WS-2	25 Jul 2016	15:14	flood	10	<10	<2	17
WS-2	1 Aug 2016	10:16	flood	40	10	22	220
WS-2	1 Aug 2016	15:47	ebb	20	<10	4	26
WS-2	8 Aug 2016	7:56	ebb	**490**	**180**	**1600**	≥1600
WS-2	8 Aug 2016	14:33	flood	<10	<10	4	17
WS-2	15 Aug 2016	9:03	flood	20	<10	7	50
WS-2	15 Aug 2016	15:17	ebb	<10	<10	<2	130
Percent Exceedance of Acute Objective (WS-2) (b)				**9%**	**9%**	**18%**	**0%**
RWQCB Basin Plan REC 1 Acute Objective				*410 CFU/100 mL STV (c)*	*130 CFU/100 mL STV (c)*	*400 MPN/100 mL STV (c)*	*10,000 MPN/100 mL Maximum*
Central Tendancy Value (WS-2) (b)				**35 CFU/100 mL**	**17 CFU/100 mL**	**18 MPN/100 mL**	**130 MPN/100 mL**
RWQCB Basin Plan REC 1 Central Tendancy Objective				*126 CFU/100 mL GM*	*35 CFU/100 mL GM*	*200 MPN/100 mL GM*	*240 MPN/100 mL Median*

Table 7-2
Redwood Creek Surface Water Bacteriological Results

Redwood Creek, Redwood City, California
EKI B60048.03

Sampling Location	Sample Date	Sample Time	Tidal Current	E. coli by EPA 9222B (CFU/100mL)	Enterococci by EPA 1600 (CFU/100mL)	Fecal coliform by EPA 9221C (MPN/100mL)	Total coliform by EPA 9221B (MPN/100mL)
WS-3	18 Jul 2016	10:35	flood	10	<10	14	27
WS-3	18 Jul 2016	16:19	ebb	<10	<10	4	22
WS-3	25 Jul 2016	8:28	ebb	30	<10	50	110
WS-3	25 Jul 2016	14:57	flood	<10	<10	4	6
WS-3	1 Aug 2016	10:12	flood	<10	<10	6	22
WS-3	1 Aug 2016	15:51	ebb	<10	<10	4	40
WS-3	8 Aug 2016	8:02	ebb	80	<10	140	900
WS-3	8 Aug 2016	14:40	flood	10	<10	2.5	5
WS-3	15 Aug 2016	8:54	flood	<10	<10	7	11
WS-3	15 Aug 2016	15:24	ebb	<10	<10	2	22
Percent Exceedance of Acute Objective (WS-3) (b)				**0%**	**0%**	**0%**	**0%**
RWQCB Basin Plan REC 1 Acute Objective				*410 CFU/100 mL STV (c)*	*130 CFU/100 mL STV (c)*	*400 MPN/100 mL STV (c)*	*10,000 MPN/100 mL Maximum*
Central Tendancy Value (WS-3) (b)				**14 CFU/100 mL**	**10 CFU/100 mL**	**8 MPN/100 mL**	**22 MPN/100 mL**
RWQCB Basin Plan REC 1 Central Tendancy Objective				*126 CFU/100 mL GM*	*35 CFU/100 mL GM*	*200 MPN/100 mL GM*	*240 MPN/100 mL Median*
WS-4	18 Jul 2016	10:58	flood	70	<10	11	33
WS-4	18 Jul 2016	16:24	ebb	10	<10	4	11
WS-4	25 Jul 2016	8:41	ebb	50	<10	11	80
WS-4	25 Jul 2016	14:47	flood	20	<10	9	80
WS-4	1 Aug 2016	NS	flood	NS	NS	NS	NS
WS-4	1 Aug 2016	15:57	ebb	<10	<10	8	130
WS-4 (a)	1 Aug 2016	"15:55" (a)	ebb	<10	<10	4	110
WS-4	8 Aug 2016	8:07	ebb	30	20	7	50
WS-4	8 Aug 2016	14:44	flood	<10	<10	9	21
WS-4	15 Aug 2016	9:21	flood	20	<10	11	17
WS-4	15 Aug 2016	15:28	ebb	<10	<10	2	2
Percent Exceedance of Acute Objective (WS-4) (b)				**0%**	**0%**	**0%**	**0%**
RWQCB Basin Plan REC 1 Acute Objective				*410 CFU/100 mL STV (c)*	*130 CFU/100 mL STV (c)*	*400 MPN/100 mL STV (c)*	*10,000 MPN/100 mL Maximum*
Central Tendancy Value (WS-4) (b)				**18 CFU/100 mL**	**11 CFU/100 mL**	**7 MPN/100 mL**	**42 MPN/100 mL**
RWQCB Basin Plan REC 1 Central Tendancy Objective				*126 CFU/100 mL GM*	*35 CFU/100 mL GM*	*200 MPN/100 mL GM*	*240 MPN/100 mL Median*
Percent Exceedance of Acute Objective (OVERALL) (b)				**4.5%**	**2.3%**	**9.1%**	**0%**
Central Tendancy Value (OVERALL) (b)				***23 CFU/100 mL***	***13 CFU/100 mL***	***13 CFU/100 mL***	***65 MPN/100 mL***
RWQCB Basin Plan (2015) Water Quality Standards (d)							
Basin Plan REC 1 (Acute Objective)				-	104 MPN/100 mL (maximum) (f)	400 MPN/100 mL (90th percentile)	10,000 MPN/mL (Maximum)
Basin Plan REC 1 (Central Tendency Objective) (e)				-	35 MPN/100 mL (GM) (f)	200 MPN/100mL (GM)	240 MPN/mL (median)
Basin Plan REC 2 (Acute Objective)				-	-	4000 MPN/100 mL (90th percentile)	-
Basin plan Rec 2 (Central Tendency Objective) (e)				-	-	2000 MPN/100 mL (mean)	-
US EPA 2012 Water Quality Standards (g)							
U.S. EPA 2012 (Acute Objective)				410 CFU/100 mL STV (c)	130 CFU/100 mL STV (c)	-	-
U.S. EPA 2012 (Central Tendency Objective) (e)				126 CFU/100 mL GM	35 CFU/100 mL geometric mean	-	-

Table 7-2
Redwood Creek Surface Water Bacteriological Results

Redwood Creek, Redwood City, California
EKI B60048.03

Notes

(a) Blind duplicate sample (with a fictitious sample time), collected immediately after the primary sample.

(b) Percent exceedance and central tendency statistics were calculated using all data shown. Non-detects were conservatively assumed to be detections at their respective reporting limits.

(c) The Statistical Threshold Value ("STV") approximates the upper 90th percentile of the water quality distribution using EPA epidemiological beach water quality datasets from the 1970s and 1980s, and assuming lognormality. No more than a 10% exceedance frequency of the STV is allowed in a 30-day interval.

(d) RWQCB, 2015,*Water Quality Control Plan for the San Francisco Bay Basin* ("Basin Plan"). California Regional Water Quality Control Board, San Francisco Bay Region, March 2015.

(e) Based on a minimum of five consecutive samples equally spaced over a 30-day period.

(f) Applicable to marine and estuarine waters only.

(g) U.S. EPA, 2012,*Recreational Water Quality Criteria.* Office of Water, EPA 820-F-12-058.

Abbreviations

NS: Not Sampled
GM: Geometric Mean
STV: Statistical Threshold Value

Reference:

Google Earth Pro, date of imagery 15 April 2016.

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Vicinity Map

0 2 4

(Approximate Scale in Miles)

N

Redwood Creek
Redwood City, CA

November 2016
EKI B60048.03

Figure 2-1

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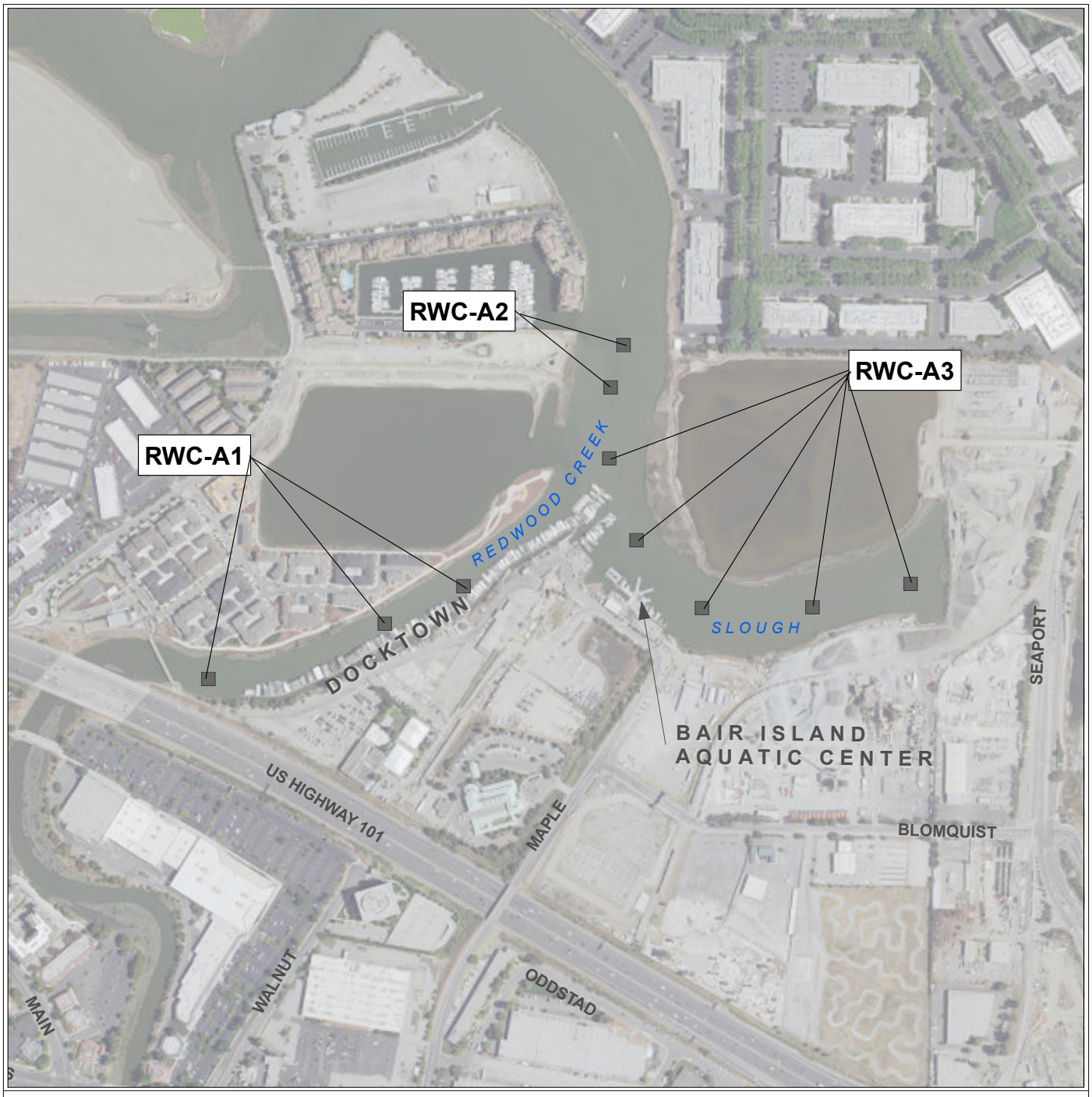

Legend

■ Sediment Sample Composite Locations

Notes
1. All locations are approximate.

Sources
Basemap is ESRI's World Imagery dated 6 October 2016.

N

0 600 1,200

(Approximate Scale in Feet)

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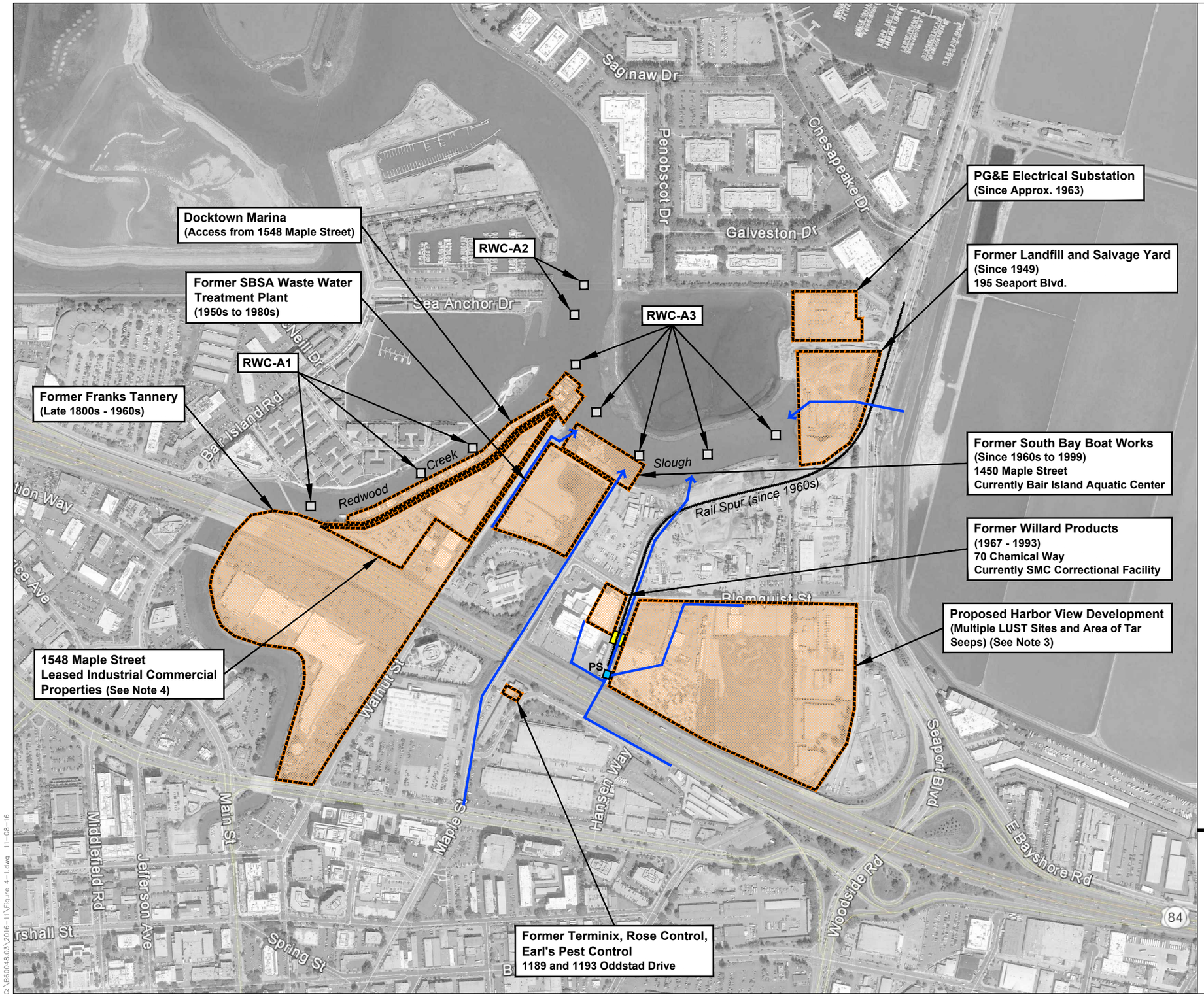
Sediment Sample Locations

Redwood Creek
Redwood City, CA
November 2016
EKI B60048.03

Figure 3-1

Path: X:\B60048\Maps\2016\10\Figure_1_SampleLocs.mxd



N

0 600 1200

(Approximate Scale in Feet)

Legend:

- Current/Historical Chemical Use Sites
- Primary Storm Water Drainage Systems and Discharge Points (West Yost, June 2015)
- Composite Sediment Sampling Location (Pacific EcoRisk, 2011)
- Chlordane Detected in Soil Sample at 2300 ug/kg (IRIS, 2014)
- PS Storm Water Pump Station

Abbreviations:

COPCs = chemicals of potential concern
ug/kg = micrograms per kilogram
LUST = leaking underground storage tank site

Notes:

1. All locations are approximate.
2. Basemap source: Google Earth Pro, date of imagery 5 April 2016.
3. Harbor View Development Proposed at 320, 330, 340, 350, 410 Blomquist Street; 19 Seaport Blvd.; and 15, 19, and 30 Stein Am Rhein Court.
4. Commercial properties include engine repair and historical boat maintenance facilities. Provides access to Docktown Marina. 1548 Maple Street is not part of Docktown Marina.

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Current/Historical Local Chemical Use Sites
Potential Local Sources of
COPCs in Sediment

Redwood Creek
Redwood City, CA

November 2016
EKI B60048.03

Figure 4-1

G:\B60048.03\2016-11\Figure 4-1.dwg 11-08-16

Legend:

Sediment Core Location (Approximate)

Reference: Thomas Guide Bay Area Metro Street Guide, 2015.

0 8 16

(Approximate Scale in Miles)

N

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Core Sediment Sample Locations in San Francisco Bay

Redwood Creek
Redwood City, CA

November 2016
EKI B60048.03

Figure 5-1

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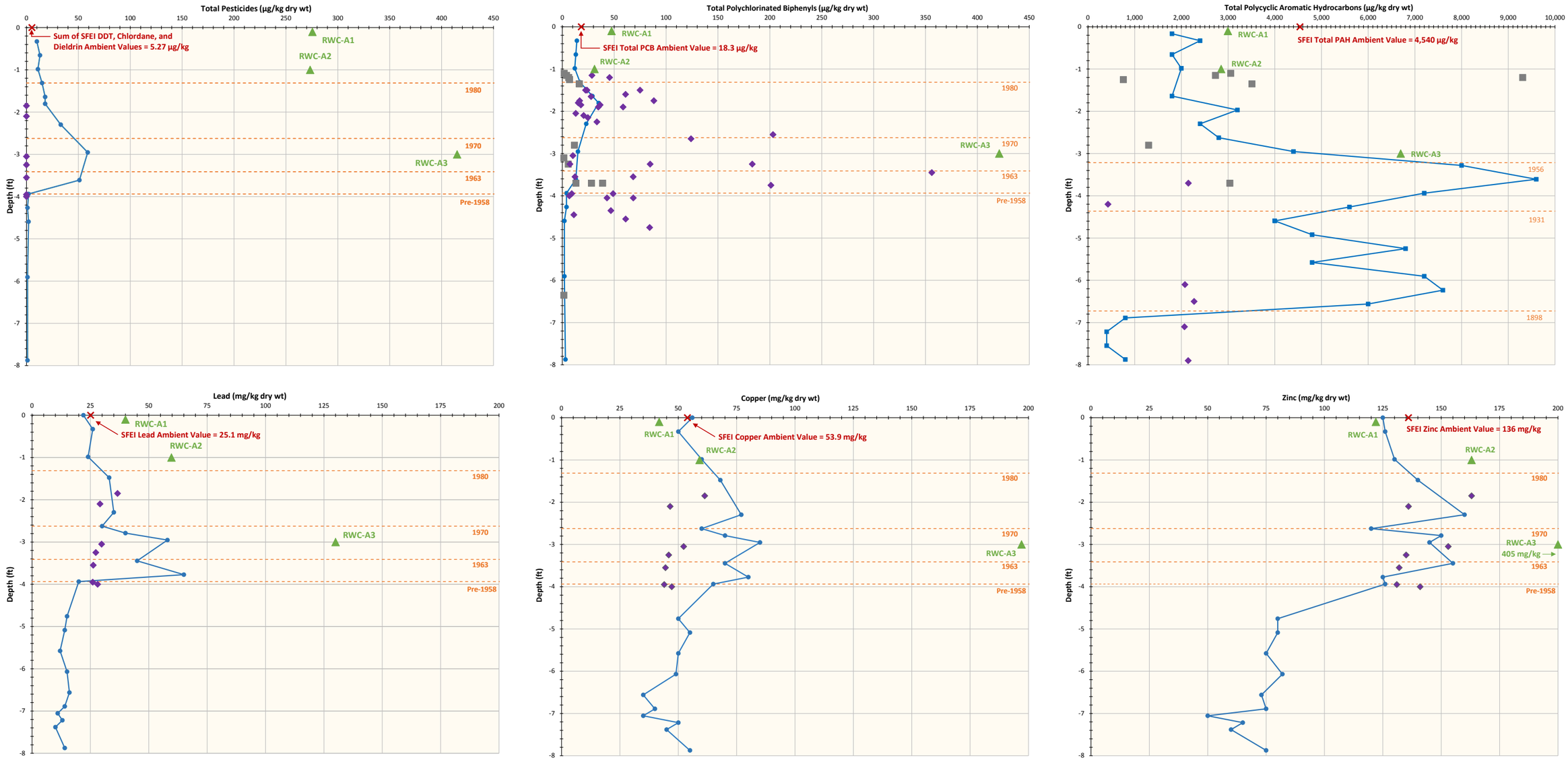

Legend

- ▲ Concentration in composite sediment cores collected from Redwood Creek (i.e., Areas 1 and 2), and nearby slough (i.e., Area 3) in 2011. Pacific EcoRisk Environmental Consulting and Testing. 2011. *Data Report: Sediment Characterization Sampling and Analysis Results (SAR) for the Redwood Creek Sediments.*
- ■ Concentration in composite sediment cores collected from Port of Redwood City Municipal Marina in 2013. Weston Solutions, Inc. 2013. *Results of Chemical, Physical, and Biological Testing of Sediments from the Port of Redwood City, Municipal Marina and F-Dock* .
- ◆ Concentration in composite sediment cores collected from Redwood City Harbor channel in 2014. Kinnetic Laboratories, Inc. and Atkins North America, Inc. 2015. *Report: Redwood City Harbor 2014 O&M Dredging Sampling and Analysis Results* , and Kinnetic Laboratories, Inc. and Atkins North America, Inc. 2015. *Supplemental Report: Redwood City Harbor 2014 O&M Dredging Composite Area 7 High Resolution Sampling and Analysis Results* .
- ● Concentration in sediment cores collected from San Pablo Bay in 1990. Venkatesan et al. 1999. *Chlorinated Hydrocarbon Pesticides and Polychlorinated Biphenyls ("PCBs") in Sediment Cores from San Francisco Bay* . Marine Chemistry. No. 64. pp. 85-97 and Hornberger et al. 1999. *Historical Trends of Metals in the Sediments of San Francisco Bay, California* . Marine Chemistry. No. 64. pp. 39-55.
- ■ Concentration in sediment cores collected from South San Francisco Bay in 2005. Nilsen et al. 2015. *Sedimentary Organic Biomarkers Suggest Detrimental Effects of PAHs on Estuarine Microbial Biomass During the 20th Century in San Francisco Bay, CA, USA.* Chemosphere. No. 119. pp. 961-970.
- ✕ Concentration represents San Francisco Bay ambient value reported in San Francisco Estuary Institute ("SFEI"). July 2015. *Updated Ambient Concentrations of Toxic Chemicals in San Francisco Bay Sediments* . Regional Monitoring Program for Water Quality in the San Francisco Bay.
- - - Horizontal dashed orange line represents age of sediment horizon as determined by age dating and reported by Hornberger et al., 1999 or Nilsen et al., 2015.

Notes:

1. Reported concentrations in composite sediment cores are plotted at the midpoints of the depth intervals from which cores were collected. For example, data for a composite core consisting of sediment collected from sediment/water interface to a depth of -6 feet are plotted at -3 feet.

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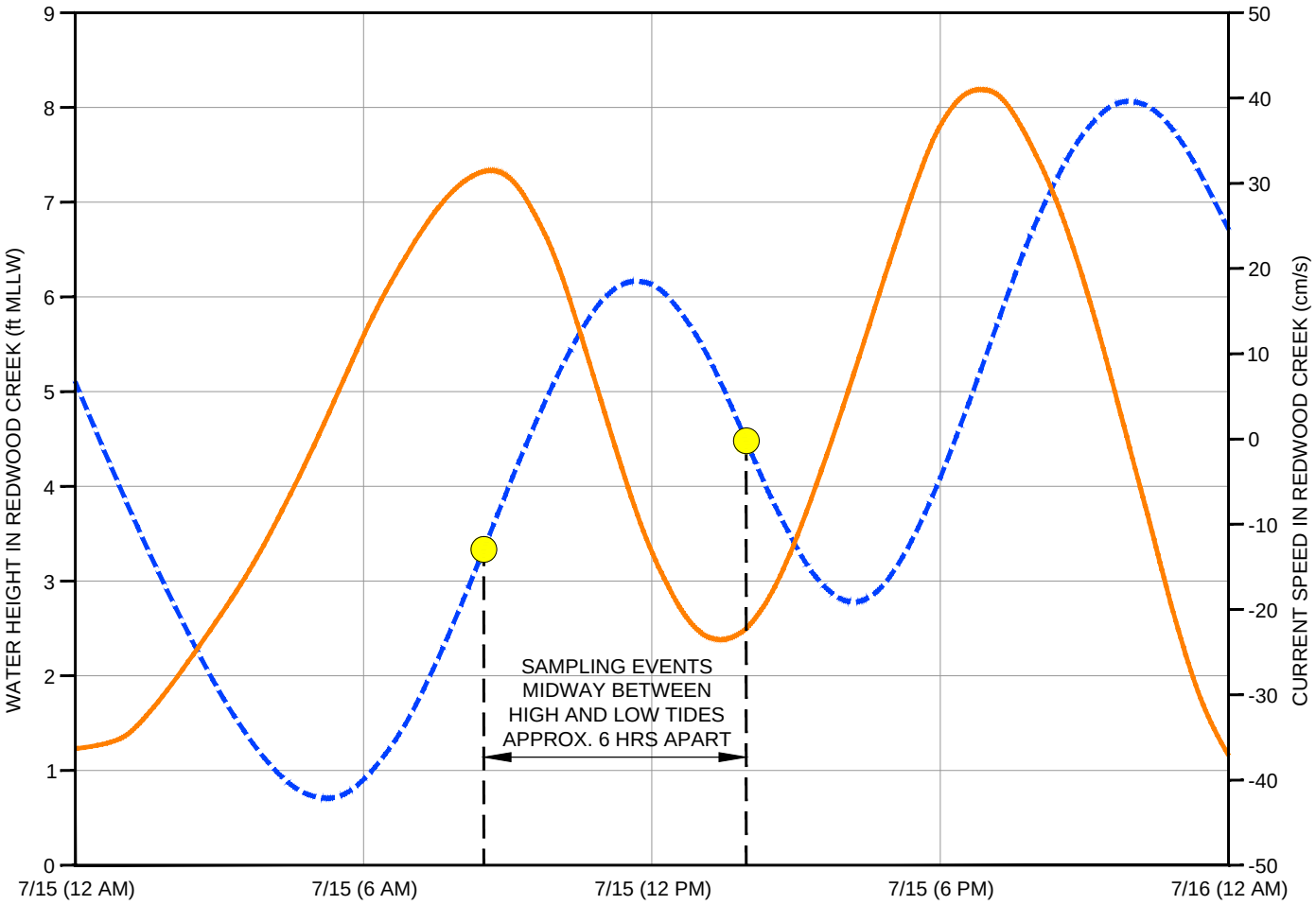
Comparison of Redwood Creek Selected COPC Concentrations with San Francisco Bay Ambient Values

Redwood Creek
Redwood City, CA
November 2016
EKI B60048.03

Figure 5-2



Legend:

- Water Height
- Current Speed

Abbreviations:

cm/s	Centimeter Per Second
ft MLLW	Feet Mean Lower Low Water

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Sampling Events to Occur Midway Between High and Low Tides

Redwood Creek
Redwood City, CA

November 2016
EKI B60048.03

Figure 7-1

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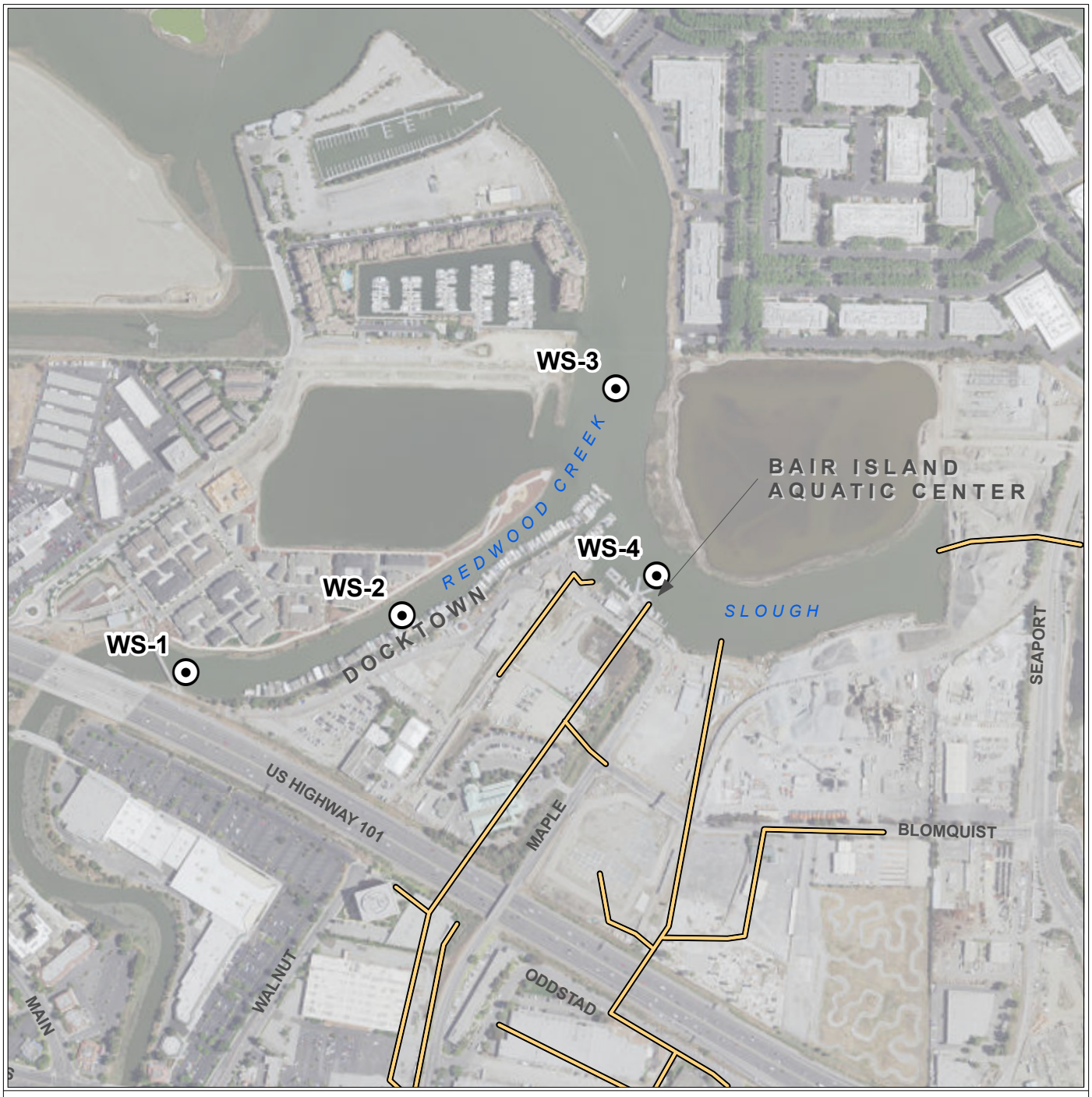

Legend

Bacteriological Water Sample Locations

Storm Drain Lines

Notes

1. All locations are approximate.

Sources

Basemap is ESRI's World Imagery dated 8 November 2016.

N

0 600 1,200

(Approximate Scale in Feet)

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Bacteriological Water Sample Locations

Redwood Creek
Redwood City, CA
November 2016
EKI B60048.03

Figure 7-2

Path: X:\B60048\Maps\2016\11\Figure_7-2_BacteriaSampLocs.mxd

Legend:

- Beach Location Sampled by San Mateo County Department of Health ("SMCDH")
- Location Sampled by EKI in Redwood Creek and Adjacent Slough

Reference: Google Earth Pro, date of imagery, 15 April 2016.

0 2 4

(Approximate Scale in Miles)

N

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Bacteriological Water Sampling Locations at Beaches in the San Francisco Bay

Redwood Creek
Redwood City, CA

November 2016
EKI B60048.03

Figure 7-3

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